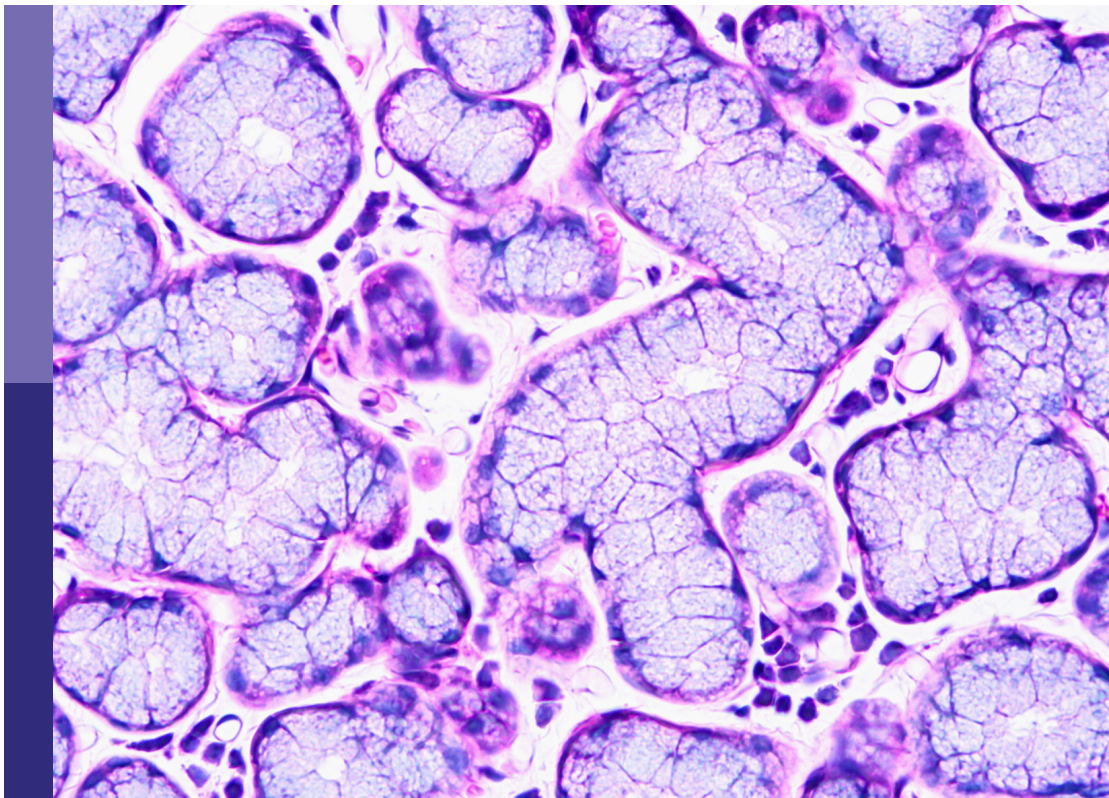
frontiers | Research Topics

Updates in pediatric dentistry

Edited by
Sreekanth Kumar Mallineni and Jayakumar Jayaraman

Published in
Frontiers in Dental Medicine
Frontiers in Pediatrics
Frontiers in Oral Health
Frontiers in Public Health



ISSN 1664-8714
ISBN 978-2-8325-6364-9
DOI 10.3389/978-2-8325-6364-9

About Frontiers

Frontiers is more than just an open access publisher of scholarly articles: it is a pioneering approach to the world of academia, radically improving the way scholarly research is managed. The grand vision of Frontiers is a world where all people have an equal opportunity to seek, share and generate knowledge. Frontiers provides immediate and permanent online open access to all its publications, but this alone is not enough to realize our grand goals.

Frontiers journal series

The Frontiers journal series is a multi-tier and interdisciplinary set of open-access, online journals, promising a paradigm shift from the current review, selection and dissemination processes in academic publishing. All Frontiers journals are driven by researchers for researchers; therefore, they constitute a service to the scholarly community. At the same time, the *Frontiers journal series* operates on a revolutionary invention, the tiered publishing system, initially addressing specific communities of scholars, and gradually climbing up to broader public understanding, thus serving the interests of the lay society, too.

Dedication to quality

Each Frontiers article is a landmark of the highest quality, thanks to genuinely collaborative interactions between authors and review editors, who include some of the world's best academicians. Research must be certified by peers before entering a stream of knowledge that may eventually reach the public - and shape society; therefore, Frontiers only applies the most rigorous and unbiased reviews. Frontiers revolutionizes research publishing by freely delivering the most outstanding research, evaluated with no bias from both the academic and social point of view. By applying the most advanced information technologies, Frontiers is catapulting scholarly publishing into a new generation.

What are Frontiers Research Topics?

Frontiers Research Topics are very popular trademarks of the *Frontiers journals series*: they are collections of at least ten articles, all centered on a particular subject. With their unique mix of varied contributions from Original Research to Review Articles, Frontiers Research Topics unify the most influential researchers, the latest key findings and historical advances in a hot research area.

Find out more on how to host your own Frontiers Research Topic or contribute to one as an author by contacting the Frontiers editorial office: frontiersin.org/about/contact

Updates in pediatric dentistry

Topic editors

Sreekanth Kumar Mallineni — Pediatric Dentist, Dr Sulaiman Al Habib Hospital, Saudi Arabia

Jayakumar Jayaraman — Virginia Commonwealth University, United States

Citation

Mallineni, S. K., Jayaraman, J., eds. (2025). *Updates in pediatric dentistry*. Lausanne: Frontiers Media SA. doi: 10.3389/978-2-8325-6364-9

Table of contents

frontiers | Frontiers in Dental Medicine

TYPE Editorial
PUBLISHED 07 May 2025
DOI 10.3389/fdmed.2025.1603591

OPEN ACCESS

EDITED AND REVIEWED BY
Tammy D. Duangthip,
The Ohio State University, United States

*CORRESPONDENCE
Jayakumar Jayaraman
jayakumar83@hotmail.com

RECEIVED 31 March 2025
ACCEPTED 07 April 2025
PUBLISHED 07 May 2025

CITATION
Jayaraman J and Mallineni SK (2025) Editorial: Updates in pediatric dentistry.
Front. Dent. Med. 6:1603591.
doi: 10.3389/fdmed.2025.1603591

Editorial: Updates in pediatric dentistry

Jayakumar Jayaraman[1]* and Sreekanth Kumar Mallineni[2]

[1]Private Practice, Richmond Pediatric Dentistry & Orthodontics, Richmond, VA, United States, [2]Pediatric Dentistry, Dr. Sulaiman Al Habib Medical Group, Ar Rayyan, Riyadh, Saudi Arabia

KEYWORDS

dental atlas, supernumerary teeth, frenectomy, moderate sedation, root canal anatomy

Editorial on the Research Topic
Updates in pediatric dentistry

Introduction

Pediatric dentistry is an ever-evolving field that continually integrates new diagnostic techniques, treatment modalities, and preventive strategies to ensure optimal oral health in children. The recent Research Topic of articles published in *Frontiers of Dental Medicine* under the theme "*Updates in pediatric dentistry*" showcases a broad spectrum of research, including advancements in diagnostic imaging, endodontic techniques, psychosocial influences on oral health, and clinical case management. This editorial summary synthesizes the key findings and contributions from these studies across six countries, highlighting their collective impact on pediatric dental care.

Advancements in diagnosis and radiographic imaging

Supernumerary teeth, often associated with complications such as impaction, crowding, and delayed eruption, require precise radiographic localization for effective management. A narrative review on radiographic localization of supernumerary teeth emphasizes the superiority of three-dimensional imaging techniques, particularly cone-beam computed tomography (CBCT), over conventional two-dimensional radiographs. CBCT enhances diagnostic accuracy by providing a clearer spatial representation of supernumerary teeth, thus aiding in surgical planning and minimizing potential complications (Mallineni et al.). In a comprehensive dental atlas on the development and eruption of human teeth in the Chinese population, the author has provided crucial data on population-specific dental development patterns (Jayaraman). Such atlases serve as essential references for forensic dentistry, growth assessments, and orthodontic treatment planning, offering insights into variations in eruption sequences that may influence clinical decisions.

Endodontic innovations and material sciences

Root canal treatment in primary molars is a challenging procedure, necessitating techniques that maximize efficiency while preserving tooth structure. An *in vitro* study comparing conventional manual files and rotary files in root canal preparation demonstrates

that rotary instrumentation results in more consistent and conservative dentin removal (Vishwanathaiah). This finding supports the growing preference for rotary endodontics in pediatric dentistry, which can enhance treatment outcomes and reduce chair time. Another *in vitro* study evaluating the push-out bond strength of three root canal materials used in primary teeth investigates the adhesion properties of various endodontic filling materials (Özer et al.). The study concludes that some materials exhibit superior bonding to root canal walls, reinforcing their suitability for long-term endodontic success in children. Further research into tricalcium silicate-based materials and their bond strength to self-adhering glass ionomer cements highlights variations in bonding efficiency (BinSaleh et al.). These findings contribute to material selection strategies, ensuring durable restorations that withstand masticatory forces in pediatric patients.

Malocclusion and dentofacial development

A study on the prevalence and contributing factors of malocclusion in children aged 7–8 years in Zhuang, southern China identifies genetic predisposition, oral habits including thumb sucking, tongue thrusting, and socioeconomic factors as significant influences on malocclusion development (Mai et al.). The study underscores the need for early orthodontic interventions to prevent complex treatment needs in later years. Similarly, an evaluation of anterior and overall tooth ratios in the Saudi population compared to Bolton's standards reveals discrepancies that may necessitate region-specific orthodontic assessments (Awawdeh et al.). These findings highlight the importance of considering ethnic and population-based differences when planning orthodontic treatments.

Psychosocial and behavioral influences on pediatric oral health

Oral health outcomes in children are significantly influenced by psychosocial determinants, as demonstrated in a study on the role of parental education, socioeconomic status, and family dynamics in shaping children's oral hygiene practices and caries prevalence (Kopycka-Kedzierawski et al.). The research highlights the need for community-based interventions that address disparities in oral health knowledge and access to care. Another study examines the association between parental factors and children's behaviors during moderate sedation in pediatric dental care (Alanbari et al.). Findings indicate that parental anxiety, past dental experiences, and education levels directly impact a child's response to sedation. These results emphasize the importance of parental counseling and preparatory strategies to improve sedation outcomes. A study from northern Vietnam evaluates parental knowledge and practices in childhood caries prevention, revealing gaps in awareness and inconsistent adherence to preventive measures (Vu et al.). These findings call for intensified educational initiatives aimed at equipping parents with accurate information on dietary habits, fluoride use, and the importance of regular dental visits.

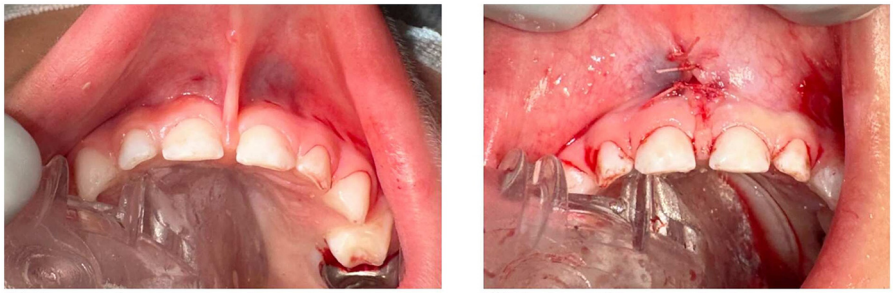
Clinical case management and preventive strategies

The case report on dental management of a child with congenital ichthyosis under general anesthesia highlights the complexities of treating pediatric patients with systemic conditions (Hino et al.). The report details modifications in treatment planning, emphasizing the necessity of interdisciplinary collaboration for safe and effective dental care. The "*Lift the lip*" screening guide, designed for dental professionals, aims to enhance early detection of oral health issues (Kotha). This initiative advocates for routine lip-lifting examinations to identify early signs of caries, and underlying systemic conditions, ultimately contributing to improved early intervention strategies. In addition, this study emphasizes the importance of evaluating soft tissue abnormalities, particularly frenum. Despite the growing acceptance of frenectomy, controversies remain regarding overdiagnosis and overtreatment. Several surgical techniques are available for frenectomy, with traditional and laser-assisted methods being the most commonly used. The laser

(a) Pre-operative

(b) Post-operative

FIGURE 1
Pre-operative (a) and post-operative (b) illustrations of frenectomy in a six month infant performed by Laser.



(a) Pre-operative *(b) Post-operative*

FIGURE 2
Pre-operative **(a)** and post-operative **(b)** illustrations of frenectomy in a three year old child performed using a conventional technique.

technology has revolutionized frenectomy procedures and its advantages includes reduced bleeding due to hemostatic effects, minimal postoperative discomfort, no need for sutures in most cases resulting in faster healing with reduced scar formation (Figure 1). Alternatively, surgical incision may require suturing to optimize healing and minimize scarring (Figure 2). Some experts argue that a functional assessment should guide treatment decisions rather than anatomic classification alone (1). Standardized diagnostic criteria and long-term outcome studies are needed to refine clinical guidelines and future research should focus on providing evidence-based recommendations.

Policy and public health implications

The article "*Allocating intricacies: pediatric oral health spotlight in the union health and well-being budget of India*" critically examines the allocation of financial and policy resources dedicated to pediatric oral health (Kumar et al.). The study highlights disparities in access to care and advocates for increased funding, improved infrastructure, and policy reforms to strengthen pediatric dental services in India.

Conclusion

The collective findings from these studies underscore the importance of a multidisciplinary approach in pediatric dentistry. Advances in diagnostic imaging, endodontic techniques, and material sciences are enhancing clinical efficiency and treatment outcomes. Concurrently, research on psychosocial influences and public health initiatives emphasizes the role of education and policy in bridging gaps in pediatric oral healthcare. Moving forward, integrating these insights into clinical practice and policy frameworks will be pivotal in ensuring comprehensive and equitable oral healthcare for children worldwide.

Author contributions

JJ: Writing – original draft, Writing – review & editing. SM: Writing – original draft, Writing – review & editing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

Publisher's note

Reference

1. Di Renzo GC, Perillo L. Maxillary and lingual frenum abnormalities: a review of current literature. *J Clin Pediatr Dent*. (2020) 44:45–50.

frontiers | Frontiers in Dental Medicine

TYPE Original Research
PUBLISHED 24 March 2023
DOI 10.3389/fdmed.2023.1140794

OPEN ACCESS

EDITED BY
Ebru Kucukyilmaz,
Izmir Kâtip Çelebi University, Türkiye

REVIEWED BY
Naji Kharouf,
Université de Strasbourg, France
Basak Bolukbasi,
Okan University, Türkiye

*CORRESPONDENCE
Hazal Özer
✉ hozer@erbakan.edu.tr

SPECIALTY SECTION
This article was submitted to Pediatric Dentistry, a section of the journal Frontiers in Dental Medicine

RECEIVED 09 January 2023
ACCEPTED 10 March 2023
PUBLISHED 24 March 2023

CITATION
Özer H, Abaklı İnci M and Açar Tuzluca S (2023) The push-out bond strength of three root canal materials used in primary teeth: *in vitro* study. Front. Dent. Med 4:1140794.
doi: 10.3389/fdmed.2023.1140794

The push-out bond strength of three root canal materials used in primary teeth: *in vitro* study

Hazal Özer*, Merve Abaklı İnci and Sevcihan Açar Tuzluca

Department of Pediatric Dentistry, Faculty of Dentistry, Necmettin Erbakan University, Konya, Turkey

The study aims to compare the bond strength of three primary tooth root canal filling materials to the root canal wall with a push-out test (Calplus, DiaPaste, BIOfactor MTA). First, 30 primary central teeth were cut transversely using a water-cooled low-speed diamond saw vertical to the long axis to obtain 2 mm thick discs from the middle third of the roots. Next the materials used were placed on dentin discs and kept in an incubator for 1 week at 37°C and 100% humidity until the hardening mechanism of the root-canal sealer was completed. Finally, a vertical force was placed on each material from apical to coronal with a 0.75 mm diameter stainless steel cylindrical piston without contacting the root canal dentin. The data were analyzed using the SPSS 22.0 program and the Mann-Whitney U test was used as a *post hoc* test. There was a statistically significant difference between the bonding values of different primary tooth root canal sealers to root canal dentin ($p < 0.05$). Among the maximum binding values, the lowest measurement was in Calplus (0.43 ± 0.28 MPa), and the highest measurement was in BIOfactor MTA (24.24 ± 17.78 MPa) ($p < 0.05$). BIOfactor MTA has a higher bonding value to root canal dentin than calcium hydroxide-based primary tooth canal sealers.

KEYWORDS

MTA (mineral trioxide aggregate), calcium hydroxide, primary tooth, root canal filling material, pediatric dentistry

1. Introduction

One of pediatric dentistry's most critical tasks is keeping the primary teeth healthy and functional in the mouth until they exfoliate naturally. Premature loss of primary teeth may result in loss of dental arch length, insufficient space for permanent teeth to erupt, the ectopic eruption of premolars, mesial movement in the molar tooth adjacent to the extraction cavity, elongation of the opposing permanent tooth, deviation in the midline with the formation of cross occlusion, malocclusions, aesthetic, chewing, and phonation problems (1–6).

In addition, caries lesions progress faster and significantly impact the pulp-dentinal complex because of their smaller thickness and wider pulp chambers. Untreated primary tooth decay spreads quickly as well, causing loss of substance and increasing the need for root canal treatment in profound caries (7–9). The purpose of root canal treatment in primary teeth is to allow teeth that function during an essential period of life to function painlessly without damaging the underlying permanent tooth germ, to heal pathologies in the furcation and periapical region, and to allow the tooth to resorption physiologically (10).

The properties of root canal sealers used in primary tooth root canal treatment are critical. For example, an ideal primary tooth root-canal sealer should be antibacterial, resorb in parallel with primary tooth resorption in the presence of permanent teeth, not harm the periapical tissues and permanent tooth germ, and be easily resorbed when

overflowing from the apex. Furthermore, ease of application, good adaptation to the canal wall, ease of removal from canals when necessary, radiopaque properties, and not causing tooth discoloration are all essential criteria (11, 12).

Although a wide range of sealers has been used in primary tooth root canal treatments, no root-canal treatment material possesses all these properties simultaneously. Hermann's introduction of calcium hydroxide paste in 1930 was indicated for use in primary teeth due to its anti-bacterial, resorbable, and biocompatible properties (13). Iodoform paste, on the other hand, demonstrated 84–100 percent success in terms of resorbing excess material and healing properties (14). The root-canal treatment materials containing a calcium hydroxide-iodoform mixture are close to ideal for primary teeth. The adaptability to the root-canal surface and the sealing properties are suitable (10).

In 1993, MTA was developed by Dr. Torabinejad; it is widely used in root canal repair, vital pulp treatments, and apical barrier formation due to its high pH, histological and biological properties similar to calcium hydroxide, excellent biocompatibility, low solubility, high sealing ability, and radiopacity (15, 16). In the studies, successful covering properties were obtained; this is attributed to the chemical properties of the material and its expansion during setting (16). Root-canal treatment materials containing MTA have been developed in recent years by improving these favorable properties of MTA and adding features such as fluidity, setting time, and adhesion that are essential in root canal sealers; it has found widespread use in endodontic treatments (17).

MTA stimulates the formation of hard tissues such as bone, dentin and cement and has a regenerative property on periapical tissues. Therefore, it has osteoconductive, osteoinductive and cementogenic properties. It stimulates the release of the lymphokines, bone-binding factors required for the repair, regeneration and bone defects of damaged cement tissue from immune cells (18).

For treatments like pulp capping, pulpotomies, apexification, root perforation repairs, root-end sealer, and apical plugs, the BIOfactor MTA employed in this study (Imicryl Dental, Konya, Turkey) has just recently entered the market. This material can be formed with a fluid or dense consistency, depending on the type of treatment. The producer of BIOfactor MTA claims that it doesn't stain teeth and has finer particle content powder for quicker hydration, easier handling, stronger sealing, and shorter setting times. The bond strength of BIOfactor MTA, a novel material, has never been examined on primary teeth. The BIOfactor MTA is also less expensive.

In a study conducted in this context, the Ph, solubility, contact angle, and crystallline microstructure under SEM and antibacterial activity were evaluated for three root-canal filling materials for primary teeth (Calplus, Bio-C Pulpecto, and zinc oxide eugenol). None of the materials had optimal properties and could be considered the most suitable filling material for primary teeth pulpectomy. However, the properties of bioceramics, such as bioactivity, solubility in fluids, and adhesiveness, would provide a crucial step in increasing the success rate of root canal treatment on primary teeth and developing more performant materials (19).

A root-canal sealer ensures the integrity of the material-dentin connection with an adhesive bond. This adhesive joint must be strong enough to withstand sealant displacement during function and operating procedures (20). This force is measured and evaluated using the push-out test. The materials to be tested are placed in cavities of a specific diameter prepared in the middle of dentin discs of a certain thickness obtained, and then the root canal sealer is pushed from the root canal with the help of a pusher tip and gives the maximum force bond strength value that allows the rupture to occur. The push-out test can also be used to assess root-canal sealing materials with low bond strength (21).

It is critical to achieve a successful root canal treatment using biocompatible, non-toxic, highly impermeable materials and suitable adaption to the canal surface in primary tooth root canal treatments. Root-canal treatment materials must have good adaptability to the root dentin surfaces. Bond strength tests are used to assess the effectiveness of endodontic material adhesion to the tooth structure. The push-out test is one of the methods used to determine the bond strength of intracanal restorations, and it more accurately models clinical conditions than other methods.

In the literature, our research is the first to investigate the bond strength of conventional primary tooth root-canal filling materials with MTA, one of the most preferred biomaterials in root canal treatments in primary teeth with no permanent. Given that different root canal sealers have different properties in bond strength to root dentin, this *in vitro* study aimed to investigate the hypothesis that the push-out test values may differ depending on the material used.

The following evidence supports this hypothesis:

Among root canal sealers, BIOfactor MTA has the highest bonding strength values to primary tooth root canal dentin.

2. Materials and methods

The Non-Pharmaceutical and Non-Medical Device Research Ethics Committee at Necmettin Erbakan University Dentistry gave authorization with decision number 2020/02-08 on the date of 05.11.2020.

2.1. Sample size calculation

From a previous study (30), sample size, effect size = 0.30, power b = 95%, $\alpha = 5\%$ were calculated based on input into an F-test family for the analysis of variance repeated measurements, and for this study, 27 samples were required. However, 60 samples obtained from 30 teeth have been included to cover any potential early problems.

2.2. Sample preparation

In our study, we used 30 freshly extracted primary central human teeth that did not exfoliate, although they were due. Instead, the teeth were kept in tap water containing 0.1% thymol at 4 °C after extraction until used in the study. A scaler was used to remove tissue residues from the root surface. Preoperative radiographs were taken to confirm the presence of a single root canal and to confirm that the root curvature was less than 20°.

The crowns were removed after the teeth were cut from the cemento-enamel junction, perpendicular to the long axis of the tooth with a low-speed IsoMet diamond saw under constant water-cooling (IsoMet 1000; Buehler, Lake Bluff, NY, USA). The length of the roots was standardized at 8 mm. Canal sealer opening of the teeth was measured under magnification (Zumax SLT Loupe 3.0x) by exiting 0.5 mm from the apical with an ISO #10 K-type endodontic hand file (Dentsply, Maillefer, Ballaigues, Switzerland). Root canals were shaped using a protaper universal file system (Dentsply, Maillefer, Ballaigues, Switzerland) in working length up to the #30 file (%0.4 taper) and the crown down technique, as recommended by the manufacturer. The canals were irrigated with 2 ml of 5% NaOCl (Imicryl, Konya, Turkey) solution at each file type and size change. It was then washed with 2 ml of saline solution. Following the completion of the preparation process, 5 ml of 17% EDTA (Imicryl, Konya, Turkey) solution was used to remove the smear layer, which was then washed with 2 ml of saline solution. For final irrigation, 5 ml of distilled water was used. The root canals were then dried with paper cones.

The prepared teeth were embedded in cold acrylic using cylindrical molds with a diameter of 10 mm and a height of 20 mm. To obtain 2 mm thick discs in the middle third of the roots, the teeth were cut transversely with a water-cooled low-speed ISOMET diamond drill (IsoMet 1000; Buehler, Lake Bluff, NY, USA) perpendicular to the long axis of the teeth. The thickness of the resulting discs was measured using a digital caliper. The resulting discs were enlarged to 1.3 mm in diameter using Gates Glidden drills number 2, 3, and 4, respectively (Dentsply, Maillefer, USA). All discs were washed with 5 ml of distilled water and dried with paper cones afterward.

Sixty dentin discs were randomly divided into three groups ($n = 20$). Root-canal sealers (BIOfactor MTA, Calplus, and DiaPaste) were placed in the root canal cavity of the discs with the carrier and compressed with an endodontic plugger according to the manufacturer's instructions. (Table 1) A scalpel was used to remove excess material from the samples' surfaces. For one week, all discs were kept in an oven at 37°C and 100% humidity until the setting mechanism of the root-canal sealers was completed.

After the sealers' setting mechanisms were completed, root surfaces were sanded to achieve a smooth and clear surface (Figure 1). Next, all discs were examined with a microscope (Olympus Optical Co. Ltd., Tokyo, Japan) to look for cracks, imperfections, or gaps between the sealer and the dentinal walls. It was then put through a push-out test on the Universal Testing Machine (Universal, Beyhekim, Turkey) (Figure 2).

TABLE 1 Root-canal sealers used in the study, as well as the content and manufacturer information. .

Product and manufacturer	Composition	Instructions for use
BIOfactor MTA (Imicryl Dental, Konya, Turkey).	Powder: tricalcium silicate, dicalcium silicate, tricalcium aluminate, ytterbium oxide as radioactive softener	Mix 3 scoops of powder with 1 drop of liquid until you get a homogeneous consistency
	Liquid: 0.5%–3% water-soluble carboxylated polymer, demineralized water	
DiaPaste (DiaDent Europe B.V.Antennestaat, the Netherlands)	Barium sulphate with pre-mixed calcium hydroxide	Inject into the canal with the syringe
Calplus (Prevest DenPro Limited EPIP Bari Brahmana, Jammu-181133, India).	Calcium hydroxide, iodoform, and silicone oil	Inject into the canal with the syringe

2.3. Push-out testing

The discs were placed in a steel holder that was screwed to an alignment device centered beneath a cylindrical steel punch. After that, the alignment device was attached to the universal tester, Instron machine (Model 4444; Instron Corp, Canton, MA). The thruster had a 0.5 mm tip, and the thrust rate was set to 1 mm/min. In each sample, a vertical force was applied to the cement. Then, using a 0.75 mm diameter stainless steel cylindrical piston, the force was applied to the sealing material from apical to coronal, providing the most coverage on the sealing material without coming into contact with the surrounding dentin (Figure 3).

The maximum force exerted on the cement before displacement was measured in Newtons (N). Thrust force was calculated in megapascals (Mpa) by dividing the force (N) by the area in mm^2. The maximum load needed to cause a sealing failure was measured in Newtons. The obtained data were converted to (Mpa) using the formula (where is π constant and

FIGURE 1
Dentin discs with root canal path before applying force.

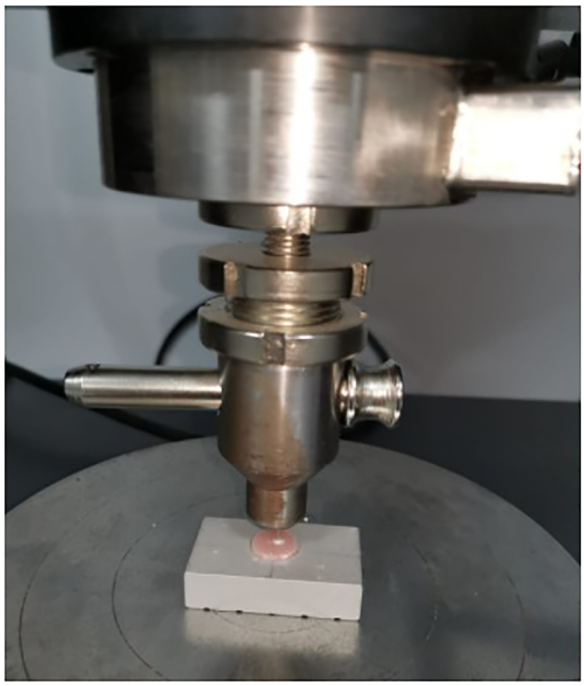


FIGURE 2
Universal testing machine.

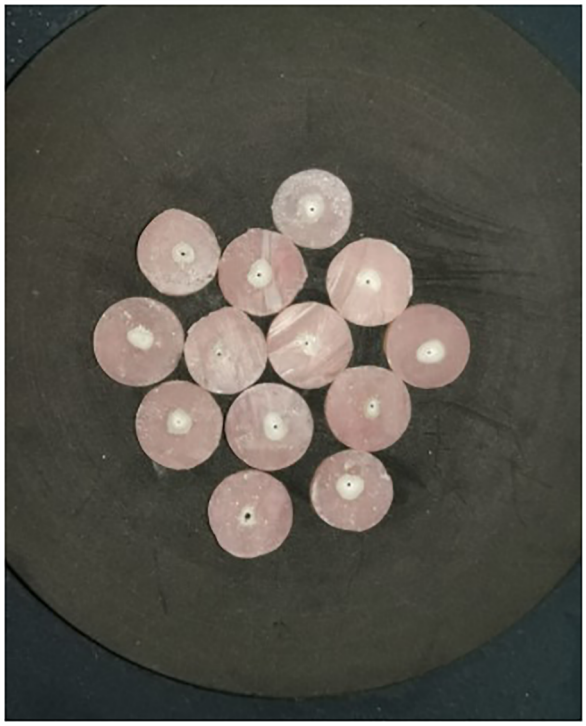


FIGURE 3
Dentin discs after force is applied.

shows canal radius and root slice thickness every two millimeters (newton/2πrh).

2.4. Failure mode analysis

Following the push-out test, samples were inspected at a 500× magnification under a stereomicroscope (SZTP; Olympus Optical Co., Tokyo, Japan) to assess the likelihood of mixed, cohesive, or adhesive failure at the dentin-material interface.

2.5. Scanning electron microscopy

Six dentin slices (two from each group) were chosen for scanning electron microscopy (SEM) analysis. For 3 min, samples subjected to the push-out test were coated with gold/palladium. The interface between dentin and root repair material was explicitly observed in samples. Scanning electron microscopy (Hitachi SU-1510; Hitachi High-Technologies Corp., Tokyo, Japan) was used to make observations at a magnification of 500× (Figure 4).

2.6. Statistical investigation

The Shapiro-Wilk test indicated that the data were normally distributed. The Kruskal-Wallis test was used for intergroup comparisons within the scope of the study, and the Mann-Whitney U test was used as a *post hoc* test. The data were analyzed using the SPSS 22.0 (IBM-SPSS Inc., Chicago, IL, USA) package program, and the study was conducted with $p < 0.05$ as a reference at the 95% confidence interval.

3. Results

Table 2 displays the mean, standard deviation, lowest, and highest bond strength values obtained from the study's groups. The maximum force measurements differ between the three groups statistically significantly. Calplus has the lowest, and BIOfactor MTA has the highest measure. The Mann-Whitney U test for pairwise comparisons revealed no statistically significant difference between DiaPaste and Calplus. However, maximum force measurements between DiaPaste and BIOfactor MTA revealed a statistically significant difference, with the BIOfactor MTA measurement being higher. Maximum force measurements between BIOfactor MTA and Calplus show a statistically significant difference, and it was determined that the BIOfactor MTA measurement was higher.

The failure mode analysis results are represented in Table 3. Instead of mixed failures, all of the groups displayed coherent failure majorities under the stereomicroscope.

4. Discussion

This study aims to use the push-out test to compare the bond strength of three different primary tooth root canal sealer materials

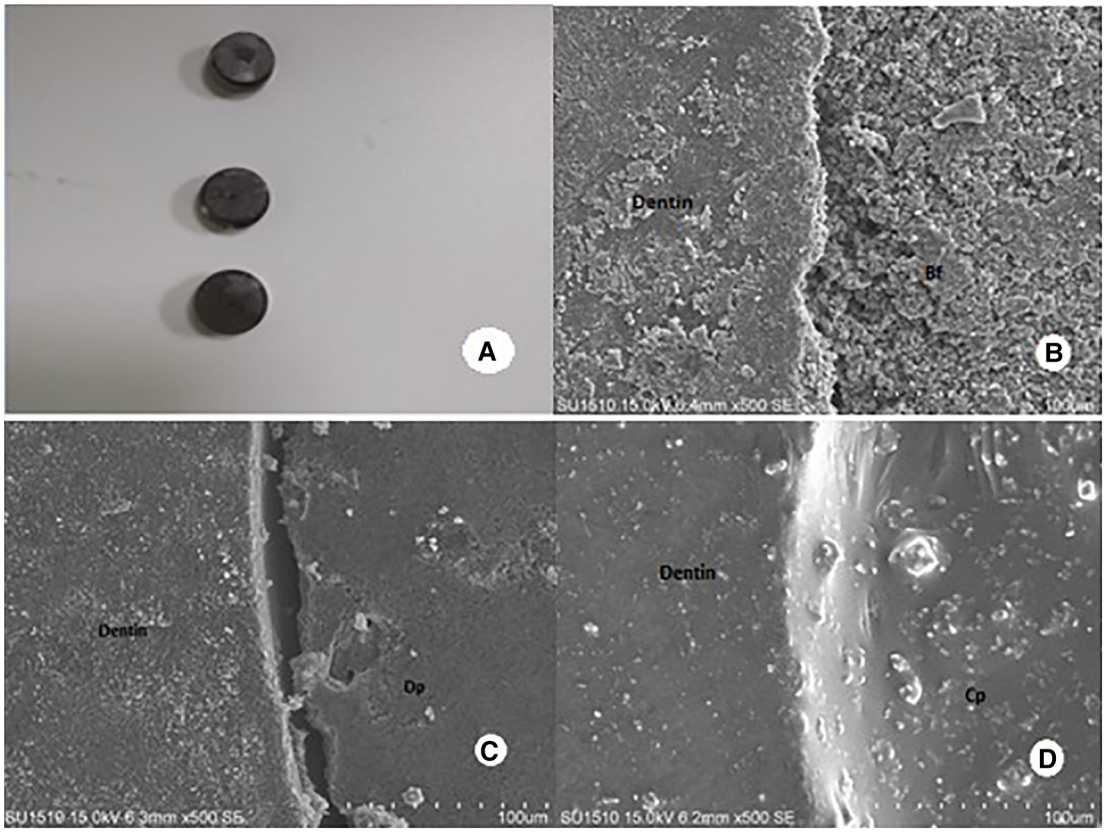


FIGURE 4
SEM images. (A) Dentin discs coated with Ag-Pd are randomly selected. (B–D) Cohesive failure modes in representative scanning electron micrographs of the root canal sealer-dentin interface after push-out test. (B) BIOfactor MTA (Bf), (C) DiaPaste, and (D) Calplus (original magnification 500×).

TABLE 2 Push-out bond strength values [Mpa].

DiaPaste	BIOfactor MTA	Calplus	*p*
1,37 ± 1,32 (0,43–4,73)[a]	24,24 ± 17,78 (3,43–81,15)[b]	0,43 ± 0,28 (0,13–3,76)[a]	0,001

med ± ss (min-max)-.
[a,b]When comparing groups, marks are used to indicate significant differences.

TABLE 3 Failure mode results (%).

Failure type	Calplus	DiaPaste	BIOfactor MTA
Adhesive	0 (0)	1 (1.66)	0 (0)
Cohesive	57 (95.0)	58 (96.67)	58 (96.67)
Mixed	3 (5)	1 (1.66)	2 (3.33)

on the root canal surface. This is the first study in the literature to investigate the bond strength of DiaPaste, Calplus, and BIOfactor MTA root canal sealers to root dentin. The hypothesis was confirmed when a statistically significant difference in push-out test bond strength was discovered between root canal sealers used.

The primary goal of root canal treatment is to clean, shape, and seal the root canal in three dimensions. The connection of root canal sealer material with dentin is directly related to the sealing of the root canal sealer (22). As root canal sealers' bonding ability to the root canal surface improves, so does the success rate of endodontic treatment (23).

Different test methods, such as the widely used push-out test and the traditional shear test, can be used to evaluate the adhesion of root canal sealers to the root-canal surface (24). Bond strength is also measured using tensile tests. It determines bond strength by pulling the canal sealer applied to the dentin discs with a tip. According to the studies, a wide range of values was obtained in the tension tests, and as a result, the push-out test method was more reliable (25). The push-out test has been reported to be a reliable and practical test for evaluating its adhesion to root dentin. Furthermore, it has many advantages, such as more closely stimulating clinical stress, allowing accurate disc standardization, being effective, reliable, and practical, and producing purer shear forces (26). As a result, the push-out test was chosen for this study.

The bond strength of various intra-root posts is affected by the type of root canal sealer material used. The binding values of zinc oxide eugenol were weaker than Metapex, a primary teeth canal sealer based on iodoform and calcium hydroxide, in a study comparing the bonding strength of three types of intracanal posts using the push-out test (27). Another study with primary anterior teeth found that the bond strength values of root canal posts treated with Metapex were more remarkable than those of zinc oxide eugenol (28).

The results of Machida et al. show that the calcium hydroxide-iodoform mixture satisfies the requirements for an optimal primary tooth canal sealing material (29). Vitapex (Neo Dental, Tokyo, Japan) and Metapex (Meta Biomed, Cheongju, Korea) are canal-sealing materials with strong antiseptic properties designed for primary teeth. It is simple to apply/remove root canals. In primary tooth pulpectomy, Vitapex or Metapex has been associated with significant clinical and radiological success rates (30).

The use of root canal sealers containing iodoform or calcium hydroxide instead of zinc oxide eugenol has increased dramatically in recent years (31). Calplus and DiaPaste were preferred as calcium hydroxide-based root canal sealers in our study, while BIOfactor MTA was chosen as a silicate-based root canal sealer. In an *in vitro* study examining the bond strength of BIOfactor MTA with the push-out test, BIOfactor MTA exhibited high bond strength to root canal dentin, at least as much as MTA-Angelus and Biodentine (32).

There was no statistically significant difference between ProRoot and BIOfactor MTA in clinical and radiological examination in the first 6 months of a clinical study evaluating the long-term success of BIOfactor MTA and ProRoot MTA in vital pulpotomy in primary molar teeth. However, at a 12-month follow-up, ProRoot MTA statistics were found to have a significantly higher clinical and radiological success rate than BIOfactor MTA (33). More research is needed to determine whether the ytterbium oxide substitution in BIOfactor MTA powder affects its chemical bonding to dentin.

The BIOfactor MTA was enhanced with ytterbium oxide as a radiopacifier substance, in contrast to other calcium silicate-based materials. It is unclear how the ytterbium oxide addition to the calcium silicate-based substance will affect its physicochemical characteristics. However, ytterbium trifluoride has been added to calcium silicate-based materials. It was found that doing so improved the material's porosity while only slightly increasing the compressive strength of portland cement (34).

There was no statistically significant difference in the push-out values of the materials in a study in which the binding strengths of the ProRoot MTA, Angelus MTA, and Biodentin materials were tested. However, there was a difference between the structural performances of the materials, i.e., the types of failure. While adhesive failure in the biodentin group is never seen, Koheziv and mixed failures were seen equally. In Proot MTA and MTA Angelus groups, most of them were seen from all types of failures, and in both groups, the types of failure were seen in an equal number (35).

The findings of this study, however, are inconclusive, and additional, well-designed research is still required to fully grasp the ideal filling substances' qualifications. Calplus and DiaPaste showed comparable push-out test resistances. Compared to Calplus and DiaPaste, BIOfactor MTA has a higher binding value. BIOfactor MTA has a sufficient bonding strength to the root dentin; however, there is still room for improvement in the MTAs' attributes. Clinical investigations on the therapeutic impact and root canal bonding capability are necessary to evaluate calcium hydroxide-based DiaPaste and Calplus thoroughly. Moreover, randomized long-term clinical studies are required to evaluate the clinical behavior of this kind of material because primary molars continuously experience root resorption. The physicochemical and antibacterial properties still need to be improved to suit the complex anatomy of primary teeth.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author/s.

Ethics statement

The studies involving human participants were reviewed and approved by the Necmettin Erbakan University Faculty of Dentistry Ethics Committee for Non-pharmaceutical and Non-medical Products Researches. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

The final version of the article has been seen and approved by all authors. HÖ – Conception, Design, Supervision, Data Collection, Literature Review, Writing, and Critical Review. MAİ – Conception, Design, Supervision, Data Collection, Literature Review, Writing, and Analysis. SAT – Data Collection, Literature Review, and Analysis. All authors contributed to the article and approved the submitted version.

Acknowledgments

The authors thank Hatice Karakaş for supporting the statistical analysis and Necmettin Erbakan University Science and Technology Research and Application Center for SEM analysis.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Çiftçi Z, Bektaş K, Yılmaz Çalışır K, Güngör Ö, Karayılmaz H. Batı akdeniz bölgesi'ndeki Çocuklarda süt dişi Çekim nedenleri. *Selcuk Dent J*. (2022) 9(1):141–6. doi: 10.15311/selcukdentj.996824

2. Alaçam A. *Pedodontide endodontik yaklaşımlar*. Ankara: Barış Yayınları (2000). 693–700.

3. Tagger E, Tagger M. Endodontic treatment of primary teeth. In: D Ørstavik, P Ford, editors. *Essential endodontology. First edition*. USA: Blackwell publishing (1998). p. 106.

4. Whirtworth JM, Nunn JH. Paediatric endodontics. In: RR Welbury, editors. *Paediatric dentistry*. New York: Oxford University Press Inc (2001). p. 159–87.

5. Dummett CO, Kopel HM. Pediatric endodontics. In: JI Ingle, LK Bakland, editors. *Endodontics. 5th ed*. London: BC Decker Inc Hamilton (2002). p. 861–902.

6. Camp JH, Barrett EJ, Pulver F. Pediatric endodontics: endodontic treatment for the primary and young, permanent dentition. In: S Cohen, RC Burns, editors. *Pathways of the pulp. 8th ed*. St. Louis: Mosby Inc (2002). p. 797–844.

7. Mulder R, Medhat R, Mohamed N. In vitro analysis of the marginal adaptation and discrepancy of stainless steel crowns. *Acta Biomater Odontol Scand*. (2018) 4 (1):20–9. doi: 10.1080/23337931.2018.1444995

8. Kidd EAM, Fejerskov O. *Essentials of dental caries*. New York: Oxford University Press (2016). 230–9.

9. Goldberg M. Deciduous tooth and dental caries. *Ann Pediatr Child Health*. (2017) 5(1):1120–5.

10. Alaçam A. Pedodontide endodontik yaklaşımlar. In: T Alaçam, İ Uzel, A Alaçam, A Aydın, editors. *Endodonti 2*. Baskı, Ankara: Şafak Matbaacılık San. Ltd. Şti (2000). p. 712–23.

11. Rifkin A. A simple, effective, safe technique for the root canal treatment of abscessed teeth. *J Dent Child*. (1980) 47:435–41.

12. Garcia-Godoy F. Evaluation of an iodoform paste in root canal therapy for infected primary teeth. *ASDC J Dent Child*. (1987) 54:30–4.

13. Sjögren U, Figdor D, Spångberg L, Sundqvist G. The antimicrobial effect of calcium hydroxide as a short term intracanal dressing. *Int Dent J*. (1991) 24:119–25. doi: 10.1111/j.1365-2591.1991.tb00117.x

14. Reddy VV. Clinical and radiological evaluation of Zinc oxide eugenol and Maisto's paste as obturating materials in infected primary teeth: a nine months study. *J Indian Soc Pedod Prev Dent*. (1996) 14:39–44.

15. Schwartz RS, Mauger M, Clement DJ, Walker WA III. Mineral trioxide aggregate: a new material for endodontics. *J Am Dent Assoc*. (1999) 130(7):967–75. doi: 10.14219/jada.archive.1999.0337

16. Torabinejad M, Hong CU, McDonald F, Ford TP. Physical and chemical properties of a new root-end filling material. *J Endod*. (1995) 21(7):349–53. doi: 10.1016/S0099-2399(06)80967-2

17. Camilleri J. Evaluation of selected properties of mineral trioxide aggregate sealer cement. *J Endod*. (2009) 35(10):1412–7. doi: 10.1016/j.joen.2009.07.008

18. Tomás-Catalá CJ, Collado-González M, García-Bernal D, Oñate-Sánchez RE, Forner L, Llena C, et al. Comparative analysis of the biological effects of the endodontic bioactive cements MTA-angelus, MTA repair HP and NeoMTA plus on human dental pulp stem cells. *Int End J*. (2017) 50(S2):e63–72. doi: 10.1111/iej.12859

19. Hachem CE, Chedid JCA, Nehme W, Kaloustian MK, Ghosn N, Sahnouni H, et al. Physicochemical and antibacterial properties of conventional and two premixed root canal filling materials in primary teeth. *J Funct Biomater*. (2022) 13 (4):177. doi: 10.3390/jfb13040177

20. Nagas E, Cehreli ZC, Uyanik MO, Vallittu PK, Lassila LVJ. Effect of several intracanal medicaments on the push-out bond strength of ProRoot MTA and biodentine. *Int End J*. (2016) 49(2):184–8. doi: 10.1111/iej.12433

21. Frankenberger R, Kramer N, Petschelt A. Technique sensitivity of dentin bonding: effect of application mistakes on bond strength and marginal adaptation. *Oper Dent*. (2000) 25:324–30.

22. Arıker İ. *Farklı gütaperka Çözücülerin trikalsiyum silikat İçerikli simanların kök kanalına bağlanma dayanımı Üzerine etkisi* [*Ph.D. Thesis*]. Ankara: Hacettepe University (2016).

23. Özbek M, Kotan G, Uysal BA. Farklı irrigasyon solusyonlarının rezin ve biyoseramik esaslı kök kanal patlarının push-out bağlanma dayanımları üzerine etkisinin incelenmesi. *NEU Dent J*. (2021) 2:56–61. doi: 10.51122/neudentj.2021.17

24. Gurgel-Filho ED, Leite FM, de Lima JB, Montenegro JPC, Saavedra F, Silva EJNL. Comparative evaluation of push-out bond strength of a MTA-based root canal sealer. *Braz J Oral Sci*. (2014) 13:114–7. doi: 10.1590/1677-3225v13n2a07

25. Goracci C, Tavares AU, Fabianelli A, Monticelli F, Raffaelli O, Cardoso PC, et al. The adhesion between fiber posts and root canal walls: comparison between microtensile and push-out bond strength measurements. *Eur J Oral Sci*. (2004) 112:353–61. doi: 10.1111/j.1600-0722.2004.00146.x

26. Özcan E, Çapar İD, Çetin AR, Arı Aydınbelge H. Farklı irrigasyon solüsyonlarının MTA fillapex kanal patının bağlanma dayanımı üzerine etkisi. *Acta Odontol Turc*. (2013) 30(1):1–5.

27. Mahmoud MA, Sultan MZ. Comparing the bonding strengths among three types of intra radical posts using push-out test: Laboratory study. *Int J Appl Dent Sci*. (2020) 6(3):263–8.

28. Pasdar N, Seraj B, Fatemi M, Taravati S. Push-out bond strength of different intracanal posts in the anterior primary teeth according to root canal filling materials. *Dent Res J*. (2017) 14(5):336–43. doi: 10.4103/1735-3327.215959

29. Matsuzaki K, Fujii H, Machida Y. Experimental study of pulpotomy with calcium hydroxide-iodoform paste in dogs' immature permanent teeth. *Bull Tokyo Dent Coll*. (1990) 31(1):9–15.

30. Won W, Kim IH, Kang CM, Kim B, Shin Y, Song JS. Comparative study of pulpal responses to ProRoot MTA, vitapex, and metapex in canine teeth. *J Dent Sci*. (2021) 16(4):1274–80. doi: 10.1016/j.jds.2020.12.011

31. Pinkham JR, Casamassimo PS, Fields HW, McTigue DJ, Nowak A. *Pediatric dentistry: Infancy through adolescence. 5th ed*. Philadelphia: WB Saunders Company (2013). 334, 345, 347.

32. Akbulut MB, Bozkurt DA, Terlemez A, Akman M. The push-out bond strength of BIOfactor mineral trioxide aggregate, a novel root repair material. *Restor Dent Endod*. (2019) 44(1):e5. doi: 10.5395/rde.2019.44.e5

33. Öznurhan F, Kayabaşı M, Keskus B. Evaluation of long-term results of two different calcium silicate based materials in primary molar teeth vital pulpotomies: an in vivo study. *Cumhuriyet Dent J*. (2020) 23(1):45–51. doi: 10.7126/cumudj.648723

34. Antonijevic D, Medigovic I, Zrilic M, Jokic B, Vukovic Z, Todorovic L. The influence of different radiopacifying agents on the radiopacity, compressive strength, setting time, and porosity of Portland cement. *Clin Oral Investig*. (2014) 18:1597–604. doi: 10.1007/s00784-013-1130-0

35. Stefaneli Marques JH, Silva-Sousa YTC, Rached-Junior FJA, Macedo LMD, Mazzi-Chaves JF, Camilleri J, et al. Push-out bond strength of different tricalcium silicatebased filling materials to root dentin. *Braz Oral Res*. (2018) 32:e18. doi: 10.1590/1807-3107bor-2018.vol32.0018

frontiers | Frontiers in Dental Medicine

TYPE Opinion
PUBLISHED 01 August 2023
DOI 10.3389/fdmed.2023.1134294

OPEN ACCESS

EDITED BY
Jayakumar Jayaraman,
Virginia Commonwealth University, United States

REVIEWED BY
Sunil Babu Kotha,
Riyadh Elm University, Saudi Arabia
Dedeepya Machiraju,
Care Dental College, India
Ami Angela Harahap,
University of North Sumatra, Indonesia

*CORRESPONDENCE
Vaibhav Kumar
drvaibhav1989@gmail.com

RECEIVED 30 December 2022
ACCEPTED 29 May 2023
PUBLISHED 01 August 2023

CITATION
Kumar V, Sangle R, Jain R, Bhanushali N, Yadav S, Qureshi A, Tandel H and Mhatre P (2023) Allocating intricacies: pediatric oral health spotlight in the union health and well-being budget of India.
Front. Dent. Med 4:1134294.
doi: 10.3389/fdmed.2023.1134294

Allocating intricacies: pediatric oral health spotlight in the union health and well-being budget of India

Vaibhav Kumar[1]*, Rushikesh Sangle[2], Romi Jain[2], Nikhil Bhanushali[2], Sakshi Yadav[2], Ayesha Qureshi[2], Harshal Tandel[3] and Pranjal Mhatre[2]

[1]Department of Public Health Dentistry, GD Pol Foundation YMT Dental College, Navi Mumbai, India, [2]Department of Public Health Dentistry, TPCT's Terna Dental College and Hospital, Navi Mumbai, India, [3]Department of Research, Suitradhaar Strategies Pvt Ltd, Kolkatta, India

KEYWORDS

union health budget, Indian healthcare, oral health, national oral health comprehensive intervention program for children, national oral health program

Introduction

Healthcare in the union health and well-being budget

Health is a state of physical, mental, and social well-being and not just the absence of disease and infirmity. Healthcare services help reduce mortality rates, keep diseases in check, and raise life expectancy, which play a substantial role in the economic growth of a country (1). The Union Budget 2021 was prescribed for the first time with consideration to holistic health care and well-being, yet, as per National Health Profile (NHP) data of 2019, India spends just over 1% of its GDP on public health, which is drastically low considering the country's population, demographics, and ever-increasing disease burden (2). However, with increased awareness about healthcare in the post-pandemic era, this trend appears to be shifting. For the financial year 2022–23, Rs 2,23,846 crore was allocated towards healthcare in the budget presented, which was 137% higher than the preceding year (Rs. 94,452 crore) (3). The Union Budget 2023–24 has been called the first of "amrit kaal", or the elixir era, aims to achieve the goal of India becoming a developed country in the next 25 years. The Ayurveda, Yoga and Naturopathy, Unani, Siddha and Homeopathy (AYUSH), Health and Family Welfare, and Finance ministries of India are responsible for allocating the entire Union Health Budget. For 2023–2024, the total budget for health across all three ministries is Rs. 1,06,654 crores. Of the total Union Health Budget, about 2.3% is allocated to pediatric healthcare (3).

Upgraded contrivances

The Prime Minister Atmanirbhar Swasth Bharat Yojana scheme

This scheme, with an outlay of 64,180 crores over 6 years, will consist of 15 health care emergency centers and two mobile hospitals, establishing critical care hospital blocks in 602 districts and 12 central institutions, strengthening national centers for disease control and its five branches and 20 metropolitan health surveillance units, providing support for health and wellness centers with integrated public health care labs in all districts and 3,382 block public

health units in 11 states, and the setting-up of nine bio-safety level three laboratories and four regional National Institutions for Virology (4).

Swachch bharat, swasth bharat

This scheme will be implemented with an allocation of 1,41,678 crores over a period of 5 years from 2021 to 2026, merging the Supplementary Nutrition Programme and the Poshan Abhiyan and is aimed at the cleaning of fecal sludge, wastewater treatment, source segregation of garbage, a reduction in the use of plastic, a reduction of air pollution, and bioremediation of all legacy dump sites while also improving the nutritional outcomes in 112 districts (5).

The Jal Jeevan Mission

This scheme will be implemented over 5 years with an outlay of 2,87,000 crores stressing the importance of clean water, sanitation, and a clean environment whilst providing the water supply in all 4,378 urban local bodies, 2.86 crores of household tap connections, and liquid waste management in 500 Atal Mission for Rejuvenation and Urban Transformation cities (6).

The Pradhan Mantri Swasthya Suraksha Yojana (PMSSY)

The budget allocated to establishing a new All India Institute of Medical Sciences (AIIMS) and refining the existing Government Medical Colleges has been reduced by Rs. 517 crores from last year (7).

The Pradhan Mantri Jan Arogya Yojana (PMJAY)

This scheme's budget allocation has doubled from Rs. 3,100 crores in 2020–21 to Rs. 6,400 crores in 2021–2022 (8). Through this scheme, the Government of India aims to establish a public health insurance fund for the economically weaker sections of society. It takes into account the inability of the population to access basic healthcare. However, no mention of oral health insurance has been made. This scheme especially lacks attention to pediatric health and, more so, to pediatric oral health.

The national AIDS and STD control programme

Unfortunately, the budget for this initiative remains unchanged at Rs. 2,900 crores (9). India, with 2–3 million individuals infected with HIV, requires significant attention and funds to manage highly prevalent STIs. In children, the Maternal-to-Child Transmission rate of HIV is about 40%–45%. The number of children enrolled in the HIV National Program are expected to be above one lakh but approximately only 30% of them are supposedly on Anti-Retroviral Therapy (10). Hence, this program is inadequate in achieving the required amount of resources and ensuring their proper distribution.

Figure 1 depicts the comparative analysis of the health care budget distribution between the years 2019–20 and 2021–22 across various health departments in India. Compared to the financial year 2019–20, the allocation of funds to the Department of Health and Family Welfare showed a significant rise. This trend was further observed in the allocation of the budget to the Department of Drinking Water and Sanitation. In the financial year 2021–22, a large sum of the Union Budget was allocated for the development and distribution of the COVID-19 vaccine.

India placed against its global contemporaries: the Ying and Yang

Total expenditure as a percentage of GDP in India is as low as 1.26%. It has been reported that India has one of the lowest public healthcare budgets in the world; countries like the United Kingdom, the Netherlands, New Zealand, Finland, and Australia spend over 9% of their total GDP on public healthcare, Japan, Canada, France, Germany, and Switzerland spend about 10%, and the United States 16%. In India, only 25% of the population has access to sanitation, and the use of diagnostic testing is almost in India. Though there has been a considerable increase in the Union Budget allocated to the healthcare sector from Rs 62,659.12 in 2019–20 to Rs 69,000 crore in 2020–21, there still seems to be scope for betterment (11). Out-of-pocket payments account for 70% of healthcare costs in India, whereas in the US these account for around 10%–12%.

Prioritising non-communicable diseases: need of the hour

In India, 63% of deaths are due to non-communicable diseases (NCDs) and 11% due to injuries. And yet the government spends less than 0.5% of its GDP on NCDs and so the states with high poverty levels have a low per capita expenditure on NCDs (12). When applied to the dental sector, this is especially true in cases of dental caries. According to a systematic review conducted by Shah et al., 49.6% of the children (approximately 100 million children) below the age of five years in India live with untreated dental caries. This substantially increases the burden of disease in the population and highlights the need for effective implementation of preventive strategies with early interventions such as fluoride application, pit and fissure sealants, etc., in the National Oral Health Policy (13).

The inverse care law: the Pandora's box

While the Indian healthcare sector is divided into public and private, the private healthcare segment in India is mainly focused

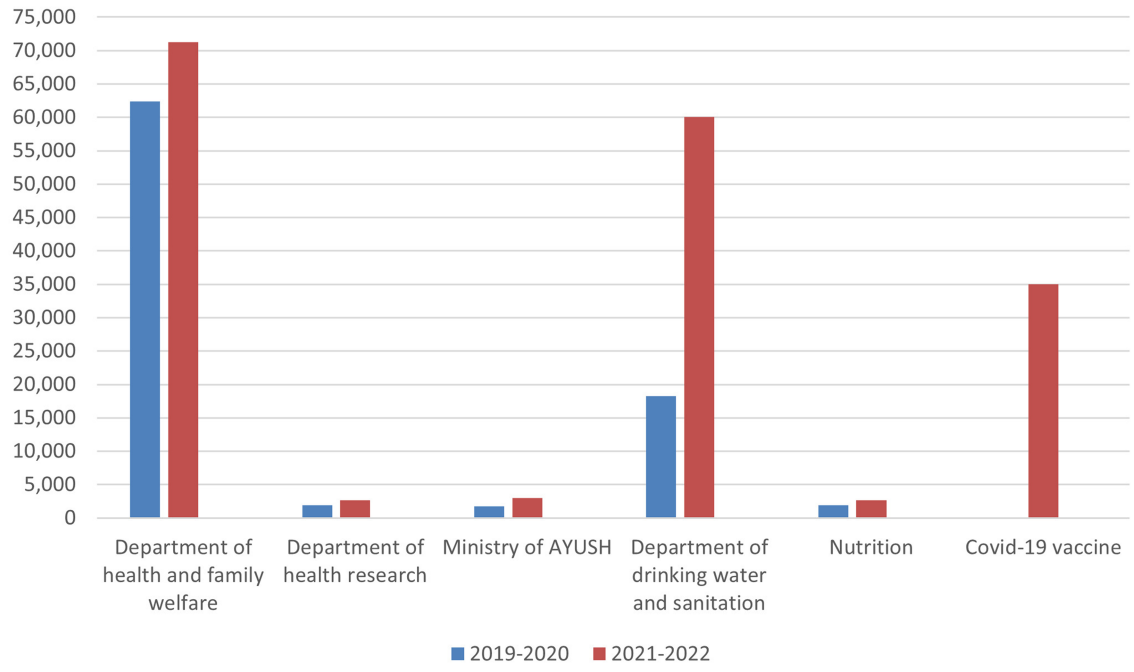


FIGURE 1
A comparative chart of the healthcare budget distribution between the years 2019–20 and 2021–22.

on urban centers, leading to the unequal distribution of services, with 75% of the healthcare infrastructure concentrated in urban areas where only 27% of the total Indian population resides. Only 11% of sub-centers, 13% of Primary Health Centers (PHCs), and 16% of Community Health Centers (CHCs) in rural India meet the Indian Public Health Standards (IPHS). Only one allopathic doctor is available for every 10,000 people and one state-run hospital is available for every 90,000 people. As per the 2017–18 budget announcement, 1,50,000 Health Sub Centers and Primary Health Centers are to be transformed into Health and Wellness Centers (AB-HWCs) by December 2022 to provide Comprehensive Primary Health Care (CPHC) to ensure healthcare for all (14). The PHCs in India are the primary point of contact for services regarding non-communicable diseases. Therefore, oral health promotion, check-ups, and appropriate referral as well as screening for chronic non-healing ulcers is an essential function of the PHCs (15).

Oral health: the "international neglect"

The Union Health and Well-Being Budget 2021 was announced for the first time as a holistic presentation of healthcare needs, assimilating and amalgamating traditional and modern healthcare delivery systems and needs. Whilst allocating significant funds toward the AYUSH (Ayurveda, Yoga, Unnani, Siddha and Homeopathy) framework, a disappointing zero percent of the GDP has been allocated towards oral and dental care needs. No distinct consideration was given to oral health care under the Union Budget 2021–22 despite the schema of the Common Risk Factor Approach proving a strong relationship between the departure from oral health and its myriad links with systemic illness.

Oral health is an integral component of general health yet oral diseases still remain a burden for developing countries like India, especially among the rural population (16). Amongst emerging countries, China enjoys a relatively favorable dental health status and, amongst high-income countries, South Korea exhibits the best dental health status (17). In India, poor oral health status maybe primarily attributed to ignorance among the masses. According to one study (Mathur 2021), 95% of adults in India suffer from gum disease, 50% of citizens do not use a toothbrush or toothpaste, and 70% of children under the age of 15 have dental caries (18), which proves that the burden of oral diseases is on the rise, with oral health being an issue of "international neglect" by policymakers (19). The capacity of the existing health system to overcome these challenges is uncertain; as shown in **Figure 2**, the budget allocation to oral health care seems negligible compared to other policies. There is no specific allotment for the oral healthcare of the pediatric population as the majority of oral diseases can be controlled if intercepted at this growing age. To improve the system and bring about a policy change, a systematic analysis of the existing oral health system is necessary.

National oral healthcare programme: the oral health delivery fabric of India – thrusting beyond boundaries

The NOHP is a stint of hope at acknowledging the gravity of oral health care. Praiseworthy initiatives like establishing 85

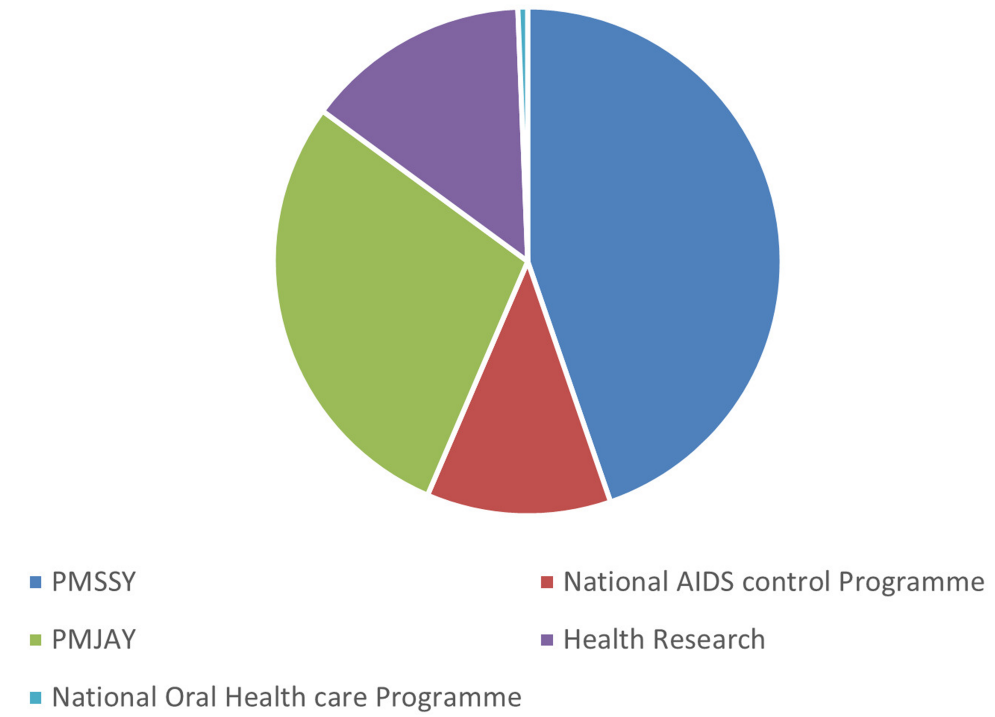


FIGURE 2
A pictorial representation of the major allocations in the healthcare budget.

Muskaan clinics providing free dentures to anyone above the age of 65 years is a part of the Danta Bhagya Yojane, the national oral health policy which was drafted in February 2021 as a part of this initiative. The policy has appreciated the importance of equity, integration, community participation, gender, prevention and promotion, and research which would help in addressing the oral disease burden in India. The Rashtriya Bal Swasthya Karyakram which is a milestone so set that appraising the overall quality of life of children which involves screening of children from birth to 18 years for defects at birth, diseases, deficiencies, and developmental delays. The National Cancer and Tobacco Control Program, National Rural Health Missions, and School Health Program are other budding prospects for efficient delivery of oral health to the population.

Centers for oral health care like the PGI Chandigarh launching the E-RCTC- a joint initiative of PGIMER Chandigarh and the Union to strengthen the National Control Tobacco Programme (NTCP) has been launched. The Maulana Azad Institute of Dental Science (MAIDS) which has fabricated the Mobile Dental Clinic Project and Antitobacco cell, Centre for Dental Education and Research (CDER) is a part of Cochrane Oral Health's Global Alliance and is the National Centre of Excellence for Implementation of the National Oral Health Programme and the World Health Organization (WHO) Collaborating Centre for Oral Health Promotion have also been devised. These schemes have the primary objective of narrowing the rural-urban gap in oral healthcare with a definite budget allocation for the same, thereby increasing the utilization of public oral health facilities and community-based awareness by at least 50% per district by 2030, establishing baseline data for the oral disease burden of the country by 2025, and reducing morbidity and mortality from them by 15% by 2030. To ensure a district-level electronic database of information on health system components by 2025 while integrating oral health information architecture and exchanges between district and primary health centers by 2030. The aims of these initiatives is to eventually strengthen the oral health care system. As no specific care or onus is given to children between 6 or 12 years of age, it becomes essential to gauge how to cease the sustained degradation of oral health care in places where access and resources are inadequate through a common risk factor approach.

Importance of pediatric oral health and incremental care

While many nations have seen improvements in a variety of oral health metrics, India has not. According to a biannual multi-centric oral health study undertaken by the Ministry of Health and WHO in India in 2007–2008, dental caries prevalence among 12-year-olds ranged from 23% to 71.5%. A systematic review that was released in 2018 indicated that 49.6% of Indian children under the age of six had untreated dental

caries (21). The number of children with untreated dental caries is roughly 10 crores if this percentage is extrapolated to children under the age of six. These figures imply that an incremental care method is more appropriate for a developing nation like India because it is periodic care which provides the children with priority dental treatment in a step-by-step manner. The procedure has its own benefits, although it is very occasionally used in complete projects. However, by identifying the needy, the treatment providers, the funding source, and using modern data processing techniques to collect and study the information, one can better understand the many factors involved, possibly make better predictions, and make better decisions about the allocation of resources to solve the problems in health care and achieve the maximum benefit of using the straightforward procedure of providing dental care incrementally to cover the children who will be the country's future citizens.

The role of the union budget of India and its influence on international agencies

The yearly upward trend in the allotment of funds to the healthcare sector is a crucial indicator of the progressive development in the country. A developing nation such as India serves as a template for international agencies as well as other developing nations to better understand the direct effects of increased financial aid on the incidence and prevalence of diseases in the population. Through the betterment in overall mortality and reduced burden of disease in the population, India serves as a great example to other countries and healthcare agencies to formulate an effective plan of action towards achieving global health.

Conclusion

The essence of this communication lies in the fact that there has been considerable progress in the Government's budget allocators and policymakers' consideration towards oral health and health, in general. Although an integral part of national upliftment, the oral health system of India is deficient in many aspects. The reorientation of oral health services is required to counteract the problems faced due to various oral diseases. Encouraging the system to bring about a change and help in providing attention to a systematic analysis of the oral health care system is necessary for the eradication of existing oral diseases.

About 50% of children in India under the age of six years live with untreated dental caries. This study throws light upon the need for the allocation of funds and the imposing of policies for the betterment of pediatric oral health and general oral health, and highlights the existence of numerous national health schemes devoted towards pediatric oral health such as Danta Bharat Yojna and Rasthriya Bal Swasthya Karyakram. The Union Health Budget allocates an average of 2.3% towards the pediatric health sector. However, the intricacies of this budget towards pediatric oral health is unknown. It is indeed high time to give due diligence to the importance of oral healthcare in India. The criticality and exigency of the deteriorating oral health status of children should not be undermined, as preventive care and pediatric oral care should be given as equal status as curative and restorative care.

The authors declare that this review is an independent opinion and that the authors do not support any particular government or political party or organization.

Author contributions

VK: Principle investigator and designing the study. RS: Protocol designing. RJ: Providing important intellectual content. NB: Providing important intellectual content. SY: Critical Revision of the study. AQ: Critical Revision of the study. HT: Critical Revision of the study. PM: Critical Revision of the study. All authors contributed to the article and approved the submitted version.

Acknowledgments

The authors wish to express their gratitude to Ridhima Gaunkar (Government Dental College and Hospital, Goa) and Jasleen Thakker (TPCT's Terna Dental College, Navi Mumbai) for their contributions towards addressing certain technical aspects of the article.

Conflict of interest

HT is employed by Suitradhaar Strategies Pvt Ltd.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Lustig N. Investing in health for economic development: the case of Mexico. In: Mavrotas G, Shorrocks A, editors. *Advancing development: Core themes in global economics*. London: Palgrave Macmillan UK (2007). p. 168–82. (Studies in Development Economics and Policy). Available at: doi: 10.1057/9780230801462_10

2. Why budget 2021 is a good start for Indian healthcare? Financialexpress (2021). Available at: https://www.financialexpress.com/budget/why-budget-2021-is-a-good-start-for-indian-healthcare-2191007/ (Accessed March 11, 2023).

3. India budget | Ministry of finance | Government of India. Available at: https://www.indiabudget.gov.in/ (Accessed March 11, 2023).

4. PM Atma Nirbhar Swasth Bharat Yojana. Available at: https://pib.gov.in/Pressreleaseshare.aspx?PRID=1704822 (Accessed May 12, 2023).

5. Swachh Bharat Mission - Gramin. Department of drinking water and sanitation. Available at: https://swachhbharatmission.gov.in/SBMCMS/index.htm (Accessed May 12, 2023).

6. Mathur B. Union budget 2021 explained: Decoding the 137 Per Cent increase in health expenditure. NDTV-Dettol Banega Swasth Swachh India (2021). Available at: https://swachhindia.ndtv.com/union-budget-2021-explained-decoding-the-137-per-cent-increase-in-health-expenditure-56568/ (Accessed March 11, 2023).

7. Home: Pradhan Mantri Swasthya Suraksha Yojana (PMSSY). Available at: https://pmssy-mohfw.nic.in/ (Accessed May 12, 2023).

8. About PM-JAY - National Health Authority | GOI. Available at: https://nha.gov.in/PM-JAY (Accessed May 12, 2023).

9. National AIDS Control Programme V | National AIDS Control Organization | MoHFW | GoI. Available at: https://naco.gov.in/national-aids-control-programme-v (Accessed May 12, 2023).

10. Nath A. Pediatric HIV in India: current scenario and the way forward. *Indian J Public Health*. (2017) 61(2):124–130. doi: 10.4103/ijph.IJPH_314_15

11. Gupta I, Ranjan A. Public expenditure on non-communicable diseases & injuries in India: a budget-based analysis. *PLoS One*. (2019) 14(9):e0222086. doi: 10.1371/journal.pone.0222086

12. SCORE G. Rural Healthcare. Available at: https://iasscore.in/current-affairs/mains/rural-healthcare (Accessed March 11, 2023).

13. National Oral Health Programme (NOHP):: National Health Mission. Available at: https://nhm.gov.in/index1.php?lang=1&level=2&sublinkid=1044&lid=608 (Accessed March 11, 2023).

14. Basavaraj P, Singla A, Gupta R, Malhi R, Pandita V, Prasad M. Eliminating health disparities by implementation of oral health allocation in union budget – empowering change. *J PEARLDENT*. (2017) 8:16–31. doi: 10.5958/2229-4457.2017.00006.X

15. IPHS 2022 Guidelines | National Health Systems Resource Centre. Available at: https://nhsrcindia.org/IPHS2022/iphs-2022-guidelines (Accessed March 11, 2023).

16. Saekel R. Comparison of oral health Status in Asia: results for eight emerging and five high income countries or regions and implications. *Chin J Dent Res Off J Sci Sect Chin Stomatol Assoc CSA*. (2016) 19(4):191–206. doi: 10.3290/j.cjdr.a37144

17. CSR: Oral Health Awareness in India. Available at: https://thecsrjournal.in/csr-oral-health-awareness-in-india/.

18. Gururaj G. Injuries in India: a national perspective. *Burd Dis*. (2019).

19. Benzian H, Hobdell M, Holmgren C, Yee R, Monse B, Barnard JT, et al. Political priority of global oral health: an analysis of reasons for international neglect. *Int Dent J*. (2011) 61(3):124–30. doi: 10.1111/j.1875-595X.2011.00028.x

20. Rashtriya Bal Swasthya Karyakram (RBSK). Available at: https://rbsk.gov.in/RBSKLive/ (Accessed May 12, 2023).

21. Ganesh A, Muthu MS, Mohan A, Kirubakaran R. Prevalence of early childhood caries in India - A systematic review. *Indian J Pediatr*. (2019) 86(3):276–86. doi: 10.1007/s12098-018-2793-y

frontiers | Frontiers in Oral Health

TYPE Opinion
PUBLISHED 03 August 2023
DOI 10.3389/froh.2023.1177251

OPEN ACCESS

EDITED BY
Jayakumar Jayaraman,
Virginia Commonwealth University,
United States

REVIEWED BY
Vishnu Teja Obulareddy,
United Smiles, United States
Pallavi Singh,
Virginia Commonwealth University,
United States

*CORRESPONDENCE
Sunil Babu Kotha
✉ sunil.babu@riyadh.edu.sa

RECEIVED 01 March 2023
ACCEPTED 05 July 2023
PUBLISHED 03 August 2023

CITATION
Kotha SB (2023) Lift the lip: a screening guide among the dental professionals.
Front. Oral. Health 4:1177251.
doi: 10.3389/froh.2023.1177251

Lift the lip: a screening guide among the dental professionals

Sunil Babu Kotha[1,2]*

[1]Department of Preventive Dentistry, Division of Pediatric Dentistry, College of Dentistry, Riyadh Elm University (REU), Riyadh, Saudi Arabia, [2]Department of Pediatric and Preventive Dentistry, Sharad Pawar Dental College and Hospital, Datta Meghe Institute of Medical Sciences (Deemed to be University), Wardha, India

KEYWORDS

visual tool, lip, screening guide, initial diagnosis, white spot lesions

Introduction

Early Childhood Caries (ECC) was defined in a declaration made by the International Association for Pediatric Dentistry (IAPD) in Bangkok as the presence of one or more decayed (non-cavitated or cavitated lesions), missing or filled (due to caries) surfaces in any primary tooth of a child younger than six years of age (1). The first sign of ECC is a lesion known as a white spot, which, if left untreated, can eventually cause the enamel to crack and progress into a cavitated carious lesion. This shift is extremely rapid and takes place in a relatively short amount of time (2). Thus, early detection is essential if one has to avoid the breakdown of the teeth leading to further destruction. These carious lesions may necessitate invasive, general anesthesia-based treatments that are expensive in terms of both time and money (3).

As we all know, Prevention is better than cure. Early identification and management during the white spot condition can reverse this disease process. The first time a child goes to the dentist is a significant milestone in their life. It affords the dentist the chance to counsel parents on the prevention of oral diseases and makes it possible for the early detection of dental caries and the halting of its progression. It is suggested that the initial appointment to the dentist take place no later than 12 months of age (4). Motivating parents to participate in early intervention programs to reduce the risk of dental decay is a difficult task. However, parents take their children to pediatricians for treatment of general physical issues. Thus, it is of the utmost importance to counsel the pediatricians regarding the child's development and eruption of teeth in addition to guidance for prevention of various oral conditions at this age, in order for these children to have better oral health in the future (2, 5, 6).

Using the technique known as "Lift the lip," the screening guide was created with the intention of assisting medical professionals in more readily recognizing the condition at a much younger age (2, 7, 8). It is a visual and nontactile method that has been created for the purpose of assessing caries and has been utilized in a number of national health and nutrition evaluation surveys (9–11). According to Begzati A et al., the presence or absence of ECC was determined via a meticulous lift-the-lip examination based on the presence of "noncavity caries/white spot lesions" or "cavity caries." (12).

Steps for this visual tool

Primary care practitioners are the target audience for the screening guide, which is designed to help them discover dental problems. This guide is not intended to serve as a substitute for the traditional oral examination that is carried out by an oral health expert in a dental environment (7).

Step 1: Raise the lip and perform a visual examination of the teeth to check for dental caries in all children younger than 5 years old: It is possible that the teeth will be in one of the following states:

1. **Condition 1:** Enamel that is completely smooth and lustrous, free of any deposits or white spot lesions.
2. **Condition 2:** During the examination, the early clinical sign of a white-spot lesion along the margins of the gingiva (a chalky-white appearance) can be observed. This lesion is typically coupled with sticky white deposits of food debris and plaque. If you practice good oral hygiene on a consistent basis and have a dental professional apply fluoride to your teeth, you may be able to reverse this condition and return your teeth to their healthy state.
3. **Condition 3:** Further demineralization can range from the superficial breakdown of enamel to the irreversible formation of a brownish or black surface on the tooth, both of which are untreatable by good oral hygiene practices. Instead, it is the task of the trained professional to restore normal form and function to this condition.

Step 2: Informing the parent or caregiver about the status: It is necessary to provide the parent or primary caregiver with an update on the situation based on the current state of affairs.

1. **Condition 1:** the child ought to pay a visit to the pediatric dentist once every six months.
2. **Condition 2:** In order to prevent further damage, the parents should be instructed to make an appointment with a dentist within two to four weeks.
3. **Condition 3:** The child must make an emergency appointment with a dentist as soon as possible in order to have the form and function of their teeth restored.

Step 3: Provide them with the referral form and oral health education resource.

The parent or caregiver should be given a referral form, and they should be encouraged to take action in accordance with the condition of the teeth.

Discussion

After birth, due to the feeding patterns and lifestyle of the child, parents/caregivers should obtain adequate training to carry out secondary prevention, where the Lift-the-Lip concept is the early phase where they may spot the condition well before the destruction of the tooth (12). At this stage, the white spot, the surface is still unbroken, and the lesion beneath the surface can be reversed. In children younger than three years old, early stages of dental caries are most frequently observed on the front surface of the front teeth; hence, a routine "lift-the-lip" examination is sufficient to identify the majority of caries (13).

Pediatric primary health care physicians see a much larger number of children than their dental colleagues do, and they have the potential to play a significant part in ensuring that children who have caries receive early treatments. Every infant should have a pediatric examination that includes "lifting the lip" and inspecting the anterior maxillary incisors for signs of caries. This should be a standard part of the examination. Every normal physical examination for children should include a quick visual examination of the child's anterior teeth. This examination should take no more than a few minutes (13). Shackleton et al. employed this technique to study differences in dental caries experience in New Zealand children. The results showed that this technique was simple to carry out and only took between two and three minutes. The lift-the-lip approach offers a complete visibility of tooth surfaces, which served to influence toothbrushing as an added maneuver to remove dental plaque. This technique helped the parents and the caregivers because it enabled them to see their children's teeth more clearly (14). This "lift the lip" concept was applied by Jeniffer Curto Manrique et al. to compare two distinct techniques of tooth brushing, the modified Bass and horizontal scrub technique with and without "lift the lip," and they came to the conclusion that lifting the lip is advantageous in not just the visual inspection, but this "lift the lip" associated with toothbrushing have the added advantage of better display of gingival one third of the teeth and the interproximal surfaces and so the cleaning (11).

It is important to point out a few of the drawbacks associated with the "lift-the-lip" assessment of younger children. The examiners could only perform a visual examination of the maxillary anterior teeth of the children who were one year old (10). In the cross-sectional study that Kaste and colleagues (10) conducted, more than 600 children (654) between the ages of 12 and 23 months were administered a brief "lift the lip" visual inspection for early childhood caries. Cariogenic scores were shown to be positive for fourteen different children. Caries status of the incisors of eight further children could not be determined due to lack of information. Only 0.8% of infants in the United States aged 12–23 months were found to have primary anterior tooth decay after the estimates were weighted to approximate the population of infants in that age range in the United States, and 1.1% of the children could not be categorized. During conversations with one of the examiners, it became clear that there was some doubt regarding classifying particular teeth as carious. As a result, the estimated number of children that received either positive or questionable ratings on this index can be thought of as follows. The inter-examiner heterogeneity can be attributed, in large part, to a lack of proper training in recognizing carious lesions in their early stages. Additionally, It might be difficult to tell the difference between white spots caused by incipient caries and developing hypocalcifications (13).

Conclusion

In conclusion, the white-spot lesions that are one of the earliest signs of dental caries should be taught to parents, caregivers, and doctors utilizing the lift-the-lip approach. When followed methodically, this approach not only lessens ECC but also but also reduce the parents to suffer both psychologically and financially.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Pitts NB, Baez RJ, Diaz-Guillory C, Donly KJ, Alberto Feldens C, McGrath C, et al. Early childhood caries: iAPD Bangkok declaration. *J Dent Child (Chic)*. (2019) 86(2):72. PMID: 31395110.

2. Gill NC. Lift the lip: a simple visual tool for caries risk assessment. *Indian Pediatr*. (2022) 59(1):89. doi: 10.1007/s13312-022-2428-2

3. American Academy on Pediatric Dentistry, American Academy of Pediatrics. Policy on early childhood caries (ECC): classifications, consequences, and preventive strategies. *Pediatr Dent*. (2008) 30(7 Suppl):40–3.

4. Sanguida A, Vinothini V, Prathima GS, Santhadevy A, Premlal K, Kavitha M. Age and reasons for first dental visit and knowledge and attitude of parents toward dental procedures for puducherry children aged 0–9 years. *J Pharm Bioallied Sci*. (2019) 11 (Suppl 2):S413–9. doi: 10.4103/JPBS.JPBS_54_19

5. Gupta SK, Gupta S, Gojanur S, Kour G, Singh K, Rani P. Pediatricians' view on early childhood caries and oral health in a north region of India: a cross-sectional study. *J Family Med Prim Care*. (2019) 8(1):220–4. doi: 10.4103/jfmpc.jfmpc_201_18

6. Shetty RM, Dixit UB. Paediatricians' views on dental and oral health and treatment needs in children. *Oral Health Prev Dent*. (2011) 9(4):315–22. PMID: 22238729.

7. Nicolae A, Levin L, Wong PD, Dave MG, Taras J, Mistry C, et al. Identification of early childhood caries in primary care settings. *Paediatr Child Health*. (2018) 23 (2):111–5. doi: 10.1093/pch/pxx155

8. Kotha SB. Lift the lip: visual tool for the early diagnosis of early childhood caries (ECC): letter to the editor. *DMIMS J Dent Res*. (2022) 6(1):37.

9. Kaste LM, Drury TF, Horowitz AM, Beltran E. An evaluation of NHANES III estimates of early childhood caries. *J Public Health Dent*. (1999) 59(3):198–200. doi: 10.1111/j.1752-7325.1999.tb03269.x

10. Kaste LM, Selwitz RH, Oldakowski RJ, Brunelle JA, Winn DM, Brown LJ. Coronal caries in the primary and permanent dentition of children and adolescents 1–17 years of age: United States, 1988–1991. *J Dent Res*. (1996) 75(Spec No):631–41. doi: 10.1177/00220345960750S03

11. Curto-Manrique J, Malpartida-Carrillo V, Arriola-Guillén LE. Efficacy of the lift-the-lip technique for dental plaque removal in preschool children. *J Indian Soc Pedod Prev Dent*. (2019) 37(2):162–6. doi: 10.4103/JISPPD.JISPPD_274_18

12. Begzati A, Berisha M, Meqa K. Early childhood caries in preschool children of Kosovo - a serious public health problem. *BMC Public Health*. (2010) 10:788. doi: 10.1186/1471-2458-10-788

13. Caufield PW, Li Y, Dasanayake A. Dental caries: an infectious and transmissible disease. *Compend Contin Educ Dent*. (2005) 26(5 Suppl 1):10–6. PMID: 17036539.

14. Shackleton N, Broadbent JM, Thornley S, Milne BJ, Crengle S, Exeter DJ. Inequalities in dental caries experience among 4-year-old New Zealand children. *Community Dent Oral Epidemiol*. (2018) 46(3):288–96. doi: 10.1111/cdoe.12364

frontiers | Frontiers in Pediatrics

TYPE Original Research
PUBLISHED 29 August 2023
DOI 10.3389/fped.2023.1237137

OPEN ACCESS

EDITED BY
Jayakumar Jayaraman,
Virginia Commonwealth University,
United States

REVIEWED BY
Elizabeth Bortell,
VCU School of Dentistry, United States
Gayatri Malik,
Geisinger Health System, United States
Jaya Chandra Bhumireddy,
RIMS Medical College Ongole, India

*CORRESPONDENCE
Mohammed Awawdeh
✉ m97a97@gmail.com

RECEIVED 08 June 2023
ACCEPTED 15 August 2023
PUBLISHED 29 August 2023

CITATION
Awawdeh M, Alsaadi W, Alraddadi FAB, Alshunaiber R, Alessa J and Alsaeed S (2023) Evaluation of the anterior and overall tooth ratios in the Saudi population versus Bolton's standards.
Front. Pediatr. 11:1237137.
doi: 10.3389/fped.2023.1237137

Evaluation of the anterior and overall tooth ratios in the Saudi population versus Bolton's standards

Mohammed Awawdeh[1,2,3]*, Waad Alsaadi[4], Faris Awadh B. Alraddadi[5,6], Renad Alshunaiber[5], Jood Alessa[5] and Suliman Alsaeed[1,2,3]

[1]Preventive Dental Science Department, College of Dentistry, King Saud bin Abdulaziz University for Health Sciences (KSAU-HS), Riyadh, Saudi Arabia, [2]King Abdullah International Medical Research Center, Ministry of National Guard Health Affairs, Riyadh, Saudi Arabia, [3]Dental Services, Ministry of the National Guard- Health Affairs, Riyadh, Saudi Arabia, [4]Department of Paediatric Dentistry and Orthodontics, College of Dentistry, King Saud University, Riyadh, Saudi Arabia, [5]College of Dentistry, King Saud bin Abdulaziz University for Health Sciences (KSAU-HS), Riyadh, Saudi Arabia, [6]Ministry of Health, Riyadh, Saudi Arabia

Understanding tooth-size discrepancy is essential in the process of diagnosis of maxillary and mandibular relationship. Due to the high incidence of tooth-size disproportion, Practitioners should consider the high incidence of tooth-size disproportion when planning treatment for their patients, as in many cases, this can be a hindrance to obtaining an ideal result. This study aimed to determine the anterior and overall tooth ratios in the Saudi population and compare them with Bolton's standards. A total of 356 patients were recruited. For the anterior ratio, around 25% of the patients had a ratio equal to Bolton's standards (77.2%). Most subjects (53.7%) had a ratio above 77.2%, and the remaining (20%) had a ratio below 77.2%. The mean amount of anterior mandibular excess was 2.17 ± 2.12 mm, and the mean amount of anterior maxillary excess was 2.16 ± 2.08 mm. For the overall ratio, less than half of the participants (43%) had a ratio equal to Bolton's standards (91.3%). Almost 34% had a ratio above 91.3%, while 23% of the participants had a ratio below 91.3%. The mean amount of overall mandibular excess was 2.54 ± 2.37 mm, and the mean amount of overall maxillary excess was 3.31 ± 3.33 mm. The majority of the study sample had an overall and anterior Bolton ratio that is different from the norms of Bolton's standards, with a tendency for increased overall and anterior ratios. Having specific standards for the Saudi population is important for better clinical assessment and treatment outcomes.

KEYWORDS
orthodontics, Bolton ratio, tooth-size discrepancy, Saudi Arabia, diagnosis

1. Introduction

There are many variables that can affect the articulation between upper and lower teeth (1, 2). More than a century ago, Edward Angle proposed his seminal classification of malocclusion (3). As the first formal classification of its kind, it was instrumental in helping the orthodontic community to understand the concept of occlusion and teeth articulation. The classification was divided into class I, Class II-1, class II-2 and class III (3). There was an understanding that class I was the goal of orthodontic treatment or at least the "normal" occlusion. However, there was criticism of Angle's classification from

different orthodontic scientists, including Ackerman and Dewy (4–8). The main contention was that if a patient has a class I molar relationship, the occlusion might still exhibit other articulation discrepancies such as crowding, spacing, increased overjet, etc. (9). To overcome this limitation, Andrews developed the famous "Six keys of Occlusion" which includes (1) Class I molar relationship, (2) flat or mild curve of Spee, (3) correct teeth angulation, (4) correct teeth inclination, (5) no rotations, (6) tight interproximal contact (9).

These keys were more representative of ideal and normal occlusion than previous occlusion classifications. However, one key variable was not considered until much later when Bolton highlighted the importance of the tooth size ratio between the upper and lower teeth (10, 11). His assertion was that if all six key requirements of ideal occlusion are met, the articulation between the teeth will not be in harmony if the size of the upper and lower teeth are not proportionally balanced. If the lower teeth are wider than normal or if the upper teeth are narrower than normal, the occlusion of the anterior teeth might exhibit an edge-to-edge occlusion (10, 11). On the other hand, if the lower teeth are narrower than normal or if the upper teeth are wider than normal, the occlusion might exhibit an increased overjet. Hence, the orthodontic community has recognized how essential tooth-size discrepancy is in the process of orthodontic diagnosis, assessment of the maxillary and mandibular relationship, and treatment planning. Tooth-size discrepancy is defined as "a relative excess of tooth structure in an arch in relation to the opposing arch with disparity in individual size of teeth" (12). The Bolton anterior ratio is defined as "the ratios of the mesiodistal widths between the six anterior mandibular teeth and the six anterior maxillary teeth (canine to canine)", whereas the overall ratio is defined as "the mesiodistal widths between the 12 mandibular teeth and the 12 maxillary teeth (first molar to first molar)" (10, 11).

According to Bolton ratio the anterior ratio should be around 77%, meaning that the width of the lower anterior teeth should be 0.77 of the total width of the upper anterior teeth. The overall ratio should be around 91%, meaning that the width of the lower teeth, first molar to first molar, should be 0.91 of the total width of the opposing upper teeth. In most patients, natural teeth are in harmony when it comes to size. However, 5% of the population has a disparity in the sizes of their teeth (1). Due to the high incidence of tooth-size disproportion, practitioners should consider this when planning treatment for their patients, as in many cases this can be a hindrance to obtaining an ideal result. It was reported that tooth size ratios during orthodontic treatment for various arch length and arch perimeter groups must be carefully examined (13).

Based on the basic six keys of occlusion developed by Andrews in 1972, after evaluation of a selected 120 cast models of ideal occlusions (9), a seventh key of occlusion, "correct tooth size", was advised by McLaughlin et al. (14). Bolton reported that 29% of patients had a tooth-size discrepancy disproportion (11), while Richardson and Malhotra reported a similar disproportion in 33.7% of their patients (15). Crosby and Alexander found anterior tooth size discrepancy to be prevalent among 22.9% of orthodontic patients (16). A similar result was also reported by Freeman et al. where they found the anterior tooth size discrepancy to be evident in 30.6% of orthodontic patients (17). In 2005, Al-Tamimi and Hashim reported that no significant difference was found in the anterior ratio when they examined Saudi military officers compared to Bolton's anterior and overall ratios (18). However, Alkofide and Hashim reported a significant difference in the anterior ratio between males and females when they examined patients with class III malocclusion (19). Furthermore, they reported a significant difference in all malocclusions cases when compared to Bolton's norms, which was also reported by other studies conducted by Lavelle et al. in England and Ta Ta et al. in Southern China (19, 20). In another study it was revealed that no significant sexual discrepancies in Bolton's anterior ratios or total ratios were reported (21).

In the literature, there are significant differences in the reported tooth-size ratios among various ethnic or racial groups as well as different genders when evaluating tooth-size ratios with different types of malocclusions. This was evident in a study by Ta Ta et al. for southern Chinese children and in Araujo et al.'s study for patients in Brazil (22, 23). Alam et al. recorded similar findings, suggesting that different ethnic groups worldwide have distinct Bolton ratios (24). However, there are other studies that reported no significant difference between different types of malocclusions and the discrepancy in both anterior and overall ratios (16, 25, 26). The interarch tooth-size relationship varies between different populations and these variations in the size of teeth are not systematic. The sample that Bolton studied was not specific in terms of population and sex composition, however, the presence of selection bias is likely (27). Therefore, this study's aim was to determine the anterior and overall tooth ratios in the Saudi population and to compare it with Bolton's standards. Such a study is crucial to guide clinicians in determining precise treatment plan for patients that takes into consideration the discrepancies in the dental ratios. No previous studies have investigated these variable in a similar design.

2. Materials and methods

2.1. Study design

The present study comprised a cross-sectional study to determine the anterior and overall tooth ratios in the Saudi population, comparing them with Bolton's standards using dental casts for patients at the dental clinics in King Abdulaziz Medical City (KAMC) in Riyadh, Saudi Arabia.

2.2. Study subjects

Dental casts with permanent dentition from first molar to first molar, of good quality and with no history of previous orthodontic treatment were included in the study. Patients with tooth agenesis or missing teeth, teeth with anomalous shapes, teeth with large restorations that have mesial or distal over contour interproximal

or occlusal wear, or interproximal cavitation due to carious lesions were excluded from the study. Inclusion criteria also included adult Saudi patients with age range below 30 years old to eliminate the risk of tooth wear. The sample included both male and female with all classes of occlusion meeting the inclusion criteria. Patients not meeting the inclusion criteria were excluded from the study. The Bolton analysis was recorded by calibrated operator through measuring the mesiodistal width of all teeth of each cast, excluding the second and third molars. All methods were conducted in accordance with the current version (2013) of the Declaration of Helsinki by the World Medical Association (WMA).

2.3. Data collection

Dental casts of patients were selected retrospectively, and those which met the inclusion criteria were reviewed. An Excel sheet was used to record the required data. The measurements were performed using a digital calliper to measure the teeth. The mesiodistal length was obtained by measuring the maximum distance between the mesial and the distal contact points of the tooth on a line parallel to the occlusal plane (28). Each arch was measured twice by a single investigator. Repeatability testing was undertaken by measuring 10% of the samples of the teeth width again after three weeks. The validity of the measurement protocol was assessed using the Intraclass Correlation Coefficient (ICC) and excellent reliability was observed with ICC values between 0.91 and 0.96. Measurements were assessed from the right first molar to the left first molar. If the second measurement differed by more than 0.2 mm from the first measurement, the tooth was measured again. All investigators were trained on measurement criteria and calibration of measuring equipment was carried out in advance. All measurements were taken under natural and neon light. Afterwards, the overall and anterior ratio calculations were taken according to Bolton's Analysis.

2.4. Statistical analysis

Data was entered and analyzed using the Statistical Package for Social Sciences (SPSS) version 25 (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.). Descriptive statistics as frequency distributions, means and percentages were calculated for the variables of the study. Inferential statistics were also calculated. One sample *t*-test, to ascertain whether a population differs significantly from a specific value, was also used to compare the average of the anterior ratio of the study's sample against the known value of Bolton's anterior ratio (77.2%). The same test was also used to compare the mean of our overall ratio with the overall Bolton ratio of 91.3%. A *p*-value equal to or below 0.05 was considered significant.

3. Results

A total of 356 subjects were included in the study. The mean mesiodistal width value of maxillary anterior teeth was 46.51 ± 3.84 mm and the mean mesiodistal width value of overall maxillary teeth to the distal of the first molar was 96.35 ± 5.83 mm. The mean mesiodistal width value of mandibular anterior teeth was 36.9 ± 3.47 mm and the mean mesiodistal width value of overall mandibular teeth to the distal of the first molar was 88.3 ± 6.20 mm. The mean values of anterior and overall ratios were 79.48 ± 6.95 mm and 91.61 ± 4.08 mm, respectively (see **Tables 1**, **2**, **Figure 1**).

Comparing these findings to the Bolton analysis, the anterior ratio for 26.4% of subjects was equal to Bolton's standards (77.2%). Most subjects (53.7%) had an increased anterior Bolton ratio, while the remaining (19.9%) had a decreased anterior Bolton ratio. The mean amount of anterior mandibular excess was 2.17 ± 2.12 mm, and the mean amount of anterior maxillary excess was 2.16 ± 2.08 mm (see **Table 3**).

For the overall ratio, 43.3% of participants had a ratio equal to Bolton's standards (91.3%). Around 43% had an increased overall Bolton ratio, while 22.8% had a decreased overall Bolton ratio. The mean amount of overall mandibular excess was 2.54 ± 2.37 mm, and the mean amount of overall maxillary excess was 3.31 ± 3.33 mm (see **Table 4**). Confidence intervals were calculated at 95% using SPSS version 26. The confidence interval was 91.19–92.04 for the overall Bolton and 78.76–80.21 for the anterior Bolton Ratio (see **Table 4**).

One sample *t*-test showed that the anterior ratio ($m = 79.48$ and SD = 91.61) differed significantly ($p < .001$) from the anterior Bolton ratio (%77.2). While the overall ratio ($m = 91.61$, SD = 4.09) did not differ significantly ($p = 0.15$) from the established overall Bolton ratio of 91.3% (see **Table 5**).

4. Discussion

In order to compare tooth discrepancy in the Saudi population with Bolton's standards which consisted of only Caucasian population, 356 casts were obtained and the mesio-distal width of teeth was measured from the first molar to the first molar in both arches. The means and the standards deviations for both anterior and overall measurements, were larger than those reported in Bolton's standards. This was in agreement with what was reported by Paredes et al. for the Spanish Population (28), Bernabé et al. for the Peruvian Adolescents population (29), and Santoro et al. for the Dominican Americans populations (30). The reason for this finding could be due to the difference in the sample size between this study and Bolton's as well as the difference in the ethnic group. For the anterior ratio, the majority of the population studied (53.7%) had an increased anterior Bolton ratio. This is similar to the findings of Santoro et al. (30), as well as Araujo and Souki for the Brazilian population (23), where they also reported a larger anterior ratio as compared to Bolton's standards. Furthermore, in 2017,

10.3389/fped.2023.1237137

TABLE 1 Description of the mean and standard deviation for each tooth.

Maxillary teeth	Mean	Standard deviation	Maximum	Minimum
Upper right first molar	10.52	.74	12.00	7.00
Upper right second premolar	7.04	.79	10.00	5.00
Upper right first premolar	7.10	.60	9.00	5.00
Upper right canine	7.73	.78	9.50	4.00
Upper right lateral incisor	6.78	.85	9.00	4.00
Upper right central incisor	8.71	.88	11.00	5.00
Upper left central incisor	8.68	.92	11.00	5.00
Upper left lateral incisor	6.79	.84	9.00	4.00
Upper left canine	7.83	.70	10.00	5.00
Upper left first premolar	7.18	.60	9.00	5.20
Upper left second premolar	7.08	.76	10.00	5.00
Upper left first molar	10.48	.69	12.00	8.00
Mandibular teeth	**Mean**	**Standard deviation**	**Maximum**	**Minimum**
Lower right first molar	10.80	.82	13.00	9.00
Lower right second premolar	7.34	1.00	11.00	5.00
Lower right first premolar	7.10	.80	11.00	4.00
Lower right canine	6.87	.70	9.00	5.00
Lower right lateral incisor	6.02	.70	8.00	4.00
Lower right central incisor	5.62	.73	10.00	4.00
Lower left central incisor	5.61	.74	10.00	4.00
Lower left lateral incisor	5.95	.72	8.00	4.00
Lower left canine	6.82	.70	9.00	4.00
Lower left first premolar	7.09	.73	9.00	5.00
Lower left second premolar	7.32	.92	11.00	5.00
Lower left first molar	10.80	.87	13.00	8.00

Hashim et al. reported that the Qatari population, which is closer to the Saudi population, also reported a statistical significance when the anterior ratio was compared to that of Bolton (31). In 2014, Subbarao et al. also reported similar findings on the Indian population where both anterior and overall ratios of Bolton did not apply (32). On the other hand, in 2003, Alkofide and Hashim reported that there was no difference in the anterior ratio of their population as compared to that of Bolton (19). Moreover, Al-Tamimi and Hashim published similar results in 2005 on the Saudi population (18). Furthermore, when studying the applicability of Bolton's analysis on the Japanese population, Endo et al. found no statistical significance in both anterior and overall ratios to Bolton's standards (25). Most participants had an increased overall Bolton ratio, which means in our populations there is, predominantly, increased mandibular excess, which is contrary to the result found by Santoro et al. (30).

Recently, a systematic review and meta-analysis aiming to estimate the tooth size discrepancy values for the Saudi population was conducted (33). The study was done by analyzing the data from eight studies on the Saudi population (33). The reported values were 79.08 ± 3.4 for the anterior ratio for all occlusal relationships (Class I, II or III) and for both genders (33). For the overall ratio, the study suggested a value of 92.51 ± 2.82, except for class III cases where the value was set at 91.97 ± 2.4 for females and 93.13 ± 2.6 for males (33). It was noted that most of the studies included in this systematic review had a relatively small sample size compared to this study where we evaluated 356 cases (34–37). However, the finding from the systematic review was not dissimilar from the results of this study, especially for the anterior ratio where both studies agreed on a value of 79%. For the overall ratio, there was a small, not clinically significant, difference between both studies (92.5 vs. 91.61). Moreover, the result of this study was similar to the studies done with Qatari and Japanese populations, exhibiting no statistical difference, but ratios higher than those suggested by Bolton (31).

TABLE 2 Descriptive analysis of the teeth sums and ratio.

Variable	Mean	Standard deviation	Variance	Maximum	Minimum	95% confidence interval for mean	
						Lower bound	Upper bound
Sum of anterior maxillary teeth width	46.52	3.84	14.76	56.00	30.00	46.12	46.92
Sum of total maxillary teeth width	96.35	5.84	34.09	112.00	75.30	95.75	96.96
Sum of anterior mandibular teeth width	36.91	3.48	12.10	46.90	26.70	36.55	37.27
Sum of total mandibular teeth width	88.30	6.20	38.45	106.00	67.10	87.65	88.94
Anterior Bolton ratio	79.48	6.95	48.35	127.40	63.97	78.76	80.21
Overall Bolton ratio	91.61	4.09	16.73	108.00	77.19	91.19	92.04

10.3389/fped.2023.1237137

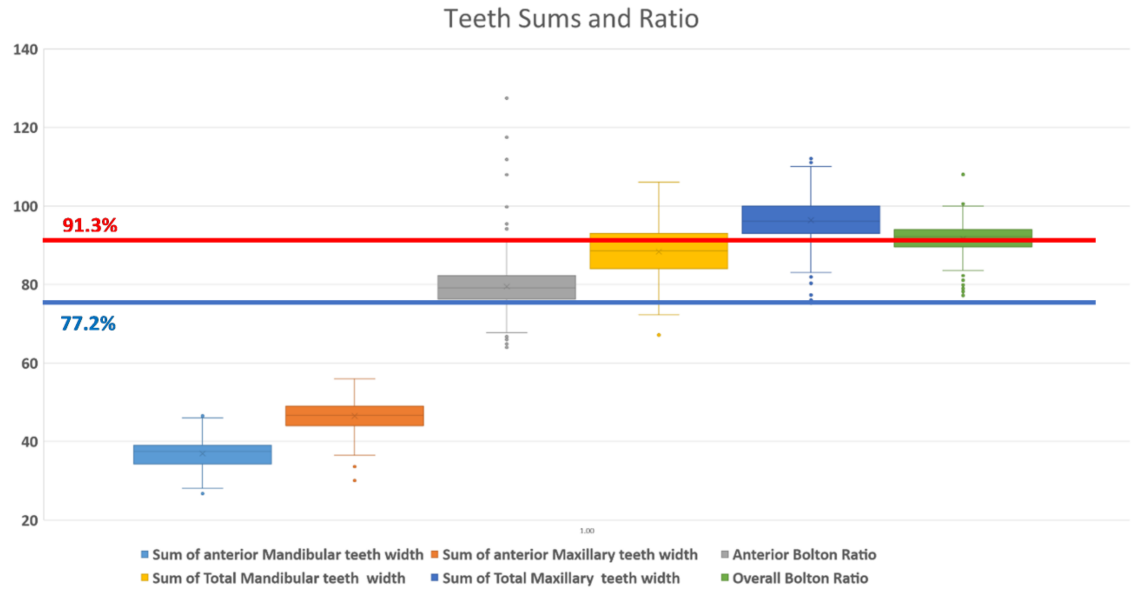


FIGURE 1
Teeth sums and ratios with Bolton's reference lines.

TABLE 3 Description of the anterior Bolton ratio.

Anterior Bolton ratio assessment	Frequency (*n*)	Percent %
Reduced anterior Bolton ratio (Less than 75.55%)	71	19.9%
Normal anterior Bolton ratio (77.2% ± 1.65)	94	26.4%
Increased anterior Bolton ratio (More than 78.85%)	191	53.7%
Total	356	100.0%

TABLE 4 Description of the overall Bolton ratio.

Overall Bolton ratio assessment	Frequency (*n*)	Percent %
Reduced overall Bolton ratio (less than 89.39%)	81	22.8%
Normal overall Bolton ratio (91.3% ± 1.91)	154	43.3%
Increased overall Bolton ratio (more than 93.21%)	121	34.0%
Total	356	100.0%

The discrepancy between the size of the upper and lower teeth can be managed clinically by different techniques (1, 38, 39). Firstly, the nature of the discrepancy has to be determined to establish whether it is an increased or decreased anterior or overall ratio. Then, the cause of this discrepancy needs to be determined. For instance, if a patient has a significantly increased anterior ratio (e.g., 80%), both the upper and lower anterior teeth need to be examined closely to evaluate if the increase in this ratio is due to wide lower anterior teeth or narrow upper anterior teeth. Hence, supporting data, such as the Golden Proportion and the reported normal widths of upper and lower incisors, can be used to conclude the cause of this increased anterior ratio. It is not uncommon to see cases with narrow upper lateral incisors which can result in an increased anterior ratio, hence the ideal plan should include composite build ups, veneers or crowns to restore the width of the upper teeth to reach a normal anterior ratio (40, 41). However, if the upper incisors are normal in width, an interproximal reduction can be performed on the lower anterior teeth to achieve harmony in occlusion with positive overjet (1, 38, 39).

In this study, the gender was not specified. Although this might be considered a limitation, most of the studies on the tooth size discrepancy could not find a significant difference between males and females, and if it exists, it was mostly not clinically or statistically significant (42–45). However, there are studies that proposed the idea that females might have narrower teeth than males, but this will be generalized to both the upper and lower teeth, which will keep the ratio unaffected (46–48).

TABLE 5 One sample *t*-test.

	Mean	Std. deviation	Std. error mean	Test value	*t*	df	Sig. (2-tailed)	Mean difference	95% confidence interval of the difference	
									Lower	Upper
Anterior Bolton ratio	79.48	6.95	0.37	77.20	6.19	355.00	0.00	2.28	1.56	3.01
Overall Bolton ratio	91.61	4.09	0.22	91.30	1.45	355.00	0.15	0.31	−0.11	0.74

Another potential limitation of this study was that the occlusion type was not studied. However, most of the studies on tooth size discrepancy have not found a difference in Bolton's ratio between class I, II or III cases (26, 49–51). This can be explained by the fact that Angle's classification evaluated the malocclusion in the anteroposterior plane which is mostly affected by the position of the jaws or the drifting of the teeth and not the tooth size proportion (3, 10).

5. Conclusions

The majority of the study sample had an overall and anterior Bolton ratio that is different from the norms of Bolton's standards, with a tendency for increased overall and anterior ratios. Having specific standards for the Saudi population is important for better clinical assessment and treatment outcomes. Overall, it is recommended to conduct more research on the Saudi population to confirm the findings of the Bolton's discrepancy outlined in this study.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the present study comprised a cross-sectional study to determine the anterior and overall tooth ratios in the Saudi population, comparing them with Bolton's standards using dental casts for patients at the dental clinics in King Abdulaziz Medical City (KAMC) in Riyadh, Saudi Arabia. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and institutional requirements.

Author contributions

Conceptualization, MA; methodology, MA, WA and FA; software, WA, FA, JA and RA; validation, WA, FA, JA and RA; formal analysis, MA and SA; investigation, WA, FA, JA and RA; resources, MA and SA; data curation, MA and SA; writing—original draft preparation, WA, FA, JA and RA; writing—review and editing, MA and SA; visualization, MA and SA; supervision, MA; project administration, MA and WA; All authors have read and agreed to the published version of the manuscript. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

1. Proffit WR, Fields HW, Larson B, Sarver DM. *Contemporary orthodontics-e-book*. Philadelphia, PA: Elsevier Health Sciences (2018). ISBN 0-323-54388-X.

2. Orthodontics—7th edition. Available at: https://www.elsevier.com/books/orthodontics/graber/978-0-323-77859-6 (Accessed May 14, 2023).

3. Angle EH. Classification of malocclusion. *Dent Cosmos*. (1899) 41:350–7.

4. Ackerman JL, Proffit WR. The characteristics of malocclusion: a modern approach to classification and diagnosis. *Am J Orthod*. (1969) 56:443–54. doi: 10.1016/0002-9416(69)90206-1

5. Dewey M. Classification of malocclusion. *Int J Orthod*. (1915) 1:133–47. doi: 10.1016/S1072-3471(15)80024-8

6. Dewey M. *Practical orthodontia*. St. Louis, MO: Mosby (1919).

7. Katz MI. Angle classification revisited 2: a modified angle classification. *Am J Orthod Dentofacial Orthop*. (1992) 102:277–84. doi: 10.1016/S0889-5406(05)81064-9

8. Riaud X. The historical flaws of Angle's classification. *Sci Arch Dent Sci*. (2019) 2:10–3.

9. Andrews LF. The six keys to normal occlusion. *Am J Orthod*. (1972) 62:296–309. doi: 10.1016/S0002-9416(72)90268-0

10. Bolton WA. Disharmony in tooth size and its relation to the analysis and treatment of malocclusion. *Angle Orthod*. (1958) 28:113–30.

11. Bolton WA. The clinical application of a tooth-size analysis. *Am J Orthod*. (1962) 48:504–29. doi: 10.1016/0002-9416(62)90129-X

12. Fields HW. Orthodontic-restorative treatment for relative mandibular anterior excess tooth-size problems. *Am J Orthod*. (1981) 79:176–83. doi: 10.1016/0002-9416(81)90315-8

13. Alam MK, Shahid F, Purmal K, Ahmad B, Khamis MF. Bolton tooth size ratio and its relation with arch widths, arch length and arch perimeter: a cone beam computed tomography (CBCT) study. *Acta Odontol Scand*. (2014) 72:1047–53. doi: 10.3109/00016357.2014.946967

14. Mclughlin R, Bennett J, Trevisi H. Systemized mechanics orthodontic treatment. (2007).

15. Richardson ER, Malhotra SK. Mesiodistal crown dimension of the permanent dentition of American Negroes. *Am J Orthod*. (1975) 68:157–64. doi: 10.1016/0002-9416(75)90204-3

16. Crosby DR, Alexander CG. The occurrence of tooth size discrepancies among different malocclusion groups. *Am J Orthod Dentofacial Orthop*. (1989) 95:457–61. doi: 10.1016/0889-5406(89)90408-3

17. Freeman JE, Maskeroni AJ, Lorton L. Frequency of bolton tooth-size discrepancies among orthodontic patients. *Am J Orthod Dentofacial Orthop*. (1996) 110:24–7. doi: 10.1016/S0889-5406(96)70083-5

18. Al-Tamimi T, Hashim HA. Bolton tooth-size ratio revisited. *World J Orthod*. (2005) 6.

19. Alkofide E, Hashim H. Intermaxillary tooth size discrepancies among different malocclusion classes: a comparative study. *J Clin Pediatr Dent*. (2002) 26:383–7. doi: 10.17796/jcpd.26.4.j46352g860700614

20. Lavelle CLB. Maxillary and mandibular tooth size in different racial groups and in different occlusal categories. *Am J Orthod*. (1972) 61:29–37. doi: 10.1016/0002-9416(72)90173-X

21. Shahid F, Alam MK, Khamis MF. Intermaxillary tooth size discrepancy in a Pakistani population: a stereomicroscope versus digital caliper. *Eur J Dent*. (2016) 10:176–82. doi: 10.4103/1305-7456.178299

22. Ta TA, Ling JY, Hägg U. Tooth-size discrepancies among different occlusion groups of southern Chinese children. *Am J Orthod Dentofacial Orthop*. (2001) 120:556–8. doi: 10.1067/mod.2001.118998

23. Araujo E, Souki M. Bolton anterior tooth size discrepancies among different malocclusion groups. *Angle Orthod*. (2003) 73:307–13.

24. Alam MK, Iida J. Overjet, overbite and dental midline shift as predictors of tooth size discrepancy in a Bangladeshi population and a graphical overview of global tooth size ratios. *Acta Odontol Scand*. (2013) 71:1520–31. doi: 10.3109/00016357.2013.775336

25. Endo T, Abe R, Kuroki H, Oka K, Shimooka S. Tooth size discrepancies among different malocclusions in a Japanese orthodontic population. *Angle Orthod*. (2008) 78:994–9. doi: 10.2319/101007-486.1

26. Uysal T, Sari Z, Basciftci FA, Memili B. Intermaxillary tooth size discrepancy and malocclusion: is there a relation? *Angle Orthod*. (2005) 75:208–13.

27. Smith SS, Buschang PH, Watanabe E. Interarch tooth size relationships of 3 populations: "does Bolton's analysis apply?". *Am J Orthod Dentofacial Orthop*. (2000) 117:169–74. doi: 10.1016/S0889-5406(00)70228-9

28. Paredes V, Gandia JL, Cibrian R. Do Bolton's ratios apply to a Spanish population? *Am J Orthod Dentofacial Orthop*. (2006) 129:428–30. doi: 10.1016/j.ajodo.2005.03.020

29. Bernabe E, Major PW, Flores-Mir C. Tooth-width ratio discrepancies in a sample of Peruvian adolescents. *Am J Orthod Dentofacial Orthop*. (2004) 125:361–5. doi: 10.1016/j.ajodo.2003.04.008

30. Santoro M, Ayoub ME, Arthur Pardi V, Cangialosi TJ. Mesiodistal crown dimensions and tooth size discrepancy of the permanent dentition of Dominican Americans. *Angle Orthod*. (2000) 70:303–7.

31. Hashim HA, Najah A-S, Hashim A-H. Bolton tooth size ratio among qatari population sample: an odontometric study. *J Orthod Sci*. (2017) 6:22. doi: 10.4103/2278-0203.197395

32. Subbarao V, Reddy R, Santi V, Anita G, Kattimani V. Interarch tooth size relationship of Indian population: does Bolton's Analysis apply? *J Contemp Dent Pract*. (2014) 15:103–7. doi: 10.5005/jp-journals-10024-1196

33. Alqahtani H. A study to estimate tooth size discrepancy values specific to Saudi orthodontic patients: a systematic review and meta-analysis. *Saudi Dent J*. (2023) 35(5):498–507. doi: 10.1016/j.sdentj.2023.03.006

34. Alshahrani AA, Alshahrani I, Addas MK, Shaik S, Binhomran FM, AlQahtani J. The tooth size discrepancy among orthodontic patients and normal occlusion individuals from Saudi Arabia: a three-dimensional scan analysis of diagnostic casts. *Contemp Clin Dent*. (2020) 11:141–9. doi: 10.4103/ccd.ccd_455_19

35. Taibah S. Bolton discrepancy among patients with anterior open bite malocclusion. *J World Fed Orthod*. (2016) 5:131–4. doi: 10.1016/j.ejwf.2016.12.002

36. Omar H, Alhajrasi M, Felemban N, Hassan A. Dental arch dimensions, form and tooth size ratio among a Saudi sample. *Saudi Med J*. (2018) 39:86–91. doi: 10.15537/smj.2018.1.21035

37. Asiry M, Hashim H. Tooth size ratios in Saudi subjects with class II, division 1 malocclusion. *J Int Oral Health*. (2012) 4:29.

38. Grauer D, Heymann GC. Clinical management of tooth size discrepancies. *J Esthet Restor Dent*. (2012) 24:155–9. doi: 10.1038/sj.bdj.2012.1011

39. Graber LW, Vig KW, Huang GJ, Fleming P. *Orthodontics-e-book: Current principles and techniques*. St. Louis, MO: Elsevier Health Sciences (2022).

40. Rossetti A, De Menezes M, Rosati R, Ferrario VF, Sforza C. The role of the golden proportion in the evaluation of facial esthetics. *Angle Orthod*. (2013) 83:801–8. doi: 10.2319/111812-883.1

41. Naini FB, Moss JP, Gill DS. The enigma of facial beauty: esthetics, proportions, deformity, and controversy. *Am J Orthod Dentofacial Orthop*. (2006) 130:277–82. doi: 10.1016/j.ajodo.2005.09.027

42. Hussein FA, Mohamed RE, El-Awady AA, Ali MM, Al-Khalifa HN, Abdallah KF, et al. Digital evaluation of Bolton's tooth size discrepancies among different malocclusions categories of Egyptian adolescent orthodontic population: a retrospective study. *Int Orthod*. (2022) 20:100660. doi: 10.1016/j.ortho.2022.100660

43. Kachoei M, Atashi MHA, Pourkhamneh S. Bolton's intermaxillary tooth size ratios among Iranian schoolchildren. *Med Oral Patol Oral Cir Bucal*. (2011) 16(4):e568–72. doi: 10.4317/medoral.16.e568

44. Machado V, Botelho J, Pereira D, Vasques M, Fernandes-Retto P, Proença L, et al. Bolton ratios in Portuguese subjects among different malocclusion groups. *J Clin Exp Dent*. (2018) 10:e864. doi: 10.4317/jced.54977

45. Al-Gunaid T, Yamaki M, Saito I. Mesiodistal tooth width and tooth size discrepancies of Yemeni Arabians: a pilot study. *J Orthod Sci*. (2012) 1:40. doi: 10.4103/2278-0203.99760

46. Leung EMY, Yang Y, Khambay B, Wong RWK, McGrath C, Gu M. A comparative analysis of tooth size discrepancy between male and female subjects presenting with a class I malocclusion. *Sci. World J*. (2018) 2018:7641908. doi: 10.1155/2018/7641908

47. Ling JY, Wong RW. Tanaka–Johnston mixed dentition analysis for southern Chinese in Hong Kong. *Angle Orthod*. (2006) 76:632–6.

48. Townsend GC. Intercuspal distances of maxillary pre-molar teeth in Australian aboriginals. *J Dent Res*. (1985) 64:443–6. doi: 10.1177/00220345850640031001

49. Ricci ID, Scanavini MA, Kaieda AK, Rosário HD, Paranhos LR. Bolton ratio in subjects with normal occlusion and malocclusion. *Braz J Oral Sci*. (2013) 12:357–61. doi: 10.1590/S1677-32252013000400015

50. Al-Khateeb SN, Abu Alhaija ESJ. Tooth size discrepancies and arch parameters among different malocclusions in a Jordanian sample. *Angle Orthod*. (2006) 76:459–65. doi: 10.1043/0003-3219(2006)076[0459:TSDAAP]2.0.CO;2

51. Mishra RK, Kafle D, Gupta R. Analysis of interarch tooth size relationship in Nepalese subjects with normal occlusion and malocclusions. *Int J Dent*. (2019) 2019:e2761427. doi: 10.1155/2019/2761427

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 11 October 2023
DOI 10.3389/fpubh.2023.1254479

OPEN ACCESS

EDITED BY
Sreekanth Kumar Mallineni,
Tohoku University, Japan

REVIEWED BY
Prathip Phantumvanit,
Thammasat University, Thailand
Karin Dowidar,
Alexandria University, Egypt

*CORRESPONDENCE
Hai Minh Vu
✉ vuminhhai777@gmail.com

RECEIVED 07 July 2023
ACCEPTED 19 September 2023
PUBLISHED 11 October 2023

CITATION
Vu DA, Vu HM, Vu HM, Tran PT, Duong HH, Tran KQ, Nguyen BX and Luong HX (2023) Parental knowledge and practice on childhood caries prevention in northern Vietnam. *Front. Public Health* 11:1254479. doi: 10.3389/fpubh.2023.1254479

Parental knowledge and practice on childhood caries prevention in northern Vietnam

Dung Anh Vu[1], Hai Minh Vu[2]*, Hoang Minh Vu[1], Phuc Thai Tran[3], Hoang Huy Duong[4], Kham Quoc Tran[5], Bach Xuan Nguyen[6] and Hien Xuan Luong[5]

[1]Department of Odonto Stomatology, Thai Binh University of Medicine and Pharmacy, Thái Bình, Vietnam, [2]Department of Trauma, Thai Binh University of Medicine and Pharmacy, Thái Bình, Vietnam, [3]Nursing Department, Thai Binh University of Medicine and Pharmacy, Thái Bình, Vietnam, [4]Department of Neurology, Thai Binh University of Medicine and Pharmacy, Thái Bình, Vietnam, [5]Faculty of Public Health, Thai Binh University of Medicine and Pharmacy, Thái Bình, Vietnam, [6]VNU University of Medicine and Pharmacy, Vietnam National University, Hanoi, Vietnam

This study was conducted to describe the knowledge and practices on dental caries prevention among parents of preschool children in Vietnam and identify associated factors. A cross-sectional study was conducted in three preschools in Northern Vietnam in 2020. A total of 316 parents of preschool children were randomly recruited. Knowledge and practices regarding early dental caries prevention were asked by using a structured questionnaire. Multivariate Tobit regression was used to examine factors associated with knowledge and practice scores. Results showed four aspects of knowledge that had the lowest proportion of parents having correct responses included timing of complete primary tooth replacement (12.3%), benefits of undergoing regular dental examination (31.7%), technique for brushing a child's teeth (33.9%), and duration for brushing (36.7%). The knowledge of parents was moderately low at 6.3/12 (SD = 2.3). The practices of parents were moderately good with the mean practice score at 6.1/9 (SD = 2.0). The proportion of parents taking children for regular checkups (56.2%) and replacing toothbrush every 3 months (53.7%) were the lowest. Information source, occupation, education and perceived necessity of oral care were found to be associated with parents' knowledge and practices. To conclude, parents had moderate levels of knowledge and practices regarding early dental caries prevention in preschool children. Further studies and interventions should be performed to improve parental knowledge and practices that could enhance the oral health of children.

KEYWORDS

knowledge, practice, dental caries prevention, children, parent

1. Introduction

Dental caries is highly prevalent among children worldwide (1). If not appropriately addressed, this condition possesses the capacity to progress to the dental pulp, resulting in discomfort for the affected individual and giving rise to localized complications associated with infection. Consequently, such complications have the potential to exert an impact on premature tooth loss, and impaired masticatory function, as well as overall physiological wellness such as weight reduction, respiratory issues, joint ailments, cardiovascular disorders, and sinusitis. Moreover, situations arise where the deciduous dentition is affected by decay and requires untimely removal,

resulting in potential complications in the subsequent eruption or alignment of the permanent dentition (2).

Various studies have provided evidence regarding the varying incidence rates of dental caries among children aged 1 to 5 years on a global level, ranging from 22 to 69% (3–5). Sergio et al. in their meta-analysis showed that the prevalence of early dental caries was 48%, with the highest rate in the Oceania continent (82%), followed by Asia (52%), Americas (48%), Europe (43%) and Africa (30%) (6). Another study's findings indicate that, within the demographic of children aged less than 36 months, the highest mean prevalence of the condition was observed in North America (31. 7%) and South Asia (30%). In contrast, the lowest mean prevalence was reported in sub-Saharan Africa (14. 3%). With children within the age range of 36 to 71 months, the East Asia/Pacific region exhibited the highest mean prevalence at 68.7%, followed closely by the Middle East/North Africa region with a prevalence of 66.2% (7).

The preschool stage marks the period when children exhibit the presence of mature primary dentition. During childhood, young individuals are capable of embarking upon the initial stages of teeth brushing, visual image identification, as well as guiding oral hygiene. Nonetheless, the prevention and management of oral diseases encounter numerous challenges as a result of the early stage of development. Furthermore, the efficacy of oral disease prevention during this stage is contingent upon the parental knowledge and practices on the instruction and supervision of children on their oral hygiene routines, including brushing and flossing, as well as ensuring regular dental check-ups (8, 9). Some studies showed that children whose parents have correct oral hygiene awareness and behaviors have a lower rate of tooth decay than children whose parents do not have proper oral care behaviors (10–12). Hence, comprehending the knowledge and practices of parents and caregivers assumes a significant role in the advancement of intervention programs intended to alter behavior and foster health promotion for enhancing the oral health of children. However, in literature, several studies have revealed a lack of parental knowledge on oral care (13, 14); meanwhile, others indicated substantial knowledge and exhibited positive attitudes, yet demonstrated suboptimal implementation of practices (15, 16). Nevertheless, the majority of studies have reached the consensus that educational programs and initiatives are necessary to enhance parents' knowledge and understanding of oral health matters (13–16).

In Vietnam, dental caries is a substantial phenomenon. Prior reports in different settings showed that the prevalence of dental caries among children aged 2–5 years was 82.9 to 89.1% (17, 18). Despite the significance of dental problems in preschool children, research related to knowledge, attitude and practice in dental care among their parents is limited. A previous study showed that the percentage of parents with appropriate knowledge, attitudes and practices was 54.6, 63.0 and 42.3%, respectively (19). More updated evidence should be provided in other settings for developing further intervention plans, which might support improving the dental health of preschool children. Therefore, this study was conducted to describe the knowledge and practices on dental caries prevention among parents of preschool children in Vietnam and identify associated factors.

2. Materials and methods

2.1. Study settings and sampling procedure

In 2020, a cross-sectional study was conducted within a Northern Vietnamese province. After considering the demographic characteristics of the province and the number of children in each preschool, we decided to perform the study in three preschools, one in an urban commune and two in rural communes to have an approximately equal number of participants between both settings. The schools were randomly selected from the list that was provided by the authorities of the communes. Then, in each school, we invited parents whose children studied in the selected schools. The inclusion criteria encompassed parents who had children between the ages of three and 5 years old currently enrolled at the corresponding school, as well as obtaining their informed consent to partake in the study. The study entailed the participation of a total of 316 parents. The response rate achieved a substantial value of 96%.

2.2. Data collection method

A structured questionnaire was utilized as a data collection instrument during participant interviews. The investigators included members of the research team and medical students with rigorous training. Every data collector attended a two-day training course. The initial day of training encompassed the instruction of data collectors on research objectives, research subjects, the structure of questionnaires, as well as appropriate interviewing techniques. On the subsequent day, the investigators actively engaged in the pilot study. The researchers conducted a trial interview with a cohort of 10 parents who fulfilled the specified eligibility criteria and were distinct from the parents of children selected for inclusion in the study. This study enabled the participants to become acquainted with the procedures of conducting interviews and to gather data reliably.

The questionnaire was developed based on reviewing the current literature on the same topics, as well as being consulted by experts in the field of community oral care and oral care for children. First, we sought and reviewed items that were proposed in the prior studies and developed a list of different questions regarding knowledge and practices on dental caries prevention for preschool children (20), especially in developing countries (13, 16, 21, 22). To ensure face validity, we performed expert panels that provided support to remove unnecessary or duplicated items and shortened the list of items. Then, by piloting the questionnaire and receiving feedback from participants, we revised the questionnaire regarding cultural background, text, language and logical order of items. The questionnaire consists of the following information:

Demographic characteristics: gender of the respondent, the gender of their children, their year of birth, level of education, occupation, living location number of children as well as the education and occupation of their spouse.

Oral health of children: We collected data on information sources for oral care and history of children's tooth decay. Moreover, the participants were instructed to assess the necessity of oral care for preschool children, with 0 = not necessary, 1 = necessary and 2 = very necessary.

Knowledge of dental caries prevention: This study used 12 questions to evaluate the knowledge of parents on dental caries prevention. They focused on the awareness of parents regarding the timing of permanent teeth eruption, dietary restrictions necessary to prevent dental diseases, habits that should be limited to minimize dental illnesses, appropriate age of tooth brushing initiation, recommended duration of tooth brushing, optimal brushing techniques, duration of brushing, factors contributing to tooth decay, and recommended

preventive measures to safeguard dental health. Each accurately responded item was awarded a score of one point. The range of the total knowledge score encompassed values between 0 and 12 points. The attainment of higher scores corresponded to a greater level of knowledge. The Cronbach's alpha of these items was 0.651, suggesting acceptable internal consistency.

Practices on dental caries prevention: Nine items about different dental caries prevention practices were asked. We evaluated the frequency with which parents remind their children about oral hygiene, including the number of times they brush their children's teeth in a day, the frequency with which they remind their children to wash their mouths and brush their teeth after meals, and the frequency at which they take their children for regular dental check-ups. Moreover, we explore the type of toothbrush and cup used by parents, as well as the selection of toothbrushes for children and guidelines on when to replace these brushes and introduce toothpaste for children. Parents' actions after being informed of their child's tooth decay were also asked. The overall evaluation of practice performance was measured on a scale ranging from 0 to 9 points, with a higher score indicating better practices. The Cronbach's alpha of these items was 0.667, suggesting acceptable internal consistency.

2.3. Statistical analysis

Collected data was reviewed, cleaned and entered on Epidata 3.1 software. Data were analyzed using STATA 14.0 software. Descriptive statistical methods were used to describe frequencies and percentages, the mean, and standard deviation. A multivariable Tobit regression model was applied to evaluate the factors related to knowledge and practice scores. A backward stepwise selection strategy was used. Variables with a value of p of the log-likelihood of less than 0.2 were included in the model. A *p*-value with a value <0.05 was used to consider the level of statistical significance.

3. Results

Table 1 shows that, among 316 parents, most of them were male (56.7%) with a mean age of 31.9 years old (SD = 5.2). The majority of them had above high school education (46.2%) and were officials (47.2%), lived in rural areas (51.6%). The major information sources for dental care included social networks (44.4%), Internet (41.6%) and medical staff (42.2%). The majority of participants perceived that oral hygiene for children was necessary/very necessary (97.8%).

Regarding knowledge Table 2 shows the parent's knowledge about dental caries prevention for children, Table 2 shows that tooth brushing age (81.3%), cause of tooth decay (71.8%), time of permanent teeth eruption (68.7%) and number of primary teeth (68.0%) were the most accurate knowledge. The mean knowledge score was 6.3/12 (SD = 2.3).

According to practice, Table 3 shows that the mean practice score was 6.1/9 (SD = 2.0). Overall, the practices of parents were good. The proportion of parents taking children for regular checkups (56.2%) and replacing toothbrush every 3 months (53.7%) were the lowest.

Table 4 depicts factors associated with knowledge and practice scores. Regarding knowledge, participants who were officials had a lower score than those who were farmers/workers (Coef. = −1.17; 95%CI = -1.83; −0.50). Participants who preferred friends/relatives and the internet as information sources had a higher knowledge score than those not. Meanwhile, for the practice score, a higher spouse's education level and family as an information source were associated with a higher practice score. Participants whose spouses were officials had lower practice scores than those who were self-employed. Notably, parents having higher perceived necessity of oral hygiene for children had significantly higher knowledge (Coef. = 0.80, 95%CI = 0.45–1.14) and practice scores (Coef. = 0.89, 95%CI = 0.58–1.20).

4. Discussion

According to the World Health Organization, a comprehensive strategy to prevent tooth decay in children cannot be carried out independently but must involve the contributions of many stakeholders such as healthcare professionals, educators, healthcare providers; caregivers and the child (23). This study informed that Vietnamese parents had moderate knowledge and practices in early caries prevention regardless of living location. Moreover, several social determinants of knowledge and practice such as occupation, information sources and the perceived necessity of oral care would be useful for further interventions in the community to improve children's oral health.

Results of this study show that parents had a moderate-low level of knowledge, which was similar to other studies in the world as well as in Vietnam when they showed that parents' knowledge about dental care was limited (19, 24, 25). One prior study shows that the percentage of parents with good knowledge of several fundamentals of dental care was less than 50% (24). Notably, four aspects of knowledge that had the lowest proportion of parents having correct responses included timing of complete primary tooth replacement (12.3%), benefits of undergoing regular dental examination (31.7%), technique for brushing a child's teeth (33.9%), and duration for brushing (36.7%). These rates were comparable to other studies in both developed and developing countries. In a study conducted in Australia, a mere 40% of parents recognized the inadequacy of daily brushing as a significant risk factor for the onset of tooth decay at an early stage (22). Another research conducted on parents in Malaysia demonstrated that only 50% of these adults possessed knowledge regarding the potential risk of tooth decay in preschool-age children who are below 2 years old (26). In a study conducted by a cohort of Qatari parents, it was observed that a significant proportion (64%) of maternal participants displayed a lack of knowledge regarding the appropriate timing of the initial dental appointment for their children (27). Another study among Saudi parents uncovered that a majority of 53% expressed a lack of inclination toward availing dental care services for their children during the initial year of their lives (28). This also indicated a significant lack of basic knowledge in oral health care for children in Vietnam. One possible explanation for this phenomenon can be attributed to the lack of dental health education programs for children in Vietnam. In practice, alongside oral health care programs in schools, there is an infrequent observation of comprehensive health education programs addressing this issue. One additional issue that we observed during this study is the lack of importance given by parents to dental care for preschool-aged children. This is due to the belief that primary teeth would be replaced by permanent teeth, and thus there would be no need to pay attention to the care of primary teeth. As a result, despite being fundamental knowledge in the care of children's oral health, parents have yet to fully

10.3389/fpubh.2023.1254479

TABLE 1 Demographic characteristics of parents.

Characteristics		Freq. (*n*)	Percent (%)
Respondent's gender	Male	179	56.7
	Female	137	43.3
Gender of child	Male	185	58.5
	Female	131	41.7
Education	Middle school	59	18.7
	High school	111	35.1
	> High School	146	46.2
Spouse's education	Middle school	51	16.1
	High school	119	37.7
	> High School	146	46.2
Occupation	Farmer/worker	52	16.5
	Officials	149	47.2
	Different	115	36.4
Spouse's occupation	Free	115	36.4
	Workers/farmers	117	37.0
	Officials	41	13.0
	Different	43	13.6
Living location	Rural	163	51.6
	Urban	153	48.4
Information sources	Family	112	35.7
	Friends and relatives	86	27.3
	Colleague	68	21.6
	Television, newspapers	127	40.3
	Internet in general	131	41.6
	Social networks	140	44.4
	Medical staff	133	42.2
	Others	13	4.1
Children with previous tooth decay	Yes	158	50.2
	No	157	49.8
Necessity of oral hygiene for children	Not necessary	7	2.2
	Necessary	107	34.0
	Very necessary	201	63.8
Characteristics		**Mean**	**SD**
Age of respondents (years old)		31.9	5.2
Number of children		2.1	0.6

realize the significance of this issue. This is asserted through the correlation between awareness of oral care necessity and the level of knowledge in parents, that individuals with higher perceived necessity levels tend to possess higher levels of knowledge. Thus, it is evident that parents would benefit from the implementation of educational programs that increase their awareness of the importance of preschool children's oral care, as well as provide assistance and guidance regarding the significance of fundamental issues such as timing of tooth replacement, or technique/duration for brushing teeth.

The findings of this study indicate that parents exhibited a moderately high level of practice, which is consistent with parental practices observed in various regions (21, 27, 29, 30). A significant proportion of parents provided accurate responses showed promising findings that further interventions should focus on informing accurate knowledge for them in order to provide fundamental for their accurate practices. However, several aspects of practices should be concerned such as regular checkups (56.2%) and replacing toothbrush every 3 months (53.7%). Indeed, regular health check-ups and toothbrush replacement play an important role in ensuring children's oral health, maintaining oral hygiene and preventing the growth of bacteria inside the oral cavity, which are the main cause of dental caries and thereby tooth decay. Therefore, parents need to form these habits to help ensure children's oral

TABLE 2 Parent's knowledge about dental caries prevention for children.

Correct content	Freq. (*n*)	Percent (%)
The time of complete replacement of primary teeth (6 to 13 years old)	39	12.3
The time of full primary teeth eruption (3–4 years old)	133	42.1
The number of primary teeth (20 teeth)	215	68.0
The time of permanent teeth eruption (6 years old and above)	217	68.7
Food needs to be limited to prevent dental diseases (different types of sweet food)	186	58.9
Bad habits to avoid to prevent dental disease (snack food, sweet food, biting pen, sucking rice, sucking fingers, breathing through the mouth, leaning on the chin, biting hard objects)	180	57.0
The age when tooth brushing starts (3 years old)	256	81.3
The manner to brush a child's teeth (brushing in longitudinal axis, circular brushing, brushing all three sides of the teeth)	107	33.9
The best brushing time (after meals)	116	36.7
The results of regular dental check-ups for children (prevention of oral diseases, early detection and treatment)	100	31.7
The causes of tooth decay (not having good oral hygiene, eating snacks, eating candy, drinking soft drinks, etc., due to bacteria)	227	71.8
Measures to protect a child's teeth (limit eating candy, limit drinking soft drinks, limit eating snacks, good oral hygiene, brush teeth with fluoride, have regular dental check-ups)	207	65.5
	Mean	SD
Knowledge score (0–12)	6.3	2.3

TABLE 3 Parents' practices in dental care for children.

Correct content	Freq. (*n*)	Percent (%)
Take the child for treatment if he or she has tooth decay	257	81.6
Regularly remind the child about oral hygiene	252	80.0
Brush the child's teeth 1–2 times a day	275	87.3
Regularly/always remind the child to rinse their mouth and brush their teeth after eating	201	63.8
Take the child for regular dental checkups 1–2 times a year	177	56.2
Use separate toothbrushes and toothcups between parent and child	199	63.2
Use a child's toothbrush to clean the child's teeth	292	92.7
Replace toothbrush every 3 months	169	53.7
Use toothpaste for children	256	81.3
	Mean	SD
Practice score (0–9)	6.1	2.0

health. Results of the regression analysis indicate that parents who primarily rely on information from friends/relatives, the Internet, and medical staff regarding child dental care tend to possess a greater level of knowledge and practices compared to individuals who do not utilize these sources of information. The aforementioned information channels demonstrate potential avenues for subsequent intervention programs aimed at enhancing parents' knowledge pertaining to children's oral care.

Collectively, it is notable that the comprehension and implementation of dental care among parents is lacking, not only within Vietnam but also globally. Research findings indicate that a notable impact on children's oral health is observed due to inadequate knowledge and awareness of dental treatment, oral hygiene, and dietary habits (30). There is robust evidence attesting to the effectiveness of assisting parents and caregivers in enhancing their knowledge, attitudes, and practices to advance children's oral health (30–33). Henceforth, health education intervention programs must be implemented moving forward to enhance parental knowledge, attitudes, and practices on dental care for children.

The research possesses certain constraints. This study was solely undertaken within a single province in northern Vietnam, thus potentially limiting its applicability to current knowledge, attitudes, and practices of parents in different localities. The investigation employed a cross-sectional study design, which constrained the potential to establish a causal relationship. Finally, the items regarding knowledge and practices in this study were not fully validated. Further studies should be warranted to examine the validity of these questions as well as provide more evidence about the knowledge and practices of parents in oral care for their children, which is important for planning effective interventions to improve children's health and well-being.

Conclusion

Parents had moderate knowledge and practices regarding early dental caries prevention in preschool children. Further studies and

10.3389/fpubh.2023.1254479

TABLE 4 Factors related to knowledge and practice of parents in early dental caries prevention.

Characteristics	Knowledge score		Practice score	
	Coef.	95%CI	Coef.	95%CI
Child's gender (Female vs. Male)			−0.29	(−0.68; 0.10)
Respondent's gender (Female vs. Male)	−0.34	(−0.77; 0.09)		
Education level (vs. <High School)				
High School	0.12	(−0.50; 0.75)		
> High School	0.60*	(−0.03; 1.24)		
Spouse's education level (vs. <high school)				
High School			0.03	(−0.55; 0.62)
> High School			0.64**	(0.05; 1.23)
Occupation (vs. Farmer/worker)				
Officials	−1.17***	(−1.83; −0.50)		
Other	−0.69*	(−1.41; 0.03)		
Spouse occupation (vs. Self-employed)				
Farmer/worker			−0.16	(−0.62; 0.30)
Officials			−0.79**	(−1.47; −0.12)
Other			−0.99***	(−1.59; −0.38)
Sources of Information (Yes vs. No)				
Family	−0.37	(−0.84; 0.09)	0.64***	(0.22; 1.07)
Friends, relatives	0.70***	(0.19; 1.22)		
Colleague			−0.49*	(−0.99; 0.01)
TV, radio	0.35	(−0.11; 0.81)		
Internet in general	0.64***	(0.17; 1.11)		
Social network	0.32	(−0.13; 0.77)		
Medical staff			0.84***	(0.44; 1.23)
Necessity of oral hygiene for children	0.80***	(0.45; 1.14)	0.89***	(0.58; 1.20)
Knowledge score			0.13***	(0.04; 0.21)
Practice score	0.20***	(0.07; 0.32)		

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

interventions should be performed to improve parental knowledge and practices that could enhance the oral health of children.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Thai Binh University of Medicine and Pharmacy. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

DV: Conceptualization, Formal Analysis, Writing – original draft, Writing – review & editing. HaV: Conceptualization, Formal Analysis, Writing – original draft, Writing – review & editing. HoV: Conceptualization, Formal Analysis, Writing – original draft, Writing – review & editing. PT: Investigation, Writing – original draft, Writing – review & editing. HD: Investigation, Writing – original draft, Writing – review & editing. KT: Supervision, Writing – original draft, Writing – review & editing. BN: Formal Analysis, Writing – original draft, Writing – review & editing. HL: Supervision, Writing – original draft, Writing – review & editing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Frencken JE, Sharma P, Stenhouse L, Green D, Laverty D, Dietrich T. Global epidemiology of dental caries and severe periodontitis - a comprehensive review. *J Clin Periodontol*. (2017) 44 Suppl 18:S94–s105. doi: 10.1111/jcpe.12677

2. Dentistry AAOP. Symposium on the prevention of oral disease in children and adolescents. *Pediatr Dent*. (2006) 28:96–198.

3. Gao SS, Duangthip D, Lo ECM, Chu CH. Risk factors of early childhood caries among young children in Hong Kong: a cross-sectional study. *J Clin Pediatr Dent*. (2018) 42:367–72. doi: 10.17796/1053-4625-42.5.8

4. Kelly B, Halford JC, Boyland EJ, Chapman K, Bautista-Castano I, Berg C, et al. Television food advertising to children: a global perspective. *Am J Public Health*. (2010) 100:1730–6. doi: 10.2105/ajph.2009.179267

5. Fleming E, Afful J. Prevalence of Total and untreated dental caries among youth: United States, 2015-2016. *NCHS Data Brief*. (2018) 307:1–8.

6. Uribe SE, Innes N, Maldupa I. The global prevalence of early childhood caries: a systematic review with meta-analysis using the WHO diagnostic criteria. *Int J Paediatr Dent*. (2021) 31:817–30. doi: 10.1111/ipd.12783

7. El Tantawi M, Folayan MO, Mehaina M, Vukovic A, Castillo JL, Gaffar BO, et al. Prevalence and data availability of early childhood caries in 193 United Nations countries, 2007-2017. *Am J Public Health*. (2018) 108:1066–72. doi: 10.2105/ajph.2018.304466

8. Dudovitz R, Teutsch C, Holt K, Herman A. Improving parent oral health literacy in head start programs. *J Public Health Dent*. (2020) 80:150–8. doi: 10.1111/jphd.12361

9. Patil AN, Karkare S, Jadhav HS, Damade Y, Punjari BK. Knowledge, attitude, and practice of parents toward their Children's Oral health and its influence on the dental caries status of 5-10-year-old schoolchildren in Nashik, Maharashtra: a cross-sectional study. *Int J Clin Pediatr Dent*. (2022) 15:S126–30. doi: 10.5005/jp-journals-10005-2137

10. Wagner Y, Greiner S, Heinrich-Weltzien R. Evaluation of an oral health promotion program at the time of birth on dental caries in 5-year-old children in Vorarlberg, Austria. *Community Dent. Oral Epidemiol*. (2014) 42:160–9. doi: 10.1111/cdoe.12072

11. Plutzer K, Spencer AJ, Keirse MJ. Reassessment at 6-7 years of age of a randomized controlled trial initiated before birth to prevent early childhood caries. *Community Dent Oral Epidemiol*. (2012) 40:116–24. doi: 10.1111/j.1600-0528.2011.00643.x

12. Nassar AA, Fatani BA, Almobarak OT, Alotaibi SI, Alhazmi RA, Marghalani AA. Knowledge, attitude, and behavior of parents regarding early childhood caries prevention of preschool children in Western region of Saudi Arabia: a cross-sectional study. *Dent J*. (2022) 10:218. doi: 10.3390/dj10120218

13. Dhull KS, Dutta B, Devraj IM, Samir PV. Knowledge, attitude, and practice of mothers towards infant Oral healthcare. *Int J Clin Pediatr Dent*. (2018) 11:435–9. doi: 10.5005/jp-journals-10005-1553

14. Bani Hani A, Tahmassebi J, Zawaideh F. Maternal knowledge on early childhood caries and barriers to seek dental treatment in Jordan. *Eur Arch Paediatr Dent*. (2021) 22:433–9. doi: 10.1007/s40368-020-00576-0

15. Suma Sogi HP, Hugar SM, Nalawade TM, Sinha A, Hugar S, Mallikarjuna RM. Knowledge, attitude, and practices of oral health care in prevention of early childhood caries among parents of children in Belagavi city: a questionnaire study. *J Fam Med Prim Care*. (2016) 5:286–90. doi: 10.4103/2249-4863.192332

16. Mahmoud N, Kowash M, Hussein I, Hassan A, Al HM. Oral health knowledge, attitude, and practices of Sharjah mothers of preschool children, United Arab Emirates. *J Int Soc Prev Community Dent*. (2017) 7:308–14. doi: 10.4103/jispcd.JISPCD_310_17

17. Nguyen YHT, Ueno M, Zaitsu T, Nguyen T, Kawaguchi Y. Early childhood caries and risk factors in Vietnam. *J Clin Pediatr Dent*. (2018) 42:173–81. doi: 10.17796/1053-4628-42.3.2

18. Hung HV, Ngoc VTN, Vu Thi H, Chu DT. Early childhood caries in obese children: the status and associated factors in the suburban areas in Hanoi, Vietnam. *Int J Environ Res Public Health*. (2021) 18:8844. doi: 10.3390/ijerph18168844

19. Thuy DTD, Phuong NTT, Hanh TTM, Chieu HN. Parental knowledge, attitudes, and practices about caring for primary teeth in Vietnam. *Mahidol Dent J*. (2021) 41:255–64.

20. Mahat G, Bowen F. Parental knowledge about urban preschool Children's Oral health risk. *Pediatr Nurs*. (2017) 43:30–4.

21. Al-Jaber AS, Al-Qatami HM, Abed Al Jawad FH. Knowledge, attitudes, and practices of parents on early childhood caries in Qatar-a questionnaire study. Eur. *J Dent*. (2022) 16:669–79. doi: 10.1055/s-0041-1739446

22. Gussy MG, Waters EB, Riggs EM, Lo SK, Kilpatrick NM. Parental knowledge, beliefs and behaviours for oral health of toddlers residing in rural Victoria. *Aust Dent J*. (2008) 53:52–60. doi: 10.1111/j.1834-7819.2007.00010.x

23. Petersen P. *The world Oral health report 2003*. Geneva: WHO (2003).

24. ElKarmi R, Shore E, O'Connell A. Knowledge and behaviour of parents in relation to the oral and dental health of children aged 4-6 years. *Eur Arch Paediatr Dent*. (2015) 16:199–204. doi: 10.1007/s40368-014-0155-7

25. Mounissamy A, Moses J, Ganesh J, Arulpari M. Evaluation of parental attitude and practice on the primary teeth of their children in Chennai: an hospital survey. *Int J Pedod Rehabil*. (2016) 1:10–4.

26. Mani S, John J, Ping W, Ismail N. *Early childhood caries: Parent's knowledge, attitude and practice towards its prevention in Malaysia*. London: IntechOpen (2012).

27. Alkhtib A, Morawala A. Knowledge, attitudes, and practices of mothers of preschool children about Oral health in Qatar: a cross-sectional survey. *Dent J*. (2018) 6:51. doi: 10.3390/dj6040051

28. Ra T, Al-Shahrani I, Al-Absi W, Al-Shahrani F, Shiban A, Bijle MN. Awareness among young parents about preventive aspects of early childhood caries in Abha City, Kingdom of Saudi Arabia. *World J Dent*. (2016) 7:10–3. doi: 10.5005/jp-journals-10015-1355

29. Vargas CM, Ronzio CR, Hayes KL. Oral health status of children and adolescents by rural residence, United States. *J Rural Health*. (2003) 19:260–8. doi: 10.1111/j.1748-0361.2003.tb00572.x

30. Chhabra N, Chhabra A. Parental knowledge, attitudes and cultural beliefs regarding oral health and dental care of preschool children in an Indian population: a quantitative study. *Eur Arch Paediatr Dent*. (2012) 13:76–82. doi: 10.1007/BF03262848

31. Naidu R, Nunn J, Irwin JD. The effect of motivational interviewing on oral healthcare knowledge, attitudes and behaviour of parents and caregivers of preschool children: an exploratory cluster randomised controlled study. *BMC Oral Health*. (2015) 15:101. doi: 10.1186/s12903-015-0068-9

32. Shaghaghian S, Zeraatkar M. Factors affecting Oral hygiene and tooth brushing in preschool children, shiraz/Iran. *J Dent Biomater*. (2017) 4:394–402.

33. Marthaler TM, Petersen PE. Salt fluoridation–an alternative in automatic prevention of dental caries. *Int Dent J*. (2005) 55:351–8. doi: 10.1111/j.1875-595X.2005.tb00045.x

frontiers | Frontiers in Pediatrics

TYPE Original Research
PUBLISHED 04 December 2023
DOI 10.3389/fped.2023.1303005

OPEN ACCESS

EDITED BY
Sreekanth Kumar Mallineni,
Tohoku University, Japan

REVIEWED BY
Jaya Chandra Bhumireddy,
RIMS Medical College Ongole, India
Anshad Mohamed Abdulla,
King Khalid University, Saudi Arabia

*CORRESPONDENCE
Mannaa Aldowsari
maldowsari@ksu.edu.sa

RECEIVED 27 September 2023
ACCEPTED 23 November 2023
PUBLISHED 04 December 2023

CITATION
BinSaleh S, Sulimany AM, Aldowsari MK, Al-Homaidhi M, Alkuait N, Almashham L and Alghamdi N (2023) Evaluation of the shear bond strength of a tricalcium silicate-based material to four self-adhering glass ionomer materials: an *in vitro* study.
Front. Pediatr. 11:1303005.
doi: 10.3389/fped.2023.1303005

Evaluation of the shear bond strength of a tricalcium silicate-based material to four self-adhering glass ionomer materials: an *in vitro* study

Saad BinSaleh[1], Ayman M. Sulimany[1], Mannaa K. Aldowsari[1]*, Majedah Al-Homaidhi[1], Nour Alkuait[2], Lama Almashham[2] and Nada Alghamdi[2]

[1]Department of Pediatric Dentistry and Orthodontics, College of Dentistry, King Saud University, Riyadh, Saudi Arabia, [2]College of Dentistry, King Saud University, Riyadh, Saudi Arabia

Background: This study aimed to evaluate and compare the shear bond strength (SBS) of EQUIA Forte HT with that of other restorative materials, including EQUIA Forte, glass ionomer cement (GIC), and resin-modified glass ionomer cement (RMGIC) when bonded to NeoMTA 2.
Materials and methods: A total of 120 holes were created in Teflon molds and filled with NeoMTA 2. The restorative materials were immediately applied using customized silicone molds. The samples were randomly divided into two main groups: one to measure the immediate SBS and the other to measure the delayed SBS. These two main groups were further divided into four subgroups based on the restorative material used: EQUIA Forte HT, EQUIA Forte, GIC, and RMGIC.
Results: The study groups showed statistically significant differences in the mean SBS ($p < 0.0001$). The immediate SBS of the RMGIC group (mean ± SD: 5.43 ± 1.22) was significantly higher than those of the GIC and EQUIA Forte groups, with no significant difference found compared to the SBS of EQUIA Forte HT. In the delayed SBS, both the RMGIC and EQUIA Forte HT groups (4.98 ± 0.67 and 4.93 ± 0.60, respectively) demonstrated significantly higher bond strengths than the GIC and EQUIA Forte groups (3.81 ± 0.57 and 4.2 ± 0.63, respectively). However, there were no statistically significant differences between the RMGIC and EQUIA Forte HT groups or between the GIC and EQUIA Forte groups.
Conclusion: Based on our findings, EQUIA Forte HT has shown promising outcomes when used as a restorative material following pulpotomies, with results comparable to those of RMGIC.

KEYWORDS
EQUIA Forte HT, NeoMTA 2, resin-modified glass ionomer, shear bond strength, pulpotomy

1. Introduction

Glass ionomer cement (GIC) materials have a wide range of applications in pediatric and restorative dentistry due to their ability to release fluoride over an extended period (1, 2). However, they are vulnerable to fracture due to their poor flexural strength and fatigue properties (3).

To circumvent these disadvantages, resin-modified glass ionomer cement (RMGIC) was developed. However, RMGIC has a mechanical strength that is inferior to that of composite resin materials and is not considered a permanent restorative material. Furthermore, it has

the disadvantage of polymerization shrinkage due to its resin content. To overcome these mechanical limitations, EQUIA Forte was introduced as a long-term restorative alternative.

EQUIA Forte is a self-curing, resin-free, highly viscous GIC that releases fluoride (F^-) and calcium ions (Ca^{2+}) (4). It is a bulk-fill glass hybrid (GH) reinforced with ultrafine reactive glass particles. To strengthen the cross-linking of the matrix and enhance the material's flexural strength, EQUIA Forte has also been reinforced with secondary silicate particles of smaller size and higher reactivity, along with acrylic acid molecules of elevated molecular weight. The application of a resin coat to these restorations is allegedly meant to enhance both their wear resistance and esthetic appearance (5).

To further enhance the aesthetic properties, EQUIA Forte HT (GC, Tokyo, Japan) was released in 2019, featuring increased translucency (6). This restorative material exhibits a refined smaller particle size distribution in comparison to its precursor, EQUIA Forte. This refinement contributed to the enhancement of both flexural and compressive strength, resulting in improved matrix loading (7).

Several studies have been conducted on EQUIA Forte HT, demonstrating its reliability as a restorative material with good clinical performance in both primary and permanent teeth (5, 8). Kutuk et al. conducted a study on EQUIA Forte HT in stress-bearing Class II restorations in pediatric patients and concluded that it offers more strength and superior aesthetics compared to a microhybrid composite (G-aenial Posterior, GC Corp., Tokyo, Japan) for both primary and permanent teeth (5).

To date, the application of the relatively newly introduced EQUIA Forte HT to the novel bioceramic material NeoMTA 2 (NuSmile, Houston, TX, USA) has not been studied for its use in primary teeth after pulpotomies. Therefore, this study aimed to evaluate and compare the shear bond strength (SBS) of EQUIA Forte HT with that of other restorative materials—namely, EQUIA Forte, GIC, and RMGIC—when applied to NeoMTA 2.

2. Materials and methods

2.1. Ethical clearance

Ethical clearance for this study was obtained from the institutional review board (No. E-22-7160), and the College of Dentistry Research Center (CDRC No. IR 043).

2.2. Sample size calculation

The sample size was calculated from the previously available literature with a 95% confidence interval and 80% power of the study. For an α value of 0.05, an effect size of 0.45, and a power of 0.95, the total sample size should be at least 120.

2.3. Study design

A total of 120 holes were created in Teflon molds, each measuring 4 mm in diameter and 2 mm in depth, filled with NeoMTA 2. Next, the surface was smoothened using a plastic filling instrument (PF13) to prepare the samples for bonding. A universal adhesive (Single Bond Universal 3M, ESPE, St. Paul, MN, USA) was applied to the surface of the bioceramic material using a rubbing motion for 20 s. The adhesive was subsequently subjected to air drying for 5 s and a light-curing process for 10 s.

To apply the restorative material, a customized silicone mold with a diameter of 3 mm and a thickness of 2 mm was fabricated for use in the bonding procedure. The mold was placed at the center of the NeoMTA 2 layer. The restorative materials were applied immediately after the placement of NeoMTA 2 according to the manufacturer's instructions (**Table 1**).

An LED light-curing device (Bluephase G2, Ivoclar Vivadent, Schaan, Liechtenstein) was used to cure all the samples. After that, the samples were divided equally into two main groups: one to measure the immediate SBS and the other to measure the delayed SBS.

Before performing the SBS tests, all the samples were preserved in artificial saliva and stored in an incubator (GI2 So-Low Cincinnati, OH, USA) at 37 °C and 100% humidity for 24 h. Next, only the samples in the delayed restorative group were loaded in a thermocycling machine (Huber, SD-Mechatronik-Thermocyclerr, Germany) at 5 °C for 2,000 cycles of thermocycling and 55 °C for 5,000 cycles of thermocycling to mimic 6 months of physiological use.

2.4. SBS test

The SBS of each sample was determined using a universal testing machine (Instron 5965, Instron, England) with a knife-edged rod moving at a crosshead speed of 0.5 mm/min (**Supplementary Material Figure S1**). The SBS was calculated in MPa using the following formula: stress (MPa) = force^2 (N)/bonding area (mm^2).

In the case of the immediate SBS group, after 24 h, the samples were mounted in the universal testing machine with the crosshead perpendicular and flush to the interface of the restoration and the bioceramic material (**Supplementary Material Figure S2**). For the delayed SBS group, the SBS test was performed after 7 days in the same manner as for the immediate SBS group.

2.5. Mode of failure

To discover the fracture pattern after the SBS test, the samples' surfaces were examined using a digital microscope (HIROX, KH-7700, Digital microscope system, Tokyo, Japan).

The failure modes were categorized as follows: (1) adhesive failure: failure between the NeoMTA 2 layer and the restorative material; (2) cohesive failure type 1: cohesive failure within the NeoMTA 2 layer; (3) cohesive failure type 2: cohesive failure within the restorative material; and (4) mixed failure: both adhesive and cohesive failures.

2.6. Statistical analysis

The immediate SBS and SBS after the aging process of NeoMTA 2 combined with the four types of restorative materials

TABLE 1 Materials used in the study (name, company, chemical composition, and manufacturer's instructions).

Material	Company	Chemical composition	Manufacturer's instructions
EQUIA Forte HT Fil shade A2	GC Corp., Tokyo, Japan	○ Powder: 95% strontium fluoroaluminosilicate glass, 5% polyacrylic acid ○ Liquid: 40% aqueous polyacrylic acid ○ EQUIA Forte Coat: 40%–50% methyl methacrylate, 10%–15% colloidal silica, 0.09% camphorquinone, 30%–40% urethane methacrylate, 1%–5% phosphoric ester monomer	○ Shake or tap the capsule to loosen the powder. ○ Depress the plunger and hold it down for 2 s. ○ Mix for 10 s. ○ Dispense within 10 s. ○ Pack, contour, and ensure that the restorative material is fully set. ○ Finish the restoration by applying EQUIA Forte HT Coat. ○ Light cure for 20 s.
EQUIA Forte Fil shade A2	GC Corp., Tokyo, Japan	○ Diurethane and methacrylate-based monomers with a modified polyacrylic acid and polybutadiene-modified diurethane dimethacrylate	○ Apply petroleum jelly inside the matrix. ○ Apply the GC Cavity Conditioner for 10 s. ○ Mix for 10 s. ○ Dispense within 10 s. ○ Finish the restoration by applying the EQUIA Coat. ○ Light cure for 20 s.
GIC Fuji™ II	GC Corp., Tokyo, Japan	○ Powder: fluoroaluminosilicate glass ○ Liquid: acrylic acid, maleic acid, tartaric acid, water	○ Add 1 level scoop of powder to 1 drop of liquid. ○ Mix the required amount of cement. ○ Form the contour during the first 2 min of setting.
GC Fuji II LC® resin-reinforced glass ionomer Fil shade A2	GC Corp., Tokyo, Japan	○ 25%–50% 2-hydroxyethylmethacrylate (HEMA) ○ 5%–10% polybasic carboxylic acid ○ 1%–5% urethane dimethacrylate (UDMA) ○ 1%–5% dimethacrylate	○ Shake the capsule or tap its side on a hard surface to loosen the powder. ○ Mix for 10 s. ○ Form the contour and place a matrix if required. ○ Light cure for 20 s.
NeoMTA 2	NuSmile Inc., Houston, TX, USA	○ Powder: tricalcium silicate (Ca_3SiO_5), dicalcium silicate (Ca_2SiO_4), tantalum oxide (Ta_2O_5), and minor amounts of calcium sulfate ($CaSO_4$) and tricalcium aluminate ($Ca_3Al_2O_6$) ○ Liquid: water (H_2O) and proprietary polymers different from the above	○ Add 1 level scoop of powder. ○ Dispense a drop of gel. ○ Integrate thoroughly. ○ Spread NeoMTA. ○ Complete the restoration immediately.
Tetric N Ceram Bond	Ivoclar Vivadent Inc. Principality, Liechtenstein.	○ BisGMA (25%–50%), water and ethanol (10%–25%), 2-hydroxyethyl methacrylate (HEMA) (10%–25%), phosphonic acid methacrylate (MDP) (10%–25%), diphenyl(2,4,6-trimethylbenzoyl) phosphine oxide (1%–2.5%), urethane dimethacrylate (0.3%–10%)	○ Apply a coat of adhesive and agitate for 20 s. ○ Disperse the adhesive with compressed air until a glossy, firm layer is obtained. ○ Light-cure for 10 s.

were reported as the mean ± standard deviation (SD). The mean SBS of each group was determined using a one-way analysis of variance (ANOVA) followed by Tukey's multiple comparison test to assess the differences between the groups. The significance of the difference between the immediate and delayed SBS for each material was calculated using the Student's *t*-test. The data were analyzed using SAS 9.4 (SAS Institute, Inc., Cary, NC, USA). A *p*-value of <0.05 was considered statistically significant.

TABLE 2 Immediate shear bond strength of the different study materials.

Group	Mean SBS (MPa)	SD	*p*-Value
RMGIC (g4)	5.43[a]	1.22	0.005
GIC (g3)	4.32[b]	1.24	
EQUIA Forte (g2)	4.20[b]	0.63	
EQUIA Forte HT (g1)	5.14[a,b]	1.08	

Different numbered letters (g1, g2, g3 and g4) indicate different sample groups. Different superscript lowercase letters indicate significant differences between materials $p \leq 0.005$.

3. Results

Table 2 shows the mean immediate SBSs of the self-adhering glass ionomer materials on NeoMTA 2. There were statistically significant differences between the mean SBSs of some of the study groups ($p = 0.005$). The SBS of the RMGIC group (5.43 ± 1.22) was significantly higher than that of the GIC and EQUIA Forte groups (4.32 ± 1.24 and 4.2 ± 0.63, respectively). However, there was no statistically significant difference between the RMGIC group and the EQUIA Forte HT group.

The mean SBSs of the self-adhering glass ionomer materials to NeoMTA 2 after the aging process are presented in Table 3. There was a statistically significant difference between the mean SBSs of some of the study groups ($p < 0.0001$). The SBSs of the RMGIC and EQUIA Forte groups (4.98 ± 0.67 and 4.93 ± 0.60, respectively) were significantly higher than those of the GIC and EQUIA Forte groups (3.81 ± 0.57 and 4.2 ± 0.63, respectively). However, there was no statistically significant difference between the RMGIC and EQUIA Forte HT groups or between the GIC and EQUIA Forte groups.

Table 4 presents the mean SBSs of the different study materials at different times. Overall, the immediate SBS was higher than the SBS after the aging process among all groups, although the differences were not statistically significant.

TABLE 3 Shear bond strength of the different study materials after the aging process.

Group	Mean SBS (MPa)	SD	*p*-Value
RMGIC (g4)	4.98[a]	0.67	<0.0001
GIC (g3)	3.81[b]	0.57	
EQUIA Forte (g2)	3.94[b]	0.77	
EQUIA Forte HT (g1)	4.93[a]	0.60	

Different numbered letters (g1, g2, g3 and g4) indicate different sample groups. Different superscript lowercase letters indicate significant differences between materials.

TABLE 4 Mean shear bond strength of the different study materials at different times.

Group	Immediate mean SBS (MPa) (mean ± SD)	Delayed Mean SBS (MPa) (mean ± SD)	*p*-Value
RMGIC	5.43 ± 1.22	4.98 ± 0.67	0.35
GIC	4.32 ± 1.24	3.81 ± 0.57	0.66
EQUIA Forte	4.20 ± 0.63	3.94 ± 0.77	0.26
EQUIA Forte HT	5.14 ± 1.08	4.93 ± 0.60	0.74

The types of failure modes in the immediate and delayed SBS groups are represented in **Supplementary Material Figure S4, S5**, respectively. In the immediate SBS groups, EQUIA Forte HT showed a combination (cohesive–adhesive) failure rate of 53.3%, while Equia Forte and GIC had adhesive failure rates of 93.3% and 86.6%, respectively. Finally, RMGIC showed a cohesive failure rate within the NeoMTA 2 layer of 93.3%.

In the delayed SBS groups, cohesive failure within the NeoMTA 2 layer was the most common form of failure found in the EQUIA Forte HT (66.6%), EQUIA Forte (53.3%), and RMGIC (73.3%) groups. However, adhesive failure was predominant in the GIC group (80%).

4. Discussion

Within the limitations of the current study, the null hypothesis that there was no significant difference between the SBS of EQUIA Forte HT and that of other restorative materials—namely, EQUIA Forte, GIC, and RMGIC—when combined with NeoMTA 2 was rejected. The results of the present study regarding both the immediate and delayed SBS revealed a significantly higher mean SBS for EQUIA Forte HT compared to GIC and EQUIA Forte. However, RMGIC showed the highest mean SBS, which is consistent with a previous study, which found that the immediate placement of RMGIC on ProRoot MTA showed the highest SBS (7.18 MPa), followed by NeoMTA 2 (4.15 MPa) (9). Al-homaidhi et al. reported that the SBS of RMGI immediately placed over NeoMTA 2 was statistically high (10), which is consistent with the results of this study.

In another recent study conducted by El-Refai et al. in 2023 (11), the delayed SBSs of four different restorative materials (Fuji II LC, EQUIA Forte Fil, Cention N, and Venus Bulk Fil) applied to a pre-mixed bioceramic material (NeoPutty) were calculated. The findings indicated that the mean SBS for the RMGIC (Fuji II LC) was high (18.33 ± 2.29 MPa), which is consistent with the results of our study. However, it was demonstrated that EQUIA Forte exhibited the lowest mean SBS (7.07 ± 1.06 MPa) of all materials. When comparing the findings of prior research, it can be observed that NeoPutty exhibits similarities to NeoMTA 2 in terms of its primary compositional elements. Similarly, EQUIA Forte can be regarded as comparable to EQUIA Forte HT (7, 12). However, it is crucial to consider a significant aspect of the methodology employed in the previous literature: the delayed application time of the restorative material.

Previous studies (13–15) have provided evidence in favor of delayed restoration following the placement of mineral trioxide aggregate (MTA). It has been claimed that the water sorption from freshly mixed MTA could be attributed to the presence of GIC, resulting in inadequate hydration of MTA and the presence of significant porosity, the interface junction between the glass ionomer and MTA exhibited a notable presence of microcracking, leading to the separation of the two materials and the subsequent degradation of the adhesive junction (11). However, additional research (16–18) has provided support for the immediate application of the restorative material directly over the MTA, taking the advantage of short initial setting time of 14 min at 37 °C, thereby aligning with the real clinical scenario.

A study conducted by Nandini et al. (16) showed that conventional GIC may be applied over a partially set MTA in a single visit. The authors also observed that the setting process of MTA remained unaffected beneath the GIC layer. Another study conducted by Palma et al. (19) yielded results comparable to those of our study: the researchers concluded that the use of Biodentine and the immediate placement of the final restoration yielded the highest average SBS (4.44 MPa). Furthermore, Alqahtani et al. (9) stated that the immediate application of the Fuji II LC resin-modified glass ionomer on ProRoot MTA exhibited significantly higher SBS compared to delayed application.

Regarding the modification of the MTA surface before the application of restorative materials, previous studies (14, 20, 21) have demonstrated that the process of acid etching when performed as a separate step, can lead to the degradation of the MTA surface. This degradation is characterized by a reduction in cohesive strength, a decrease in microhardness, a decline in compressive strength, and the formation of an amorphous gel-like surface structure.

Furthermore, it is imperative to prioritize the simplification of dental procedures and the reduction of working time when addressing pediatric patients. Based on this fact, it can be inferred that employing a universal bonding agent without performing a distinct pre-etching procedure would be the more favorable approach. Furthermore, the selection of the 3M Single Bond Universal Adhesive for the present study was predicated upon its pH value of 2.7. Based on this characteristic, it can be categorized as an ultra-mild etching system, thereby enabling the generation of appropriate surface micro-irregularities on the NeoMTA 2 surface while maintaining the integrity of the surface crystals, which is essential for establishing a strong adhesive junction (22).

In the present study, EQUIA Forte HT exhibited the second highest SBS among all the materials. When a conventional GIC is applied on top of MTA, two potential reactions may occur at the interface. First, the carboxylate groups (COO^-) of the polyacrylic acid within the GIC may interact with the calcium ions present in the MTA, resulting in the formation of calcium salts. Second, the silicate hydrate gel of the MTA can undergo condensation with the silicate hydrate gel of the GIC, leading to the generation of by-products (16). Rodríguez-Lozano et al. (23) demonstrated that NeoMTA 2 exhibits a greater release of calcium ions compared to alternative bioceramic materials, such as NeoMTA Plus and Bio-C Repair, suggesting the theoretical existence of a strong bond between EQUIA Forte HT and NeoMTA 2. However, the lack of calcium, which is substituted by strontium in EQUIA Forte HT, could be a cause of the weak bonding to NeoMTA 2, which resulted in a lower mean SBS than in conventional RMGIC. Nicholson et al. (24) also stated that strontium functions as a cement-forming ion. However, the addition of strontium oxide powder to GIC did not significantly enhance its properties (24).

EQUIA Forte HT is a high-viscosity GIC that does not contain any resinous constituents. As a result, the formation of strong chemical bonds with the resinous component of the universal adhesive is not feasible, suggesting potential limitations in the capacity for chemical bonding with 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP) molecules. The main mechanism of bonding in EQUIA Forte HT is likely the micromechanical interlocking facilitated by etching the surface of NeoMTA 2 using the ultra-mild universal adhesive. Nevertheless, the resulting micromechanical interlocking may not have had major effects. This is primarily due to the high viscosity of EQUIA Forte, which may have impeded its flow and penetration into the micro-irregularities of the NeoMTA 2 surface (11).

This suggests that the primary chemical interaction occurs between the silicate hydrate gel of the MTA and the silicate hydrate gel of the GIC. It should be noted that there is a lack of literature on the chemical interactions at the interface between EQUIA Forte HT and NeoMTA 2. Tsuzuki et al. found that the early stages of the GIC-setting reaction comprised both endothermic and exothermic reactions, confirming the occurrence of reactions other than carboxylate formation (25).

In 2021, Duman et al. compared the SBSs of Medcem Pure Portland Cement, Medcem MTA, and NeoMTA to those of compomer, RMGIC, EQUIA Forte HT, and Cention N (26). They found that EQUIA Forte HT showed the highest SBS along with Medcem Pure Portland Cement, while the lowest SBSs of all groups were yielded by EQUIA Forte HT and NeoMTA.

In the previous study done by Duman et al.2021, the samples were loaded with different biomaterials and held at 37 °C for 4 h in distilled water, as it was believed that a moist environment is necessary to ensure the appropriate setting of MTA. However, this technique proved ineffective due to the lack of moisture control, resulting in heightened porosity and solubility, which ultimately compromised the material's strength (27). Therefore, preserving the samples for 4 h might not be favorable for the experiment, which is why this step was not performed in our study.

Moreover, comparing the findings of different research studies is challenging due to the variability of multiple relevant factors, including the specific characteristics of the restorative materials, adhesive systems, technical application methods, and restoration application time used. Such comparisons are further complicated by variations in experimental methods, such as the rate of load application and the magnitude of the maximum load employed to assess the SBS.

Overall, the immediate SBS was higher than the SBS after the aging process among all groups in our study, although the difference was not statistically significant. Concerning the failure modes, the examination demonstrated that the two most common failure modes for EQUIA Forte HT were cohesive failure within the bioceramic material (Neo MTA 2) or combination (cohesive–adhesive) failure.

Cohesive failure indicates that the materials have reached maximum adhesive strength; therefore, it is a preferred mode of fracture. In the present study, the immediate SBS of EQUIA Forte HT showed a 53.3% combination (cohesive–adhesive) failure rate and a 66.6% cohesive failure rate within NeoMTA 2 in the delayed SBS group. The results are somewhat consistent with previously conducted studies on MTA and premixed bioceramics, which showed more cohesive and mixed cohesive–adhesive failures (9, 10).

Davis et al. explained the intricate nature of mixed-mode failures (28). These failures pose challenges in terms of interpretation, as it is uncertain whether the bond failure was the cause or the consequence of the crash. Quantifying the degree of bond degradation is difficult, as it is inherently subjective and cannot be measured precisely. Consequently, the terminology employed to describe the extent of degradation is limited to subjective terms, such as "moderate" or "predominant." The sole ascertainable fact is that the bond strength decreased compared to its initial value. Regarding the impact of thermocycling on the SBS, Arıc et al. determined that the mean SBS of RMGIC decreased following this process (29).

In vitro, studies ignore the presence of dentin and thus do not fully reflect real clinical settings in which three interfaces can be identified: the interface between the bioceramic and dentin, the interface between the restorative material and dentin, and the interface between the bioceramic and the restorative material. This study assessed only the third interface. Therefore, further clinical trials are needed, particularly in the presence of saliva contamination. Additionally, only immediate placement was assessed in this study, highlighting the pressing need for future studies to assess the delayed application time of the restorative material.

5. Conclusion

Following conclusions are drawn. First, this study can aid clinicians in selecting the optimal material for clinical applications. Based on our results, EQUIA Forte HT has shown promising outcomes when used as a restorative material following MTA pulpotomies, with results comparable to those of RMGIC. Second, we showed that the immediate SBS was higher than the SBS after the aging process among all the studied groups. However, these differences were not statistically significant.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics Statement

Ethical clearance for this study was obtained from the institutional review board (No. E-22-7160), and the College of Dentistry Research Center (CDRC No. IR 043).

Author contributions

SB: Data curation, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. AS: Formal analysis, Methodology, Supervision, Writing – original draft, Writing – review & editing. MA: Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. MA: Supervision, Writing – original draft, Writing – review & editing. NA: Data curation, Visualization, Writing – original draft. LA: Data curation, Visualization, Writing – original draft. NA: Data curation, Visualization, Writing – original draft.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Acknowledgments

The authors would like to thank the College of Dentistry Research Center and the Deanship of Scientific Research at King Saud University, Saudi Arabia, for funding this project.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fped.2023.1303005/full#supplementary-material

References

1. Ge KX, Quock R, Chu CH, Yu OY. The preventive effect of glass ionomer restorations on new caries formation: a systematic review and meta-analysis. *J Dent*. (2022) 125:1–10. doi: 10.1016/j.jdent.2022.104272

2. Sikka N, Brizuela M. *Glass ionomer cement*. Treasure Island, FL: StatPearls Publishing (2023). (Updated March 19, 2023).

3. Amend S, Boutsiouki C, Bekes K, Kloukos D, Lygidakis NN, Frankenberger R, et al. Clinical effectiveness of restorative materials for the restoration of carious primary teeth without pulp therapy: a systematic review. *Eur Arch Paediatr Dent*. (2022) 23:727–59. doi: 10.1007/s40368-022-00725-7

4. Lauro D, Di Duca A, Montuori F, Dal P, Di Lauro A, Di Duca F, et al. Citation: fluoride and calcium release from alkasite and glass ionomer restorative dental materials: in vitro study. *J Funct Biomater*. (2023) 14:109. doi: 10.3390/jfb14020109

5. Kutuk ZB, Ozturk C, Cakir FY, Gurgan S. Mechanical performance of a newly developed glass hybrid restorative in the restoration of large MO class 2 cavities. *Niger J Clin Pract*. (June 2019) 22(6):833–41. doi: 10.4103/njcp.njcp_628_18

6. Kisby L. Glass-hybrid restorations in pediatric patients. *Compend Contin Educ Dent*. (2021) 42(Suppl. 1):4–5.

7. EQUIA. ForteTM HT EQUIA ForteTM HT Comprehensive Guide (2018). Available at: http://www.gceurope.comhttp://uk.gceurope.com (Accessed March 2023).

8. Mickenautsch S. High-viscosity glass-ionomer cements for direct posterior tooth restorations in permanent teeth: the evidence in brief. *J Dent*. (2016) 55:121–3. doi: 10.1016/j.jdent.2016.10.007

9. Alqahtani AS, Sulimany AM, Alayad AS, Alqahtani AS, Bawazir OA. Evaluation of the shear bond strength of four bioceramic materials with different restorative materials and timings. *Materials (Basel, Switzerland)*. (2022) 15(13):4668. doi: 10.3390/ma15134668

10. Al-Homaidhi M. Shear bond strength of an endodontic tricalcium silicate-based putty to different adhesive systems at different time intervals. *J Res Med Dent Sci*. (2021) 9(9):149–53.

11. El-Refai D. Shear bond strength of NuSmile-neoputty bio-ceramic material to four different restorative materials used in pedodontics. *Egypt Dent J*. (2023) 69 (2):1343–65. doi: 10.21608/edj.2023.186169.2402

12. Primus C. Bioactive ceramics for pediatric dentistry. In: Fuks AB, Moskovitz M, Tickotsky N, editors. *Contemporary endodontics for children and adolescents*. Cham: Springer (2023). p. 362–63. doi: 10.1007/978-3-031-23980-9_11

13. Atabek D, Sillelioglu H, Ölmez A. Bond strength of adhesive systems to mineral trioxide aggregate with different time intervals. *J Endod*. (2012) 38(9):1288–92. doi: 10.1016/j.joen.2012.06.004

14. Kayahan MB, Nekoofar MH, Kazandag` M, Canpolat C, Malkondu O, Kaptan F, et al. Effect of acid-etching procedure on selected physical properties of mineral trioxide aggregate. *Int Endod J*. (2009) 42(11):1004–14. doi: 10.1111/j.1365-2591.2009.01610.x

15. VanderWeele RA, Schwartz SA, Beeson TJ. Effect of blood contamination on retention characteristics of MTA when mixed with different liquids. *J Endod*. (2006) 32(5):421–4. doi: 10.1016/j.joen.2005.09.007

16. Nandini S, Ballal S, Kandaswamy D. Influence of glass-ionomer cement on the interface and setting reaction of mineral trioxide aggregate when used as a furcal repair material using laser Raman spectroscopic analysis. *J Endod*. (2007) 33(2):167–72. doi: 10.1016/j.joen.2006.10.010

17. Ballal S, Venkateshbabu N, Nandini S, Kandaswamy D. An in vitro study to assess the setting and surface crazing of conventional glass ionomer cement when layered over partially set mineral trioxide aggregate. *J Endod*. (2008) 34(4):478–80. doi: 10.1016/j.joen.2008.01.020

18. Tsujimoto M, Tsujimoto Y, Ookubo A, Shiraishi T, Watanabe I, Yamada S, et al. Timing for composite resin placement on mineral trioxide aggregate. *J Endod*. (2013) 39(9):1167–70. doi: 10.1016/j.joen.2013.06.009

19. Palma PJ, Marques JA, Falacho RI, Vinagre A, Santos JM, Ramos JC. Does delayed restoration improve shear bond strength of different restorative protocols to

calcium silicate-based cements? *Materials (Basel)*. (2018) 11(11):2216. doi: 10.3390/ma11112216

20. Lee YL, Lee BS, Lin FH, Yun Lin A, Lan WH, Lin CP. Effects of physiological environments on the hydration behavior of mineral trioxide aggregate. *Biomaterials*. (2004) 25(5):787–93. doi: 10.1016/S0142-9612(03)00591-X

21. Namazikhah MS, Nekoofar MH, Sheykhrezae MS, Salariyeh S, Hayes SJ, Bryant ST, et al. The effect of pH on surface hardness and microstructure of mineral trioxide aggregate. *Int Endod J*. (2008) 41(2):108–16. doi: 10.1111/j.1365-2591.2007.01325.x

22. Giannini M, Makishi P, Ayres APA, Vermelho PM, Fronza BM, Nikaido T, et al. Self-etch adhesive systems: a literature review. *Braz Dent J*. (2015) 26:3–10. doi: 10.1590/0103-6440201302442

23. Rodríguez-Lozano FJ, Lozano A, López-García S, García-Bernal D, Sanz JL, Guerrero-Gironés J, et al. Biomineralization potential and biological properties of a new tantalum oxide (Ta_2O_5)–containing calcium silicate cement. *Clin Oral Invest*. (2022) 26:1427–41. doi: 10.1007/s00784-021-04117-x

24. Deb S, Nicholson JW. The effect of strontium oxide in glass–ionomer cements. *J Mater Sci Mater Med*. (1999) 10:471–4. doi: 10.1023/A:1008944924726

25. Tsuzuki FM, Pascotto RC, Malacarne LC, Bento AC, Neto AM, de Castro-Hoshino LV, et al. Studies of the early stages of the dynamic setting process of chemically activated restorative glass-ionomer cements. *Biomater Investig Dent*. (2021) 8(1):39–47. doi: 10.1080/26415275.2021.1898964

26. Çalışkan A, Çalışkan S, Duman S. Comparison of medcem MTA, medcem pure Portland cement and NeoMTA to pediatric restorative materials to shear bond strength. Necmettin Erbakan Universitesi Dis Hekimligi Dergisi (NEU Dent J). *Necmettin Erbakan*. (2021) 3(3):115–21.

27. Savitri D, Suprastiwi E, Margono A. Applying glass ionomer cement to MTA flowTM and biodentineTM and its effects on the interface layer. *J Phys Conf Ser*. (2017) 884:1–5. doi: 10.1088/1742-6596/884/1/012109

28. Davis MJ, McGregor A. *Assessing adhesive bond failures: mixed-mode bond failures explained. Proceedings of the ISASI Australian safety seminar*; 4–6 June 2010; Canberra, Australia (2010).

29. Arıcı S. Nursel arıcı; effects of thermocycling on the bond strength of a resin-modified glass ionomer cement: an in vitro comparative study. *Angle Orthod*. (2003) 73(6):692–6. doi: 10.1043/0003-3219(2003)073<0692:EOTOTB>2.0.CO;2

frontiers | Frontiers in Pediatrics

TYPE Original Research
PUBLISHED 15 January 2024
DOI 10.3389/fped.2024.1308039

OPEN ACCESS

EDITED BY
Sreekanth Kumar Mallineni,
Tohoku University, Japan

REVIEWED BY
Ahmad Faisal Ismail,
International Islamic University Malaysia, Malaysia
Sunil Babu Kotha,
Riyadh Elm University, Saudi Arabia

*CORRESPONDENCE
Haoyu He
✉ hehaoyu_gxmu@outlook.com
Xiaojuan Zeng
✉ xiaojuan.zeng@qq.com

RECEIVED 05 October 2023
ACCEPTED 04 January 2024
PUBLISHED 15 January 2024

CITATION
Mai W, Xiao L, Chen S, Chen S, Li A, Zhang T, He H and Zeng X (2024) Prevalence and contributing factors of malocclusion in Zhuang children aged 7–8 years in southern China.
Front. Pediatr. 12:1308039.
doi: 10.3389/fped.2024.1308039

Prevalence and contributing factors of malocclusion in Zhuang children aged 7–8 years in southern China

Wenjia Mai[1], Lijuan Xiao[1], Shaoyong Chen[2], Shuang Chen[2], Andi Li[2], Tingting Zhang[2], Haoyu He[2]* and Xiaojuan Zeng[2]*

[1]Department of Orthodontics, College & Hospital of Stomatology, Guangxi Medical University, Nanning, Guangxi, China, [2]Department of Dental Public Health, College & Hospital of Stomatology, Guangxi Medical University, Nanning, Guangxi, China

Introduction: Malocclusion, a common oral health problem in children, is associated with several contributing factors. This study aimed to investigate the prevalence of mixed dentition stage malocclusion and its contributing factors in Chinese Zhuang children aged 7–8 years.
Methods: Overall, 2,281 Zhuang children, about 7–8 years old, were randomly selected using a stratified whole-cluster sampling method from schools in counties in Northwestern Guangxi, China. The children were examined on-site for malocclusion and caries by trained dentists, and basic data on the children were collected using questionnaires, including age, sex, parental education, parental accompaniment, and children's knowledge of malocclusion and treatment needs. Data were analyzed using the chi-square test and logistic regression analysis.
Results: The total prevalence of malocclusion in Zhuang children aged 7–8 years was 58.5%, with the highest prevalence of anterior crossbite tendency, and the prevalence of anterior crossbite and anterior edge-to-edge occlusion was 15.1% and 7.7%, respectively. This was followed by an anterior increased overjet of 13.3% and an inter-incisor spacing of 10.3%. The lowest prevalence was 2.7% for anterior open bite. Sex, parental accompaniment, parental education, and decayed, missing, and filled teeth of the first primary molar were factors that contributed to malocclusion in Zhuang children.
Conclusion: Malocclusion is a common oral problem among Zhuang children. Therefore, more attention must be paid to the intervention and prevention of malocclusion. The impact factors should be controlled as early as possible.

KEYWORDS

cross-sectional study, malocclusion, prevalence, mixed dentition, Zhuang children

1 Introduction

Malocclusion is a variety of deformities caused by irregularities in the relationship between the maxillary and mandibular teeth, dental arches, and hard and soft tissues of the craniomaxillofacial region. Malocclusion is regarded as one of the three primary oral disorders that impact oral functionality, facial appearance, social engagement, as well as the physical and mental well-being of individuals (1).

When the first permanent molars in schoolchildren, aged 7–8 years old, establish occlusal contact, the maxillary and mandibular anterior begin to erupt. This stage is considered critical for the later establishment of a harmonious and stable occlusal

relationship and is also the starting stage for early intervention in correcting malocclusion during the mixed dentition period (2). Studies have shown that malocclusion during the mixed dentition phase can lead to malocclusion of the permanent dentition if early intervention is not performed. In addition, the adverse consequences of malocclusion during mixed dentition, even at an early age, may negatively impact children's emotions and social aspects (3).

A systematic review and meta-analysis found that the pooled national prevalence of malocclusion in Chinese schoolchildren from 1991 to 2018 was 47.92%. However, the prevalence, which ranged from 30.07% to 75.43%, exhibited significant variation across different regions of China (4). In addition, many studies have indicated a high occurrence of malocclusion in permanent teeth, with reported rates varying between 10.0% and 97.0% (5, 6). This variation may be ascribed to variances in territory, customs, race, economic conditions, survey standards, and indicators (7). To date, epidemiological descriptions of mixed dentition malocclusion worldwide remain scarce, and information on the prevalence of malocclusion in children with mixed dentition in the Chinese population, especially in ethnic groups, is limited.

The Zhuang is the largest minority ethnic group in China, second only to the Han, and its population is mainly located in the Guangxi Zhuang Autonomous Region of southern China. Counties in western Guangxi are the main sources of Zhuang. The high prevalence of caries, low oral health awareness, low socioeconomic status, and low parental accompaniment in the Zhuang region may have influenced the occurrence of malocclusion in children residing in this region (8). Nevertheless, there is insufficient data regarding the frequency of malocclusion among children of the Zhuang ethnicity in China. The objective of this research was to investigate the prevalence of malocclusion during the early mixed dentition period and its contributing factors in Guangxi Zhuang children. To identify the elements that influence malocclusion during this period and implement strategies for prevention and early intervention can decrease the prevalence and severity of malocclusion in the future (9, 10).

2 Materials and methods

2.1 Sample selection

This study was conducted in Guangxi Province, South China, in 2022. Four counties, Jingxi, Long'an, Tiandeng, and Dahua, were randomly selected from western Guangxi province. All participants under investigation from these counties were 7–8 years old and belonged to the Zhuang ethnic group, which is China's largest minority residing in Guangxi.

The sample size was calculated using the sample size formula $N = \text{deff}\frac{\mu^2_{\alpha/2}p(1-p)}{\sigma^2}$. Owing to the lack of data on the prevalence of malocclusion in children aged 7–8 years in this region, the estimated rate p was set at 50%, the relative permitted error δ of the overall rate p was set at 5%, the test level was bilateral $\alpha = 0.05$, $\mu\alpha/2 = 1.96$, and the efficiency of the sampling design was deff = 4.5, which was calculated as a sample size of 1,729 children. Taking into account a non-response rate of 20%, the sample size needed was 2,162. The total number of people in the four counties surveyed was 2,281, which was larger than the required sample size.

This study excluded children who had previously received or were currently receiving orthodontic treatment, as well as those with systemic diseases or obvious craniofacial deformities like ectodermal dysplasia, Down syndrome, cleft lip, and/or palate. Exclusion also applied to children who declined to take part in the assessment and those who were uncontactable or declined to give their consent to participate.

The Ethical Review Committee of Guangxi Medical University College of Stomatology granted approval for this study (No. 2022043). Consent forms were obtained from the parents or guardians of all children involved in this study, indicating their informed agreement.

2.2 Clinical examination

Malocclusion and caries in all participants were examined by trained and calibrated dentists using a Community Periodontal Index probe, plane mouth mirror, and measuring ruler under an artificial light source. The types of malocclusions, including upper anterior space, anterior overjet, anterior edge-to-edge occlusion, anterior crossbite, anterior overbite, anterior open bite, posterior transverse discrepancy, and Angle classification, were defined (Table 1). Additionally, the decayed, missing, and filled teeth (dmft/DMFT) scores of the primary canine, first primary molar, second permanent molar, and first permanent molar were recorded separately. The scores were statistically analyzed according to categorical information, categorized according to the corresponding tooth positions, and labeled as dmft/DMFT = 0,

TABLE 1 Types of malocclusion and related diagnostic criteria.

Types	Diagnosis criteria	
Upper anterior space	Normal (<=2) Excess (>2)	Recorded the space between maxillary mesial incisors.
Anterior overjet	Normal (>0, <=3)	Recorded the distance from the incisal edge of the most labial maxillary incisors to the most labial surface of the corresponding mandibular incisors.
	Excess (>3)	
	Edge-to-edge occlusion (=0)	
	anterior crossbite (<0)	
Anterior overbite	Normal (=<1/3 lower incisors)	Recorded the vertical overlap of the upper and lower incisors.
	Excess (>1/3 lower incisors)	
Anterior open bite	Absent Present (>0)	Recorded the vertically separated distance between the upper and lower incisors.
Posterior transverse discrepancy	Absent Present	Recorded the molars with crossbite or scissor-bite relationship.
Angle classification	Angle Class I Angle Class II Angle III	Recorded the molars' relationship between the mesiobuccal cusp of the maxillary first molar and the buccal groove of the mandibular first molar. When the first molars were not present in occlusion, the second primary molars were used.

dmft/DMFT = 1, dmft/DMFT = 2, dmft/DMFT = 3, and dmft/DMFT = 4. The World Health Organization diagnostic criteria for dental caries were used to evaluate the dental caries status.

To guarantee the accuracy and dependability of data collection, a total of eight examiners underwent training and calibration. Before conducting the formal investigation, we examined 108 children aged 7–8 years. 8 examiners, each 2 as a group, with a group of 2 senior doctors as the gold standard, and the results of each group were tested for inter-examiner reliability with the gold standard by Kappa values. 1 week later, we re-examined these 108 children as a way of calculating intra-examiner reliability. The inter-examiner reliability had Kappa values ranging from 0.84 to 0.91, while the intra-examiner reliability had Kappa values ranging from 0.86 to 0.95.

Radiographic examinations were not performed. At the end of the oral examination, a written notification was dispatched to the child's parents or guardians, informing them of the necessity for the child to receive treatment.

The questionnaire was designed in Chinese to collect data on sociodemographic variables, including age, sex, parental education (lower than college degree/ college degree and higher), and parental accompaniment (parents/only father/only mother/no parents). Parental accompaniment was counted based on whether the parents accompanied the children home in the last 6 months. Additionally, a questionnaire was employed to gather information regarding the children's knowledge of orthodontics (known/unknown) and their self-need for orthodontics (yes/no/unknown). Before starting the formal questionnaire, we conducted a pre-survey of 108 children aged 7–8 in Chinese. The trained examiners explained all the questions of the questionnaire to the children in detail, and all the questions raised by the children were satisfactorily resolved. Eventually, all children completed the questionnaire under the supervision and assistance of the examiners. To retest the reliability of the questionnaire, these 108 children were re-examined a week later. The Kappa values were all higher than 0.88.

2.3 Statistical analysis

The Statistical Package for the Social Sciences software (IBM SPSS Statistics, version 25) was utilized for conducting the statistical analyses. The prevalence of malocclusion (%) and categorical variables were calculated. Proportions were compared using the chi-square test. Statistically significant differences were deemed when the *P*-value was less than 0.05. This study utilized binary logistic regression to examine the impact of the independent factors on malocclusion in children. In terms of statistics, various factors were included in a logistic model, and those that did not demonstrate a significant correlation were subsequently eliminated using a stepwise approach.

3 Results

A total of 2,344 Zhuang children from four counties in Guangxi (Tiandeng, Long'an, Dahua, and Jinxi) were asked to undergo a dental examination. Out of these, a total of 2,297 individuals consented to take part in the research, resulting in a response rate of 96.4%. Finally, 2,281 children were analyzed, excluding 16 with incomplete data.

3.1 Prevalence of malocclusion

Among the 2,281 children clinically examined, 947 (41.5%) had normal occlusion, whereas 1,334 had malocclusion, with a total malocclusion prevalence of 58.5%. Of the 1,334 children, the highest number of malocclusions was Angle Class I, with 607 children, with a prevalence of 26.6%, followed by Angle Class II, with 532 children, with a prevalence of 23.3%, and the lowest number of children with Angle Class III malocclusion was 195, with a prevalence of 8.5% (Table 2).

The clinical classifications of the malocclusions are presented in Table 2. The prevalence of anterior crossbite tendency was the highest at 15.1% and 7.7% for anterior crossbite and anterior edge-to-edge occlusion, respectively. This was followed by an anterior increased overjet of 13.3% and an inter-incisor spacing of 10.3%. The lowest prevalence was 2.7% for anterior open bite.

3.2 Relationship between malocclusion and demographic characteristics

Table 2 displays the prevalence of malocclusion in children with various demographic characteristics. The findings indicated that the prevalence of malocclusion among children aged 8 was notably greater (60.1%) compared to children aged 7 (54.9%). Furthermore, the prevalence of males was considerably greater (60.9%) compared to females (55.5%). In addition, children who resided without their parents' company exhibited the greatest prevalence of malocclusion (67.3%, $P < 0.001$). By two-by-two comparison, it was found that the prevalence in the unaccompanied group was significantly higher than that in the only mother- and parent-accompanied groups; however, there was no statistically significant distinction with the group accompanied by only fathers. Additionally, a correlation existed between parental education and the prevalence of malocclusion. The prevalence of malocclusion in the children of parents with lower than a college education was significantly higher in both groups (65.2% and 65.3%) than in the group with a college education and higher (43.0% and 44.6%).

3.3 Relationship between malocclusion and dmft/DMFT

Table 3 presents the analysis of malocclusion according to different dmft/DMFT in children's primary canine teeth, first primary molars, second primary molars, and first molars. Except for the first molar, significant variations in the dmft scores were observed among the remaining teeth. The examination of dmft in primary canine teeth revealed that the dmft = 4 group had the

10.3389/fped.2024.1308039

TABLE 2 Prevalence of different types of malocclusion based on demographic characteristics (Chi-square test).

	Number of participants	Total prevalence of malocclusion *n* (%)	*P*-value (x^2)	Angle classification of malocclusion *n* (%)			Upper anterior space *n* (%)	Anterior overjet *n* (%)	Anterior overbite *n* (%)	Anterior crossbite tendency *n* (%)		Anterior open bite *n* (%)	Posterior transverse discrepancy *n* (%)
				Class I	Class II	Class III				Edge-to-edge	Crossbite		
Age			0.021 (5.287)										
7 years old	701	385 (54.9)		158 (22.5)	169 (24.1)	58 (8.3)	46 (6.6)	51 (7.3)	62 (8.8)	62 (8.8)	99 (14.1)	14 (2.0)	31 (4.4)
8 years old	1,580	949 (60.1)		449 (28.4)	363 (23.0)	137 (8.7)	189 (12.0)	253 (16.0)	89 (5.6)	113 (7.2)	245 (15.5)	47 (3.0)	93 (5.9)
Sex			0.009 (6.807)										
Female	1,020	566 (55.5)		254 (24.9)	222 (21.8)	90 (8.8)	88 (8.6)	121 (11.9)	56 (5.5)	87 (8.5)	148 (14.5)	31 (3.0)	68 (6.7)
Male	1,261	768 (60.9)		353 (28.0)	310 (24.6)	105 (8.3)	147 (11.7)	183 (14.5)	95 (7.5)	88 (7.0)	196 (15.5)	30 (2.4)	56 (4.4)
Total	2,281	1,334 (58.5)		607 (26.6)	532 (23.3)	195 (8.5)	235 (10.3)	304 (13.3)	151 (6)	175 (7.7)	344 (15.1)	61 (2.7)	124 (5.4)

TABLE 3 Malocclusion in children with socio-demographic characteristics, dmft/DMFT, orthodontic perceptions and self-needs ($n = 2,281$).

	Normal *n* (%)	Malocclusions *n* (%)	*P*-value (x^2)
Parental companionship			<0.001 (32.580)
Parents	468 (46.4)	540 (53.6)[b]	
Only father	68 (42.5)	92 (57.5)[a,b]	
Only mother	189 (43.5)	245 (56.5)[b]	
No parents	222 (32.7)	457 (67.3)[a]	
Father's education			<0.001 (97.962)
College degree and higher	393 (57.0)	296 (43.0)	
Lower than college degree	554 (34.8)	1,038 (65.2)	
Mother's education			<0.001 (88.786)
College degree and higher	416 (55.4)	335 (44.6)	
Lower than college degree	531 (34.7)	999 (65.3)	
Primary canine dmft			0.014 (12.429)
dmft = 0	656 (43.6)	847 (56.4)	
dmft = 1	105 (39.6)	160 (60.4)	
dmft = 2	97 (39.0)	152 (61.0)	
dmft = 3	46 (38.3)	74 (61.7)	
dmft = 4	43 (29.9)	101 (70.1)	
First primary molar dmft			0.008 (13.787)
dmft = 0	237 (48.0)	257 (52.0)	
dmft = 1	117 (43.2)	154 (56.8)	
dmft = 2	196 (40.4)	289 (59.6)	
dmft = 3	166 (40.3)	246 (59.7)	
dmft = 4	231 (37.3)	388 (62.7)	
Second primary molar dmft			0.017 (12.112)
dmft = 0	255 (46.7)	291 (53.3)	
dmft = 1	111 (42.4)	151 (57.6)	
dmft = 2	206 (41.4)	291 (58.6)	
dmft = 3	148 (41.5)	209 (58.5)	
dmft = 4	227 (36.7)	392 (63.3)	
First molar DMFT			0.713 (2.122)
DMFT = 0	822 (41.7)	1,149 (58.3)	
DMFT = 1	71 (41.5)	100 (58.5)	
DMFT = 2	38 (37.3)	64 (62.7)	
DMFT = 3	12 (50.0)	12 (50.0)	
DMFT = 4	4 (30.8)	9 (69.2)	
Orthodontic perceptions			0.136 (2.218)
Know	507 (43.0)	672 (57.0)	
Unknown	440 (39.9)	662 (60.1)	
Orthodontic self-needs			0.002 (12.318)
Yes	117 (36.1)	207 (63.9)[a]	
No	460 (45.4)	553 (54.6)[b]	
Unknown	370(39.2)	574(60.8)[a]	
Total	947(41.5)	1,334(58.5)	

[a,b]two-by-two comparison in Chi-square test.

TABLE 4 Binary logistic regression analysis of contributing factors and malocclusion.

		B	standard error	*P*	Odds ratio(95%CI)
Sex	Female				
	Male	0.240	0.089	0.007	1.271 (1.068–1.513)
Parental companionship	Parents			<0.001	
	Only father	0.134	0.177	0.448	1.144 (0.809–1.617)
	Only mother	0.138	0.12	0.249	1.148 (0.908–1.451)
	No parents	0.504	0.107	<0.001	1.656 (1.344–2.040)
Father's education	College degree and higher				
	Lower than college degree	0.610	0.117	<0.001	1.840 (1.464–2.313)
Mother's education	College degree and higher				
	Lower than college degree	0.467	0.114	<0.001	1.595 (1.275–1.996)
First primary molar dmft	dmft = 0			0.009	
	dmft = 1	0.180	0.157	0.253	1.197 (0.879–1.630)
	dmft = 2	0.318	0.133	0.017	1.374 (1.058–1.785)
	dmft = 3	0.329	0.140	0.019	1.389 (1.056–1.827)
	dmft = 4	0.444	0.127	<0.001	1.559 (1.215–1.999)
	Constant	−0.963	0.137	<0.001	0.382

highest prevalence of malocclusion (79.1%, $P < 0.05$), while the dmft = 0 group had the lowest prevalence of malocclusion at 56.4%. Interestingly, in the analysis of dmft scores of the first and second primary molars, it was found that the prevalence of malocclusion with dmft = 4 was the highest at 62.7% and 63.3%, whereas the prevalence of malocclusion with dmft = 0 was the lowest at 52.0% and 53.3%, respectively, and these variations were statistically significant. In addition, in the analysis of the DMFT scores of the first molars, the prevalence of malocclusion with DMFT = 4 was still the highest, but the disparity lacked statistical significance.

3.4 Relationship between malocclusion and orthodontic perceptions and self-needs

Regarding children's orthodontic self-needs, the chi-square analysis showed that the group of children who needed orthodontic treatment for their own malocclusion had the highest prevalence of malocclusion (63.9%, $P < 0.05$). The prevalence of malocclusion in the group of unknowns was 60.8%, which was significantly higher than the prevalence in the group of children who did not need orthodontic treatment (54.6%). Table 3 showed that there was no notable correlation between children's knowledge of orthodontics and the prevalence of malocclusion.

3.5 Binary logistic regression analysis of contributing factors and malocclusion

The prevalence of malocclusion in Zhuang children was influenced by sex, parental accompaniment, parental education, and dmft of the first primary molar, as indicated by the results of conditional binary logistic regression analysis. ($P < 0.05$, Table 4). Male children had a 1.271-fold increased risk of malocclusion compared to female children. Children who live without parental accompaniment have a 1.656 times greater risk of malocclusion compared to children who live with their parents. The risk of malocclusion in children living without parental accompaniment was 1.656 times higher than that in children living with parents. Whereas the prevalence of malocclusion in children accompanied by only their mothers or fathers was different from that in children accompanied by their parents, but the difference did not have statistically significant. In addition, the risk of malocclusion in children with fathers with lower than a college education was 1.840 times higher than in those with a college education and higher. The risk of malocclusion in children with mothers with lower than a college education was 1.595 times higher than in those with a college education and higher. Furthermore, children with first primary molar dmft ≥ 2 had a greater risk of developing malocclusion compared to those with first primary molar dmft = 0 (odds ratio 1.374, 1.389, and 1.559, respectively).

4 Discussion

The prevalence of malocclusion varies according to region and ethnicity. This study analyzed 2,281 Zhuang children, approximately 7–8 years of age, and found that the overall prevalence of malocclusion was 58.5%. The prevalence was lower than the 71.21% reported in a national malocclusion prevalence survey conducted in China in 2000 (2). Nevertheless, the prevalence in this investigation surpassed the pooled prevalence of malocclusion in Chinese students over the last 30 years (47.92%) reported in a systematic review (4). However, the prevalence of malocclusion among 6–8-year-old children in mixed dentition public schools in southern Brazil is 69.1%, and a systematic review showed that the pooled prevalence of malocclusion among children in India is 66.7% (confidence interval 50.7–81.06) (11, 12). This may be related to the following reasons: First, the prevalence in different regions and ethnic groups may have certain differences; Zhuang children are mainly located in southern China; the Zhuang region has poor economic conditions; people have low awareness of oral health;

and the prevalence of caries is high, which may influence the high prevalence in Zhuang children (8). In addition, the prevalence of crowded teeth was not counted in this study because the anterior teeth of children aged 7–8 years had just erupted, there was temporary malocclusion, and later, with the replacement of teeth and the growth of the jaw, the temporary misalignment could be corrected on its own; therefore, the prevalence of crowding was not statistically significant. In addition, in this survey, the highest incidence of Angle Class I malocclusion was 26.6%, with Angle Class II malocclusion (23.3%) and Angle Class III malocclusion (8.5%) following suit. These findings align with previous research conducted in various countries (1, 13–15).

The highest prevalence in the clinical classification of malocclusion was observed in the tendency for anterior crossbite, with anterior crossbite and anterior edge-to-edge occlusion having prevalence rates of 15.1% and 7.7%, respectively. According to the prevalence of Angle classification, it is estimated that the anterior crossbite during the mixed dentition phase of Zhuang children is mostly dentary or functional. In addition to genetic factors and bad oral habits, anterior crossbite is associated with tooth decay, premature primary tooth loss, and an irregular eruption sequence of permanent teeth.

In this study, the second most prevalent malocclusion observed was an anterior increased overjet (13.3%), which agrees with observations reported in Tanzania (16). In addition to different ethnicities and genetic factors, increased anterior overjet is also associated with bad oral habits, such as tongue thrust, digit sucking, lower lip biting, and mouth breathing (17, 18). When treating deep overjet in mixed dentition at an early stage, the following factors should be considered: (1) increased overjet affects children's appearance, which has an impact on their psychological health and makes them easy targets for ridicule by other students (19); (2) children with maxillary anterior protrusion have a higher risk of traumatic injuries to their upper anterior teeth (20); (3) increased overjet is more likely to cause an increase in the plaque index in the anterior tooth area and gingival inflammation (21); (4) early intervention in children with mandibular retrusion can improve the dimensions of their upper airway and reduce the potential risk of developing obstructive sleep apnea syndrome in the future (22).

This study also found that the prevalence of malocclusion was greater in male children than in females, which is in accordance with the results in Germany. Christopher et al. reported that the prevalence of deep cover and overlay in 9-year-old children in Germany was higher in males than in females (23). The growth spurts during puberty happen at 13 years old for males and 11 years old for females. Females grow faster than males by 2 years, and this can impact the occurrence of mixed dentition malocclusion. This is because certain temporary malocclusions like increased overjet, deep overbite, crowding, and anterior spacing are resolved as the jaws grow and permanent teeth come in (24).

The prevalence of malocclusion in children was linked to the educational background of their parents. Parents with lower than a college education had a considerably greater prevalence of malocclusion in their children than those with a college education and higher. The growth and development of children are also significantly influenced by parents. This study revealed that malocclusion was most common among children who lived without their parents, which was considerably higher compared to children who were accompanied by only mother and parent groups. However, the difference was not statistically significant when compared to the group accompanied by only father. This suggests that there is a connection between parental accompaniment and malocclusion in children, especially the mother's accompaniment, which has a significant impact on children's growth and progress. Binary logistic regression also suggested that children without parental companions have a 1.656 times greater risk of malocclusion compared to those with parental companions. Parents with higher educational levels have more ways to acquire oral healthcare knowledge and are more receptive to it. The presence of parents during the growth period of children is beneficial for the timely detection of oral problems and consultation, helps to cultivate proper oral habits, and reduces malocclusion caused by bad oral habits. A study in Sichuan showed that the lack of parental accompaniment increases the likelihood of left-behind children experiencing mental health issues, as well as their hesitancy to confide in others regarding their emotional distress (25). The increased prevalence of malocclusion in children could be attributed to these factors.

Significant lifestyle and dietary changes have occurred as a result of the swift growth of China's economy. The intake of large quantities of fine foods reduces the stimulation of the masticatory muscles and affects normal orofacial development and occlusal relationships, and the intake of large quantities of sugary foods has resulted in a growing incidence of tooth decay in the primary dentition of children each year (26, 27). In China, Guangxi is the primary region for sugar production, leading to a higher likelihood of local residents consuming sugary food items. Numerous candies, cookies, carbonated beverages, and sugar-laden foods are sold in numerous school cafeterias (28). Excessive consumption of sugar has been linked to the high occurrence of dental cavities in children residing in Guangxi, as indicated by previous research (27). This study found a correlation between the decay of primary canine teeth and primary molars and malocclusion in children. The decay of the first primary molars posed a potential danger for malocclusion in children, and children with a dmft ≥ 2 score had a higher risk of developing malocclusion compared to those with a dmft = 0 score (odds ratio values were 1.374, 1.389, and 1.559) in this study. Indian researchers have also reported similar findings, demonstrating a positive association between the severity of malocclusion and dmft /DMFT. Higher dmft /DMFT scores were found to indicate more severe malocclusion (29, 30). Decay or premature loss of primary teeth will affect masticatory function in children, and it is easy to develop bad chewing habits such as unilateral posterior teeth chewing and anterior teeth chewing. In addition, premature loss of primary teeth will lead to the movement of adjacent teeth to the missing teeth, which will affect the occlusal relationship in that area, simultaneously resulting in insufficient eruption space for the permanent teeth in that area. Therefore, the permanent teeth will not be able to

erupt normally or erupt in an ectopic manner, ultimately affecting the occurrence of malocclusion (17, 31). However, this study can only conclude that dmft of the first primary molars poses a potential hazard for malocclusion in children. Further analysis of the causal relationship between dmft of the primary teeth and malocclusion is needed in the future.

4.1 Limitations of the study

There are certain constraints associated with this study. The effect of genetic factors on the prevalence of malocclusion was not included. Future studies should conduct oral examinations of the children and their immediate and collateral relatives and genetic analysis using gene sequencing to explore the role of genetic factors in the formation of malocclusion. In addition, this study did not include information on the bad oral habits of all children. Future studies should conduct separate one-on-one interviews with children and guardians to collect accurate information on children's bad habits. Finally, the trauma of primary anterior teeth was not counted in this survey because the permanent anterior teeth have erupted, and the future experimental design can design a cohort study from the age of 3 years to further clarify the effect of primary tooth trauma on malocclusion.

5 Conclusions

The present study provided information on the prevalence of malocclusion and its influencing factors in 7–8-year-old Zhuang children. Malocclusion was a common oral problem in Zhuang children; therefore, early attention should be paid to oral health. In addition to the current main concern about the effects of children's caries, the dangers of malocclusion in early childhood should also be emphasized, and the influencing factors of malocclusion should be prevented and intervened with. Therefore, this study provides a reference for future studies focusing on the prevention of malocclusion in children.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding authors.

Ethics statement

The studies involving humans were approved by The Ethical Review Committee of Guangxi Medical University College of Stomatology. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

WM: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Writing – original draft. LX: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Writing – original draft. ShaC: Data curation, Formal Analysis, Investigation, Methodology, Writing – review & editing. ShuC: Data curation, Formal Analysis, Investigation, Methodology, Writing – review & editing. AL: Data curation, Investigation, Writing – review & editing. TZ: Data curation, Investigation, Writing – review & editing. HH: Conceptualization, Methodology, Writing – review & editing. XZ: Conceptualization, Methodology, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article.

This study was supported for funding by the Guangxi Health Commission of China.

Acknowledgments

The authors would like to thank all participants who cooperated with the oral examination. In addition, the authors thank the four county disease control departments and schools for their support of this oral survey.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

1. Salim NA, Al-Abdullah MM, AlHamdan AS, Satterthwaite JD. Prevalence of malocclusion and assessment of orthodontic treatment needs among Syrian refugee children and adolescents: a cross-sectional study. *BMC Oral Health*. (2021) 21:305. doi: 10.1186/s12903-021-01663-4

2. Fu M, Zhang D, Wang B, Deng Y, Wang F, Ye X. The prevalence of malocclusion in China–an investigation of 25,392 children. *Zhonghua Kou Qiang Yi Xue Za Zhi*. (2002) 37:371–3.

3. Guimarães SPA, Jorge KO, Fontes MJF, Ramos-Jorge ML, Araújo CTP, Ferreira EF, et al. Impact of malocclusion on oral health-related quality of life among schoolchildren. *Braz Oral Res*. (2018) 32:e95. doi: 10.1590/1807-3107bor-2018.vol32.0095

4. Lin M, Xie C, Yang H, Wu C, Ren A. Prevalence of malocclusion in Chinese schoolchildren from 1991 to 2018: a systematic review and meta-analysis. *Int J Paediatr Dent*. (2020) 30:144–55. doi: 10.1111/ipd.12591

5. Fatani NH, Hammam MB, Oraif H, Taher S, Taju W, Bukhari O. Prevalence of malocclusion among schoolchildren in Makkah, Saudi Arabia. *Open Access Maced J Med Sci*. (2019) 7:856–61. doi: 10.3889/oamjms.2019.188

6. Disha P, Poornima P, Pai SM, Nagaveni NB, Roshan NM, Manoharan M. Malocclusion and dental caries experience among 8-9-year-old children in a city of South Indian region: a cross-sectional survey. *J Educ Health Promot*. (2017) 6:98. doi: 10.4103/jehp.jehp_24_17

7. Zhou Z, Liu F, Shen S, Shang L, Shang L, Wang X. Prevalence of and factors affecting malocclusion in primary dentition among children in Xi'an, China. *BMC Oral Health*. (2016) 16:91. doi: 10.1186/s12903-016-0285-x

8. Wu S, Zhang T, Liu Q, Yu X, Zeng X. Effectiveness of fluoride varnish on caries in the first molars of primary schoolchildren: a 3-year longitudinal study in Guangxi Province, China. *Int Dent J*. (2020) 70:108–15. doi: 10.1111/idj.12528

9. Borrie F, Bearn D. Early correction of anterior crossbites: a systematic review. *J Orthod*. (2011) 38:175–84. doi: 10.1179/14653121141443

10. Sunnak R, Johal A, Fleming PS. Is orthodontics prior to 11 years of age evidence-based? A systematic review and meta-analysis. *J Dent*. (2015) 43:477–86. doi: 10.1016/j.jdent.2015.02.003

11. Mehta A, Negi A, Verma A, Jain K. Pooled prevalence estimates of malocclusion among Indian children and adolescents: a systematic review and meta-analysis. *Int J Adolesc Med Health*. (2022) 34:371–80. doi: 10.1515/ijamh-2020-0142

12. Fadel MAV, Santos BZ, Antoniazzi RP, Koerich L, Bosco VL, Locks A. Prevalence of malocclusion in public school students in the mixed dentition phase and its association with early loss of deciduous teeth. *Dental Press J Orthod*. (2022) 27:e2220120. doi: 10.1590/2177-6709.27.4.e2220120.oar

13. Akbari M, Lankarani KB, Honarvar B, Tabrizi R, Mirhadi H, Moosazadeh M. Prevalence of malocclusion among Iranian children: a systematic review and meta-analysis. *Dent Res J (Isfahan)*. (2016) 13:387–95. doi: 10.4103/1735-3327.192269

14. Borzabadi-Farahani A, Borzabadi-Farahani A, Eslamipour F. Malocclusion and occlusal traits in an urban Iranian population. An epidemiological study of 11- to 14-year-old children. *Eur J Orthod*. (2009) 31:477–84. doi: 10.1093/ejo/cjp031

15. Bourzgui F, Sebbar M, Hamza M, Lazrak L, Abidine Z, El Quars F. Prevalence of malocclusions and orthodontic treatment need in 8- to 12-year-old schoolchildren in Casablanca, Morocco. *Prog Orthod*. (2012) 13:164–72. doi: 10.1016/j.pio.2011.09.005

16. Mtaya M, Brudvik P, Astrøm AN. Prevalence of malocclusion and its relationship with socio-demographic factors, dental caries, and oral hygiene in 12- to 14-year-old Tanzanian schoolchildren. *Eur J Orthod*. (2009) 31:467–76. doi: 10.1093/ejo/cjn125

17. Zou J, Meng M, Law CS, Rao Y, Zhou X. Common dental diseases in children and malocclusion. *Int J Oral Sci*. (2018) 10:7. doi: 10.1038/s41368-018-0012-3

18. Majorana A, Bardellini E, Amadori F, Conti G, Polimeni A. Timetable for oral prevention in childhood–developing dentition and oral habits: a current opinion. *Prog Orthod*. (2015) 16:39. doi: 10.1186/s40510-015-0107-8

19. Bellot-Arcís C, Montiel-Company JM, Almerich-Silla JM. Psychosocial impact of malocclusion in spanish adolescents. *Korean J Orthod*. (2013) 43:193–200. doi: 10.4041/kjod.2013.43.4.193

20. Batista KB, Thiruvenkatachari B, Harrison JE, O'Brien KD. Orthodontic treatment for prominent upper front teeth (class II malocclusion) in children and adolescents. *Cochrane Database Syst Rev*. (2018) 3:Cd003452. doi: 10.1002/14651858.CD003452.pub4

21. Kolawole KA, Folayan MO. Association between malocclusion, caries and oral hygiene in children 6 to 12 years old resident in suburban Nigeria. *BMC Oral Health*. (2019) 19:262. doi: 10.1186/s12903-019-0959-2

22. Xiang M, Hu B, Liu Y, Sun J, Song J. Changes in airway dimensions following functional appliances in growing patients with skeletal class II malocclusion: a systematic review and meta-analysis. *Int J Pediatr Otorhinolaryngol*. (2017) 97:170–80. doi: 10.1016/j.ijporl.2017.04.009

23. Lux CJ, Dücker B, Pritsch M, Komposch G, Niekusch U. Occlusal status and prevalence of occlusal malocclusion traits among 9-year-old schoolchildren. *Eur J Orthod*. (2009) 31:294–9. doi: 10.1093/ejo/cjn116

24. Zhang SY, Liu G, Liu LJ, Ma ZG, Han YS, Shen XZ, et al. [Relationship of certain skeletal maturity indicators of hand and wrist with adolescent growth spurt]. *Zhonghua Yi Xue Za Zhi*. (2008) 88:2198–200.

25. Tang W, Wang G, Hu T, Dai Q, Xu J, Yang Y, et al. Mental health and psychosocial problems among Chinese left-behind children: a cross-sectional comparative study. *J Affect Disord*. (2018) 241:133–41. doi: 10.1016/j.jad.2018.08.017

26. Ciochon RL, Nisbett RA, Corruccini RS. Dietary consistency and craniofacial development related to masticatory function in minipigs. *J Craniofac Genet Dev Biol*. (1997) 17:96–102.

27. Wang Z, Rong W, Zhang Y, Zeng X, Li Z, Liu Z. Prevalence and contributing factors of dental caries of 6-year-old children in four regions of China. *PeerJ*. (2019) 7:e6997. doi: 10.7717/peerj.6997

28. Pang M, Zeng XJ, Tang QW. A study of dental caries and risk factors in children of Guangxi area. *Shanghai Kou Qiang Yi Xue*. (2015) 24:611–5.

29. Singh A, Purohit B. Is malocclusion associated with dental caries among children and adolescents in the permanent dentition? A systematic review. *Community Dent Health*. (2021) 38:172–7. doi: 10.1922/CDH_00340Singh06

30. Sá-Pinto AC, Rego TM, Marques LS, Martins CC, Ramos-Jorge ML, Ramos-Jorge J. Association between malocclusion and dental caries in adolescents: a systematic review and meta-analysis. *Eur Arch Paediatr Dent*. (2018) 19:73–82. doi: 10.1007/s40368-018-0333-0

31. Gilchrist F, Marshman Z, Deery C, Rodd HD. The impact of dental caries on children and young people: what they have to say? *Int J Paediatr Dent*. (2015) 25:327–38. doi: 10.1111/ipd.12186

frontiers | Frontiers in Dental Medicine

TYPE Original Research
PUBLISHED 27 August 2024
DOI 10.3389/fdmed.2024.1434417

OPEN ACCESS

EDITED BY
Thantrira Porntaveetus,
Chulalongkorn University, Thailand

REVIEWED BY
Shihai Jia,
The University of Utah, United States
Ines Morais Caldas,
Universidade do Porto, Portugal

*CORRESPONDENCE
Jayakumar Jayaraman
jayakumar83@hotmail.com

RECEIVED 17 May 2024
ACCEPTED 31 July 2024
PUBLISHED 27 August 2024

CITATION
Jayaraman J (2024) Development and eruption of human teeth in the Chinese population: a comprehensive dental atlas. Front. Dent. Med 5:1434417. doi: 10.3389/fdmed.2024.1434417

Development and eruption of human teeth in the Chinese population: a comprehensive dental atlas

Jayakumar Jayaraman*

Department of Pediatric Dentistry, Virginia Commonwealth University School of Dentistry, Richmond, VA, United States

Aim: The first comprehensive chart on dental development was published 75 years ago based on Caucasian children and this has been used as a standard dental chart to date. Few population specific charts have been developed recently and updated dental charts on modern subjects can provide more information on dental development patterns. This study aims to construct a comprehensive dental atlas for modern Chinese children and young adults to assist in clinical, forensic, and public health applications.
Methods: The study sample comprised of 2,306 subjects, age ranging from 2 to 24 years belonging to Chinese ethnicity. Dental formation and eruption of permanent teeth and resorption of primary teeth were analyzed separately for females and males. For each age range, the number of teeth (n), and the stage of development was calculated for first (Q1), second (Q2) and third quartiles (Q3). Similar analysis was performed for the position of permanent teeth and the resorption of primary teeth. To determine the variations between the sex, Mann-Whitney *U*-test was conducted by comparing the median (Q2) stages.
Results: Variations in dental formation and eruption of permanent teeth and resorption of primary teeth were observed between maxillary and mandibular dentitions and between the sex, however the difference was not statistically significant ($p = 0.535$ to $p = 1.000$). The dental atlas was presented separately for Chinese females and males.
Conclusion: This atlas on modern Chinese population serves as a practical tool to assist in clinical diagnosis and treatment planning, in forensic investigations as well as indicators of developments in public health.

KEYWORDS

dental atlas, Chinese, dental development, dental chart, primary teeth, permanent teeth, human dentition, forensics age estimation

1 Introduction

Dental development is a sequential process that passes through several stages of formation to erupt to its final position in the arch. The primary teeth and first permanent molars start to develop in-utero and skeletal specimens serve as an ideal tool to evaluate early stages of dental development. This is usually conducted by direct vision of the skeletal remains; however, radiological and histological evaluation can also be of some assistance. For permanent teeth, radiographs provide an excellent platform to record dental development. Different methods of staging dental development have been proposed in the literature that varies between 4 and 32 stages (1–3); the most accepted being the eight-stage Anglo-Canadian classification system (1). Similarly, the

stages of resorption of roots of primary teeth have been analyzed that classified into 4 and 5 stages respectively (3, 4). The eruption of teeth has been evaluated and a five-stage classification system was proposed to relate the position of the tooth in the arch (5). This original system has been modified into a four-stage system in the London Atlas study (4).

The first comprehensive chart on dental development was published in 1941 based on Caucasian children in the United States and this has been commonly used as a standard dental atlas chart for several decades (6). The reliability of using this chart has been questioned due to the smaller number of samples in each age group. This chart was based on histological specimens of only 25 children out of which only seven were in the age range of 2 to 15 years (7). Several investigators have shown the presence of population differences in dental development (8, 9). Considering this, population specific charts has been developed and this includes London Atlas based on Caucasian and Bangladeshi populations in London (4), Australian Atlas (10, 11), and most recently, WITS Atlas based on southern African population (12).

Chinese constitute one of the major population and occupies one fifth of the total human population in the world and about 94% of people living in Hong Kong are of Chinese, predominantly of Cantonese origin but there was some admixture of other subgroups (13). The data on eruption of permanent teeth in Chinese was first presented 50 years ago and was not updated since then (14). Moreover, their study did not analyze the entire picture of dental development namely dental formation, eruption and resorption. To our understanding, there was no comprehensive dental atlas for Chinese population. This study was aimed to evaluate dental development pattern and subsequently construct dental atlas for Chinese children and young adults.

2 Materials and methods

2.1 Study population

The study comprised of 2,306 subjects, age ranging from 2 to 24 years with equal number of males and females, refer to Table 1. All the subjects were of southern Chinese ethnicity belonging to middle socioeconomic status and the Dental Panoramic Tomographs (DPT) were obtained from the archives of a teaching hospital in Hong Kong, Special Administrative Region of China. The radiographs were previously scored for a Dental Age Estimation study and have been re-used in the current study (15). The study was approved by the Institutional Review Board (Reference No: UW 12-280). The author retains ownership of the collected dataset and subsequent secondary analysis of the de-identified data presented in this manuscript. Only healthy subjects are included and those with severe

TABLE 1 Distribution of Chinese subjects used to analyse the formation and eruption of permanent teeth and resorption of primary teeth.

	Maturation[b]		Eruption[b]		Resorption[c]	
Age[a]	Males	Females	Males	Females	Males	Females
2.5	52	53	20	20	20	20
3.5	46	50	20	20	20	20
4.5	50	56	20	20	20	20
5.5	98	99	20	20	20	20
6.5	58	52	20	20	20	20
7.5	50	55	20	20	20	20
8.5	49	50	20	20	20	20
9.5	49	50	20	20	20	20
10.5	48	50	20	20	20	20
11.5	57	44	20	20	20	20
12.5	47	49	20	20	20	20
13.5	51	54	20	20	20	20
14.5	53	49	20	20	20	20
15.5	44	43	20	20	–	–
16.5	42	45	20	20	–	–
17.5	47	56	20	20	–	–
18.5	70	36	20	20	–	–
19.5	32	33	20	20	–	–
20.5	51	43	20	20	–	–
21.5	54	37	20	20	–	–
22.5	40	38	20	20	–	–
23.5	43	37	20	20	–	–
24.5	52	44	20	20	–	–
Total	**1,183**	**1,123**	**460**	**460**	**260**	**260**

[a]Age in midpoint of 1 year.
[b]Permanent dentition.
[c]Primary dentition.
–No data available as the tooth underwent normal physiological exfoliation.

anomalies that might affect dental development were excluded from the study. All the radiographs were scored by a single trained and calibrated examiner (JJ) with intra-examiner reliability Kappa score of 0.85. These scores correspond to "almost perfect" correlation (16). The radiographs were digitized at 300 dpi in gray scale format using a flatbed scanner and viewed in a dark room on a wide screen monitor at a magnification rate of 160% (Philips 271E, Philips Industries, Taiwan). When in doubt, the digitized images were enlarged up to 300% for better evaluation. Each tooth was designated by an alphabet followed by a number, for example, UL1 refers to Upper Left Central Incisor, UL2 refers to Upper Left Lateral Incisor and so on. The median (Q2), lower (Q1) and upper (Q3) interquartile ranges for each tooth was calculated separately for males and females. This analysis was conducted for formation and eruption of permanent dentition and resorption of primary dentition at different age ranges. The median stages are compared in this study due to the assumption that the data is not normally distributed. To determine the variations in dental development in males and females, Mann-Whitney *U*-test was conducted by comparing the median (Q2) stages of dental formation, eruption stages and resorption stages (SPSS Version 20.0, IBM Corp, Armonk, NY).

2.2 Formation of permanent teeth

Formation of permanent tooth was evaluated from 2,306 subjects based on Anglo-Canadian standards of dental formation designated in alphabets stages A to H, starting with initial calcification of tooth (stage A) up to completion of the root development (stage H), see Figure 1. All the teeth on the left side of the arch were evaluated for the stage of development (1). When a tooth in the left side is missing, the corresponding tooth on the right side was scored. The stages were recorded on a score card including the details of sex, ethnicity, date of birth and the date of exposure of the radiograph. The data was entered in the Microsoft Access database to calculate the average age for each corresponding stage of development (TDS) for each tooth morphology type (TMT). The details were then transferred to Microsoft Excel spreadsheet separately for males and females aged 2 to 24 years. For each age range, the number of teeth (n) and the corresponding stage of development were calculated for lower quartile (Q1), second quartile (Q2) and upper quartile (Q3) ranges. The stage corresponding to median (Q2) was used to develop dental formation charts for each age range, and separately for males and females.

2.3 Eruption of permanent teeth

To evaluate the position of permanent teeth in the arch, a total of 920 radiographs were randomly chosen from the total dataset partitioned by age and sex. This comprised twenty radiographs per age and sex of subjects aged 2 to 24 years. The most used

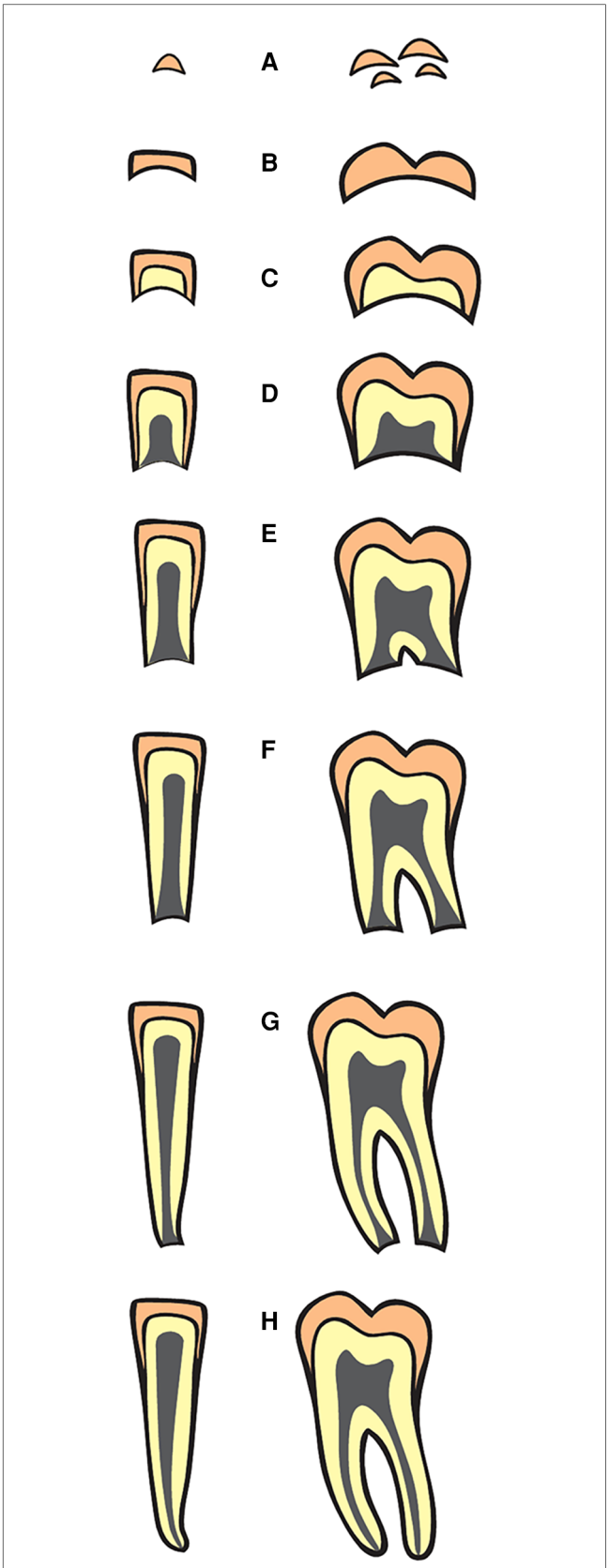


FIGURE 1
Classification of staging of dental formation (Stages A to H) in single and multi-rooted teeth (Data source: reference (1)).

classification stages of eruption of teeth follows five stages designated by P-I to P-V. Position P-I corresponds to tooth in full occlusion and P-V signifies the position of the tooth below the apical third of the primary root or more than 2 mm below the bone when the predecessor is absent. This observation was based on the permanent molars (5). However, this classification system did not consider of position of permanent teeth at subsequent categorical stages of development. In this study, a new classification system for staging dental eruption was adopted designated as E1 to E6, where E1 to E3 infers intra-osseous and E4 to E6 corresponds to extra-osseous positioning of permanent teeth. Stage E4 refers to radiographic position of tooth just above the alveolar bone level. A detailed description of this classification system was presented in Figure 2.

2.4 Resorption of primary teeth

A total of 520 radiographs, comprising of 20 radiographs for each sex and age between ages 2 and 14 were chosen to evaluate the resorption pattern of primary teeth (3). This sample was randomly obtained from the same data used to analyze eruption pattern of permanent teeth. Resorption of maxillary and mandibular primary teeth was analyzed by stages defined by Moorrees and co-workers; Ac corresponds to tooth with complete root development without radiological signs of resorption, Res1/4 showing one quarter root resorption, Res1/2 and Res3/4 corresponding to half and three quarters of resorption respectively, see Figure 3.

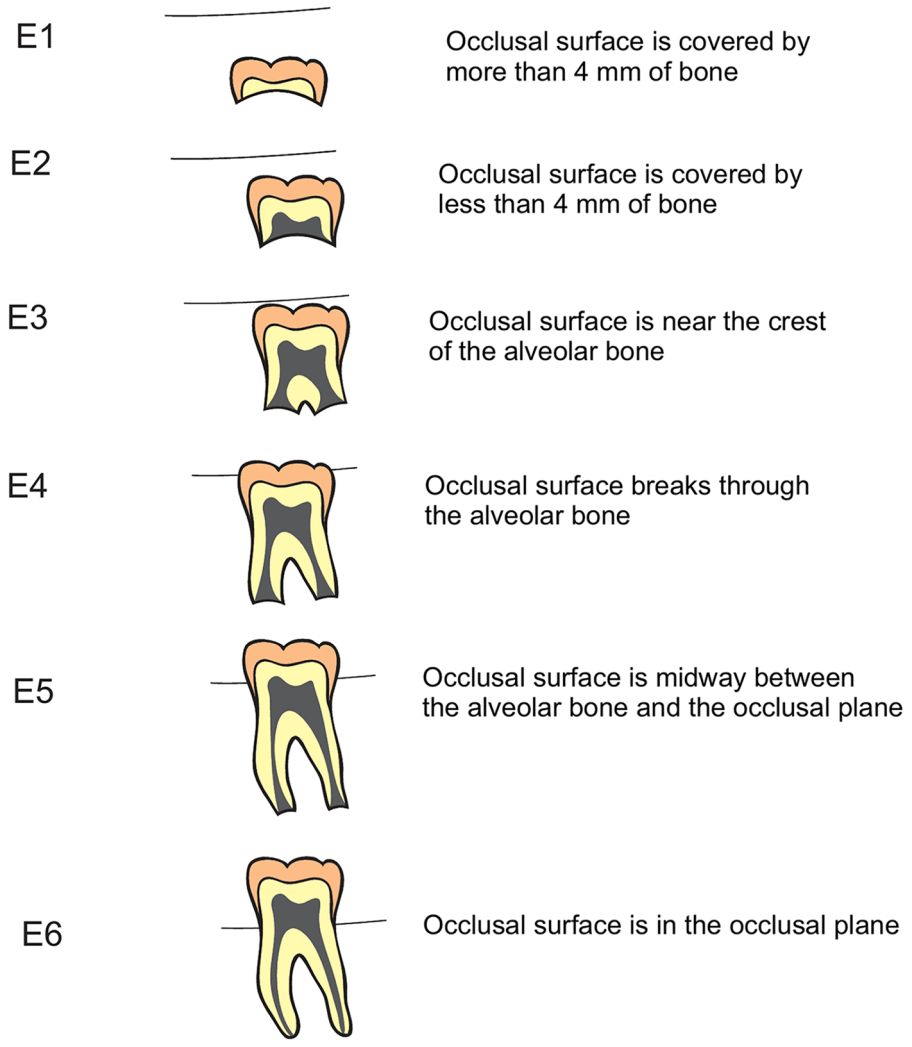


FIGURE 2
Classification of staging of eruption of teeth (Stages E1 to E6) in relation to alveolar bone level (Data source modified from: reference (5)).

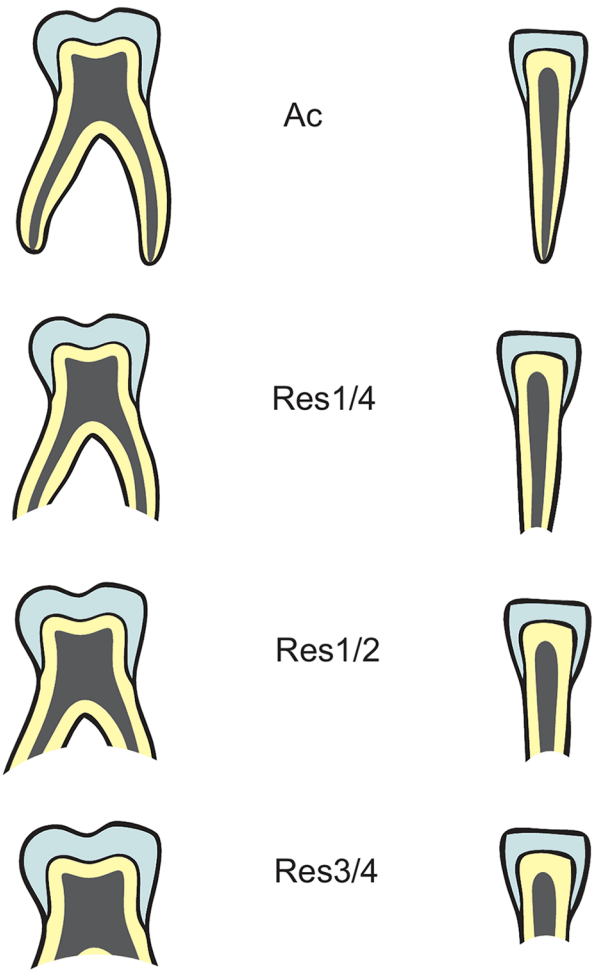


FIGURE 3
Classification of resorption patterns (Stages Ac, Res1/4, Res1/2, Res3/4) of single and multi-rooted primary teeth (Data source: reference (3)).

3 Results

3.1 Assessment of dental development

Mann-Whitney *U*-test was used to compare the median stage (Q2) of formation between males and females in the maxillary and mandibular dentitions at each age range from 2 to 24 years. One or two stage difference was observed in the median stages of dental formation of permanent teeth between maxillary and mandibular dentitions and between the sex. Between sexes, stage difference in formation of teeth was observed in all the age ranges except 3 and 7 years in the maxillary dentition and 4, 7, and 14 years in the mandibular dentition. The difference was not statistically significant between the sexes across all the age ranges ($p = 0.535$ to $p = 1.000$), see Table 2.

The median positioning of the permanent teeth as indicated by the rate of eruption varied between males and females and between the dentitions. In both maxillary dentition, and mandibular dentitions, difference in eruption pattern between the sexes was observed more in the younger age ranges and the most varying presentation in the eruption was observed in the third molars in both maxillary dentitions. Mann-Whitney *U*-test no statistically significant difference between the sexes in all the age groups ($p = 0.721$ to $p = 1.000$), see Table 3.

For the children aged 2 to 14 years, the resorption pattern of primary teeth was more pronounced in the maxillary dentition compared to the mandibular dentition. At 2 years, all the primary teeth showed complete root development in males and except maxillary and mandibular canines that had an open apex. Both canines underwent root closure in the subsequent year. Difference in resorption between males and females was observed in 2, 4, 5, 8, 9, and 10 year-old children in the maxillary dentition and 2, 5, 6, and 10-year-old children in the mandibular dentition. However, Mann-Whitney *U*-test showed no statistically significant difference in the resorption pattern of primary teeth in males and females in all age ranges ($p = 0.690$ to $p = 1.000$), see Table 4.

3.2 Construction of dental charts

The formation and eruption patterns of permanent teeth and resorption pattern of primary teeth were different between males and females by one or two stages difference in most age ranges. Since dental development was different between the males and females, the data were presented as gender specific charts for females (Figure 4) and males (Figure 5). Templates of ten primary and sixteen permanent tooth morphology type (TMT) on the right side were obtained from a dental anatomy textbook (17). The images of teeth were carefully hand drawn and digitized using Adobe Photoshop software (Version CS6, Adobe Systems Ltd, Ireland). Internal tooth structures including enamel, dentin and pulp were colored appropriately to differentiate primary and permanent teeth. To illustrate different stages of dental formation, single tooth diagrams were prepared to exhibit eight stages of development resulting in a total of 128 images (16 TMT x 8 stages). For tooth resorption stages for primary tooth, three root resorption stages were incorporated yielding 30 images (10 TMT×3 stages). To construct dental charts, for each age range, images relating to the data for formation, and resorption were obtained. Individual images were then compiled to produce dental atlas charts for males and females aged 2 to 14 years. Since all permanent teeth except third molars completed development by 14 years, for ages 15 to 22 years, charts were constructed only for third molars. The images and charts were constructed by the first author (JJ) using Corel Draw Graphics software (CorelDRAW Graphics Suite X8, ON, Canada).

4 Discussion

Differences in dental emergence have been reported in different population groups. For example, advanced dental formation and emergence was reported in the WITS Atlas (12) based on black southern Africans compared to London Atlas that was based on

TABLE 2 Formation of maxillary and mandibular permanent teeth of 2 to 24 years old Chinese females and males.

MAXILLA											MANDIBLE									
Age[b]	Teeth[c]	Males				Females					Teeth[c]	Males				Females				
		n	Q1	Q2	Q3	*n*	QI	Q2	Q3	*p*-value		*n*	Q1	Q2	Q3	*n*	QI	Q2	Q3	*p*
2.5	ULI	46	D	D	D	41	D	D	D		LL1	49	D	D	D	49	D	D	D	
	UL2	40	C	C	D	38	B	B	D		LL2	49	C	D	D	49	C	C	D	
	UL3	38	C	C	C	44	B	B	B		LL3	50	C	C	C	51	C	C	C	
	UL4	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]		LL4	29	A	A	B	26	A	A	B	
	UL5	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]		LL5	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	
	UL6	49	D	D	D	40	D	D	D	0.710	LL6	42	D	D	D	37	D	D	D	0.805
3.5	ULI	44	D	D	D	50	D	D	D		LL1	44	D	D	E	50	D	D	E	
	UL2	43	C	D	D	49	D	D	D		LL2	40	D	D	D	50	D	D	D	
	UL3	44	C	D	D	49	B	D	D		LL3	45	C	D	D	50	C	C	D	
	UL4	38	B	B	B	44	B	B	B		LL4	44	B	B	C	49	B	B	C	
	UL5	18	A	B	B	13	A	B	B		LL5	30	A	B	B	28	A	A	B	
	UL6	46	D	D	D	49	D	D	D		LL6	46	D	D	D	50	D	D	D	
	UL7	19	A	A	B	16	B	B	B	1.000	LL7	27	A	A	B	22	A	A	A	0.710
4.5	ULI	50	D	D	D	56	D	D	D		LL1	50	D	E	E	56	D	E	E	
	UL2	49	D	D	D	56	D	D	D		LL2	50	D	D	D	56	D	D	D	
	UL3	48	D	D	D	56	D	D	D		LL3	50	D	D	D	56	D	D	D	
	UL4	50	B	B	C	55	B	C	C		LL4	50	B	C	C	56	B	C	C	
	UL5	43	A	B	B	45	B	B	B		LL5	45	B	B	B	52	B	B	B	
	UL6	50	D	D	E	56	D	D	E		LL6	50	D	E	E	56	D	E	E	
	UL7	46	A	B	B	43	B	B	B	0.902	LL7	29	B	B	B	31	B	B	B	1.000
5.5	ULI	96	D	E	E	98	E	E	E		LL1	99	E	F	F	95	E	F	F	
	UL2	97	D	D	E	97	D	E	E		LL2	95	E	E	E	97	E	E	E	
	UL3	99	D	D	D	98	D	D	E		LL3	99	D	D	D	99	D	D	E	
	UL4	100	C	D	D	98	D	D	D		LL4	99	C	D	D	99	D	D	D	
	UL5	92	C	C	D	93	C	C	D		LL5	99	C	C	D	98	C	C	D	
	UL6	99	E	E	F	99	E	F	F		LL6	100	E	E	F	98	E	F	F	
	UL7	98	C	C	C	98	C	C	D	0.902	LL7	97	B	C	C	98	C	C	C	0.902
6.5	ULI	58	E	F	F	52	E	E	F		LL1	58	F	F	F	52	F	F	F	
	UL2	58	D	E	E	51	E	E	E		LL2	56	E	E	F	52	E	F	F	
	UL3	58	D	D	E	51	D	E	E		LL3	58	D	D	E	51	D	E	E	
	UL4	57	D	D	D	52	D	D	D		LL4	58	D	D	D	52	D	D	D	
	UL5	58	C	D	D	50	C	D	D		LL5	56	C	D	D	50	C	D	D	
	UL6	55	F	F	F	52	F	F	G		LL6	55	F	F	F	52	F	F	G	
	UL7	58	C	D	D	50	C	D	D	0.902	LL7	57	C	C	D	51	C	D	D	0.535
7.5	ULI	48	F	F	F	55	F	F	F		LL1	50	G	G	G	55	F	G	G	
	UL2	48	E	F	F	53	E	F	F		LL2	49	F	G	G	55	F	F	G	
	UL3	49	E	E	E	55	E	E	F		LL3	49	D	E	E	55	E	E	F	
	UL4	49	D	D	D	54	D	D	E		LL4	49	D	D	E	54	D	E	E	

(*Continued*)

10.3389/fdmed.2024.1434417

TABLE 2 Continued

MAXILLA											MANDIBLE									
Age[b]	Teeth[c]	Males				Females					Teeth[c]	Males				Females				
		n	Q1	Q2	Q3	*n*	QI	Q2	Q3	*p*-value		*n*	Q1	Q2	Q3	*n*	QI	Q2	Q3	*p*
	UL5	49	D	D	E	54	D	D	D		LL5	49	D	D	D	54	D	D	E	
	UL6	49	G	G	G	55	G	G	G		LL6	50	G	G	G	54	G	G	G	
	UL7	49	D	D	D	55	D	D	D	1.000	LL7	50	D	D	D	55	D	D	D	1.000
8.5	ULI	48	F	F	G	50	F	G	G		LL1	48	G	H	H	49	H	H	H	
	UL2	48	F	F	F	49	F	F	G		LL2	49	F	G	G	50	G	G	H	
	UL3	49	E	E	F	48	E	F	F		LL3	48	E	E	F	49	E	F	F	
	UL4	48	D	E	E	47	D	D	E		LL4	49	E	E	E	48	E	E	E	
	UL5	48	D	D	E	48	D	E	E		LL5	49	D	E	E	50	D	E	E	
	UL6	48	G	H	H	49	H	H	H		LL6	49	G	G	H	50	H	H	H	
	UL7	48	D	D	D	50	D	D	D	0.721	LL7	49	D	D	D	50	D	D	D	0.798
9.5	ULI	46	F	G	G	48	G	G	H		LL1	48	H	H	H	28	H	H	H	
	UL2	42	F	G	G	47	F	G	G		LL2	48	G	H	H	48	G	H	H	
	UL3	46	F	F	F	49	F	F	F		LL3	48	F	F	F	48	F	F	G	
	UL4	49	E	F	F	49	E	F	F		LL4	49	E	F	F	50	F	F	F	
	UL5	49	E	E	F	50	E	F	F		LL5	47	E	E	F	49	E	F	F	
	UL6	49	H	H	H	50	H	H	H		LL6	–	–	–	–	–	–	–	–	
	UL7	49	D	D	E	50	D	D	E		LL7	49	D	D	E	50	D	E	E	
	UL8	21	A	B	B	23	A	B	B	0.382	LL8	25	A	A	B	25	A	A	B	0.798
10.5	ULI	45	G	H	H	47	H	H	H		LL1	26	H	H	H	26	H	H	H	
	UL2	45	G	H	H	47	G	H	H		LL2	46	H	H	H	26	G	H	H	
	UL3	47	F	F	F	44	F	G	G		LL3	47	F	F	F	49	F	G	G	
	UL4	44	F	F	F	45	F	F	G		LL4	48	F	F	F	50	F	F	G	
	UL5	44	F	F	F	43	F	F	G		LL5	48	F	F	F	50	F	F	F	
	UL6	–	–	–	–	–	–	–	–		LL6	–	–	–	–	–	–	–	–	
	UL7	48	D	E	E	49	E	E	F		LL7	48	E	E	E	50	E	E	F	
	UL8	30	A	B	B	30	B	B	C	0.442	LL8	35	A	A	B	35	A	B	C	0.645
11.5	ULI	–	–	–	–	–	–	–	–		LL1	–	–	–	–	–	–	–	–	
	UL2	–	–	–	–	–	–	–	–		LL2	–	–	–	–	–	–	–	–	
	UL3	52	F	F	G	42	G	G	H		LL3	56	F	F	G	42	G	G	H	
	UL4	50	F	G	G	38	F	G	H		LL4	56	F	G	G	43	F	G	H	
	UL5	54	F	F	G	38	F	G	G		LL5	55	F	F	G	43	F	F	G	
	UL6	–	–	–	–	–	–	–	–		LL6	–	–	–	–	–	–	–	–	
	UL7	56	E	F	G	43	E	F	G		LL7	56	E	F	G	40	E	F	G	
	UL8	37	B	C	C	34	B	C	D	0.382	LL8	44	B	C	C	35	B	C	D	0.645
12.5	ULI	–	–	–	–	–	–	–	–		LL1	–	–	–	–	–	–	–	–	
	UL2	–	–	–	–	–	–	–	–		LL2	–	–	–	–	–	–	–	–	
	UL3	41	F	G	G	48	G	G	H		LL3	47	F	G	H	47	G	G	H	
	UL4	38	G	G	H	48	G	H	H		LL4	47	G	G	H	48	G	G	H	

(*Continued*)

10.3389/fdmed.2024.1434417

TABLE 2 Continued

MAXILLA											MANDIBLE									
Age[b]	Teeth[c]	Males				Females					Teeth[c]	Males				Females				
		n	Q1	Q2	Q3	*n*	QI	Q2	Q3	*p*-value		*n*	Q1	Q2	Q3	*n*	QI	Q2	Q3	*p*
	UL5	43	G	G	G	49	G	G	H		LL5	46	F	G	G	49	F	G	G	
	UL6	–	–	–	–	–	–	–	–		LL6	–	–	–	–	–	–	–	–	
	UL7	46	F	G	G	48	F	G	G		LL7	46	F	G	G	49	F	G	G	
	UL8	35	C	D	D	40	C	D	D	0.721	LL8	42	C	D	D	42	C	C	D	0.574
13.5	ULI	–	–	–	–	–	–	–	–		LL1	–	–	–	–	–	–	–	–	
	UL2	–	–	–	–	–	–	–	–		LL2	–	–	–	–	–	–	–	–	
	UL3	49	G	G	H	52	G	H	H		LL3	33	G	G	H	54	H	H	H	
	UL4	49	G	H	H	50	H	H	H		LL4	50	G	H	H	53	H	H	H	
	UL5	50	G	H	H	51	G	H	H		LL5	50	G	G	H	52	G	H	H	
	UL6	–	–	–	–	–	–	–	–		LL6	–	–	–	–	–	–	–	–	
	UL7	50	G	G	H	52	G	G	H		LL7	49	G	G	H	54	G	G	H	
	UL8	38	D	D	D	48	D	D	D	0.878	LL8	45	D	D	D	46	D	D	D	0.721
14.5	ULI	–	–	–	–	–	–	–	–		LL1	–	–	–	–	–	–	–	–	
	UL2	–	–	–	–	–	–	–	–		LL2	–	–	–	–	–	–	–	–	
	UL3	52	H	H	H	43	G	H	H		LL3	16	G	G	G	12	G	G	H	
	UL4	16	H	H	H	10	G	G	H		LL4	20	G	H	H	22	G	H	H	
	UL5	26	G	H	H	15	G	G	H		LL5	53	H	H	H	49	H	H	H	
	UL6	–	–	–	–	–	–	–	–		LL6	–	–	–	–	–	–	–	–	
	UL7	52	G	H	H	49	G	H	H		LL7	53	G	H	H	49	G	H	H	
	UL8	44	D	D	D	44	D	D	D	0.721	LL8	49	D	D	E	47	D	D	E	1.000
15.5	UL8	34	D	D	E	33	D	D	E		LL8	39	D	E	F	40	D	D	E	
16.5	UL8	38	D	E	G	42	D	E	F		LL8	39	D	E	F	43	D	E	F	
17.5	UL8	36	E	F	G	44	D	E	F		LL8	43	F	F	G	51	E	F	G	
18.5	UL8	54	F	G	G	27	E	F	G		LL8	59	G	G	G	33	F	G	G	
19.5	UL8	26	G	H	H	25	F	G	H		LL8	29	G	G	G	25	G	G	G	
20.5	UL8	34	G	H	H	33	F	G	H		LL8	44	G	G	H	34	G	G	H	
21.5	UL8	41	G	H	H	31	G	H	H		LL8	43	G	H	H	27	G	H	H	
22.5	UL8	32	H	H	H	25	H	H	H		LL8	38	G	H	H	34	H	H	H	
23.5	UL8	37	H	H	H	28	H	H	H		LL8	39	H	H	H	32	H	H	H	
24.5	UL8	40	H	H	H	30	H	H	H	0.529	LL8	46	H	H	H	38	H	H	H	0.971

Q1- lower quartile, Q2- median, Q3- upper quartile.

n - Number of teeth, *p* - Level of significance.

[a]No data available to assess the stage of dental development.

[b]Age in midpoint of one year.

[c]Tooth nomenclature adopted from the British Dental Journal nomenclature system.

–Indicates Stage H (complete root development) and the corresponding data not included in the analysis.

10.3389/fdmed.2024.1434417

TABLE 3 Position of maxillary and mandibular permanent teeth in the arches of 2 to 21 years old Chinese females and males.

Maxilla										
Age*	Gender	UL1	UL2	UL3	UL4	UL5	UL6	UL7	UL8	*p*-value^
2.5	♂	1	2	1	1	–	2	–	–	
	♀	2	2	1	1	–	3	–	–	0.721
3.5	♂	1	2	1	1	1	3	1	–	
	♀	2	2	1	1	1	3	1	–	0.798
4.5	♂	2	2	1	1	1	3	1	–	
	♀	2	2	1	1	1	3	1	–	1.000
5.5	♂	2	2	1	1	1	4	2	–	
	♀	2	2	1	1	1	4	2	–	1.000
6.5	♂	3	2	1	2	1	5	2	–	
	♀	3	2	1	2	1	6	2	–	0.878
7.5	♂	5	3	1	2	1	6	3	–	
	♀	6	3	1	2	1	6	3	–	0.959
8.5	♂	6	5	1	2	1	6	3	–	
	♀	6	5	2	2	1	6	3	–	0.878
9.5	♂	6	6	2	2	2	6	3	1	
	♀	6	6	2	2	2	6	3	1	1.000
10.5	♂	6	6	4	4	3	6	3	2	
	♀	6	6	5	4	3	6	4	1	0.798
11.5	♂	6	6	5	5	5	6	4	2	
	♀	6	6	5	6	5	6	4	1	0.721
12.5	♂	6	6	6	6	5	6	5	2	
	♀	6	6	6	6	6	6	4	2	0.959
13.5	♂	6	6	6	6	6	6	5	2	
	♀	6	6	6	6	6	6	6	2	0.721
14.5	♂	6	6	6	6	6	6	6	2	
	♀	6	6	6	6	6	6	6	2	1.000
15.5	♂	6	6	6	6	6	6	6	3	
	♀	6	6	6	6	6	6	6	3	1.000
16.5	♂	6	6	6	6	6	6	6	3	
	♀	6	6	6	6	6	6	6	3	1.000
17.5	♂	6	6	6	6	6	6	6	3	
	♀	6	6	6	6	6	6	6	4	0.959
18.5	♂	6	6	6	6	6	6	6	5	
	♀	6	6	6	6	6	6	6	4	0.759
19.5	♂	6	6	6	6	6	6	6	5	
	♀	6	6	6	6	6	6	6	5	1.000
20.5	♂	6	6	6	6	6	6	6	6	
	♀	6	6	6	6	6	6	6	6	1.000
21.5	♂	6	6	6	6	6	6	6	6	
	♀	6	6	6	6	6	6	6	6	1.000
Mandible										
Age*	Gender	LL1	LL2	LL3	LL4	LL5	LL6	LL7	LL8	*p*-value^
2.5	♂	2	2	1	1	–	3	–	–	
	♀	2	2	1	1	–	3	–	–	1.000
3.5	♂	2	1	1	1	1	3	1	–	
	♀	2	2	1	1	1	3	1	–	0.878
4.5	♂	2	2	1	1	1	3	1	–	
	♀	2	2	1	1	1	3	1	–	1.000
5.5	♂	2	2	1	1	1	4	1	–	
	♀	2	2	1	1	1	4	2	–	0.878
6.5	♂	5	3	1	1	1	5	2	–	
	♀	5	3	1	1	1	5	2	–	1.000
7.5	♂	5	5	1	2	1	6	2	–	
	♀	6	5	2	2	1	6	2	–	0.878
8.5	♂	6	5	2	2	1	6	3	–	
	♀	6	6	2	2	1	6	3	–	0.878

(*Continued*)

TABLE 3 Continued

Mandible										
Age*	Gender	LL1	LL2	LL3	LL4	LL5	LL6	LL7	LL8	*p*-value^
9.5	♂	6	6	2	2	1	6	3	1	
	♀	6	6	2	3	2	6	4	–	0.651
10.5	♂	6	6	5	4	2	6	4	1	
	♀	6	6	5	5	2	6	4	1	0.878
11.5	♂	6	6	6	5	3	6	5	2	
	♀	6	6	6	6	4	6	5	1	0.721
12.5	♂	6	6	6	6	6	6	5	2	
	♀	6	6	6	6	6	6	6	2	0.878
13.5	♂	6	6	6	6	6	6	5	3	
	♀	6	6	6	6	6	6	6	3	1.000
14.5	♂	6	6	6	6	6	6	5	3	
	♀	6	6	6	6	6	6	6	3	0.721
15.5	♂	6	6	6	6	6	6	5	3	
	♀	6	6	6	6	6	6	5	3	1.000
16.5	♂	6	6	6	6	6	6	6	4	
	♀	6	6	6	6	6	6	6	3	0.959
17.5	♂	6	6	6	6	6	6	6	4	
	♀	6	6	6	6	6	6	6	4	1.000
18.5	♂	6	6	6	6	6	6	6	5	
	♀	6	6	6	6	6	6	6	5	1.000
19.5	♂	6	6	6	6	6	6	6	6	
	♀	6	6	6	6	6	6	6	5	0.721
20.5	♂	6	6	6	6	6	6	6	6	
	♀	6	6	6	6	6	6	6	6	1.000
21.5	♂	6	6	6	6	6	6	6	6	
	♀	6	6	6	6	6	6	6	6	1.000

**Age in midpoint of 1 year.*
♂ – male, ♀ - female.
^- Mann-Whitney U-test.
p - Level of significance.
–Data not available as the tooth did not exhibit signs of formation.

Bangladeshi and Caucasian children (4). Dental age estimation was conducted using the London Atlas on mixed ethnic population in London and found to be accurate compared to Schour & Massler and Ubelaker charts (18). A similar finding was observed when the London Atlas was tested in Hispanic (19) as well as Iranian populations (20). In contrast, a study that tested the applicability of three dental charts including the London Atlas in New Zealand population found that all the charts demonstrated low accuracy and precision. This study further emphasized the need for population specific dental charts for accurate age estimation (21). Like population variations, sex difference in dental maturation was also an established phenomenon. Advanced dental emergence has been reported in girls compared to boys (22–24). However, a study that tested the accuracy of London Atlas in Portuguese population found difference between sexes and indicated the need for separate dental charts for each sex (25). In the present study, some difference was observed between the sexes; in females, both maxillary and mandibular first molars attained median stage of root closure at 8.5 years, one year earlier than in males. Similarly, canines and maxillary first premolars completed root development much earlier in females. In contrast, males showed advancement in the formation of maxillary third molar as the root apex closed at 19.5 years compared to 21.5 years in females. This trend was not observed in the mandibular third molar development, where root closure occurred around 21.5 years in both sex. Since the difference was not statistically significant, the data for males and females were combined and reported as a single dental atlas.

Eruption of permanent teeth is influenced by many other factors; socio-economic status, with their implicit connection with nutritional and health status (26), fluoride ingestion (27), and climate (28) have all been analyzed to possibly affect eruption timings. In contrast, a study conducted in southern Chinese children reported no significant difference in the eruption of teeth among children of low, medium and high socio-economic status (14). A similar finding was also observed in African Black children (29). Esan & Schepartz performed sample size calculation and found that a minimum sample size of 40 per age cohort was required to develop population specific dental atlas (12). In the present study, the data on dental maturation of permanent teeth from 2,306 subjects was re-used from the previous dental age study, accounting to over 80 subjects in each age cohort between 2 and 24 years of age (15). However, to analyze eruption of permanent teeth and resorption of primary teeth, we utilized only 40 samples per age cohort from the total sample. This sample size was relatively higher or equivalent to previous studies on dental atlas (4, 12).

The Chinese children in this study demonstrated advanced dental eruption in so much that all permanent teeth had erupted

TABLE 4 Resorption of maxillary and mandibular primary teeth of 2 to 13 years old Chinese females and males.

Maxilla											
Age*	Males					Females					
	i1	i2	c	m1	m2	i1	i2	c	m1	m2	*p*-value^
2.5	Ac	Ac	Ac	Ac	Ac	Ac	Ac	G	Ac	Ac	0.690
3.5	Ac	Ac	Ac	Ac	Ac	Ac	Ac	Ac	Ac	Ac	1.000
4.5	Ac	Ac	Ac	Ac	Ac	Res1/4	Ac	Ac	Ac	Ac	0.690
5.5	Ac	Ac	Ac	Ac	Ac	Res1/4	Ac	Ac	Ac	Ac	0.690
6.5	Res1/2	Res1/2	Ac	Ac	Ac	Res1/2	Res1/2	Ac	Ac	Ac	1.000
7.5	x	Res3/4	Ac	Ac	Ac	x	Res3/4	Ac	Ac	Ac	1.000
8.5	x	x	Res1/4	Ac	Ac	x	x	Res1/4	Res1/4	Ac	0.690
9.5	x	x	Res1/4	Res1/2	Res1/4	x	x	Res1/2	Res1/2	Res1/4	0.841
10.5	x	x	Res3/4	x	Res3/4	x	x	x	Res3/4	Res1/2	0.841
11.5	x	x	x	x	Res3/4	x	x	x	x	Res3/4	1.000
12.5	x	x	x	x	x	x	x	x	x	x	1.000
13.5	x	x	x	x	x	x	x	x	x	x	1.000
Mandible											
Age*	Males					Females					
	i1	i2	c	m1	m2	i1	i2	c	m1	m2	*p*-value^
2.5	Ac	Ac	Ac	Ac	Ac	Ac	Ac	G	Ac	Ac	0.690
3.5	Ac	Ac	Ac	Ac	Ac	Ac	Ac	Ac	Ac	Ac	1.000
4.5	Ac	Ac	Ac	Ac	Ac	Ac	Ac	Ac	Ac	Ac	1.000
5.5	Res3/4	Res1/2	Ac	Ac	Ac	Res1/2	Res1/2	Ac	Ac	Ac	0.841
6.5	x	Res3/4	Ac	Ac	Ac	x	Res1/2	Ac	Ac	Ac	0.841
7.5	x	x	Ac	Ac	Ac	x	x	Ac	Ac	Ac	1.000
8.5	x	x	Ac	Ac	Ac	x	x	Ac	Res1/4	Res1/4	0.690
9.5	x	x	Res1/2	Res1/2	Res1/4	x	x	Res1/2	Res1/2	Res1/4	1.000
10.5	x	x	x	x	Res1/2	x	x	Res3/4	X	Res3/4	0.690
11.5	x	x	x	x	Res3/4	x	x	x	x	Res3/4	1.000
12.5	x	x	x	x	x	x	x	x	x	x	1.000
13.5	x	x	x	x	x	x	x	x	x	x	1.000

*Age in midpoint of 1 year.
^- Mann-Whitney *U*-test.
p - Level of significance.
G - Open Root apex.
x - No data available as the tooth underwent normal physiological exfoliation.

at 11.5 years whilst the London Atlas children had retained primary maxillary canines and both maxillary and mandibular second molars at this age. When the sex data were combined to compare the timing of eruption of the permanent teeth between the London Atlas and Chinese subjects in the current study, it was found that except for maxillary canines, all maxillary and mandibular incisors erupted earlier in subjects in the London Atlas. In contrast, pre-molars erupted earlier in Chinese children; however, first and second molars were similar between these groups. Both London Atlas and Chinese subjects had half of the roots of third molars formed at 16.5 years, whilst the Black African children demonstrated similar stage at 14.5 years. The root closure of third molars occurred at 17.5 years in Black African subjects whilst it happened at 21.5 years in Chinese and London Atlas subjects. These findings suggest the possibility of population variations in dental formation in third molars between the London Atlas, African Black and the Chinese subjects (4, 12). Comparison of dental development between the London Atlas and the WITS Atlas for each age cohort had been already reported (12). Another area of discussion is influence of secular trends in dental development. It has been shown that children born in different centuries (30) and between few decades (31, 32) have different patterns of dental development. This trend has also been observed in 5–6 years old Chinese children (33). To address this issue, in the current study, we utilized only radiographs belonging to modern samples. This study was conducted in 2012 and the search criteria was restricted to include only the most recent samples to represent modern day children, adolescents and young adults. The age of subjects ranged from 2 to 24 years and the date of birth of the subjects were between 1985 and 2010. For example, for 5-year old children, those who were born around 2005 alone were obtained and a similar search strategy was extended to all other age ranges.

Standards for emergence of permanent teeth in southern Chinese children were first reported in 1965 (12). This study was

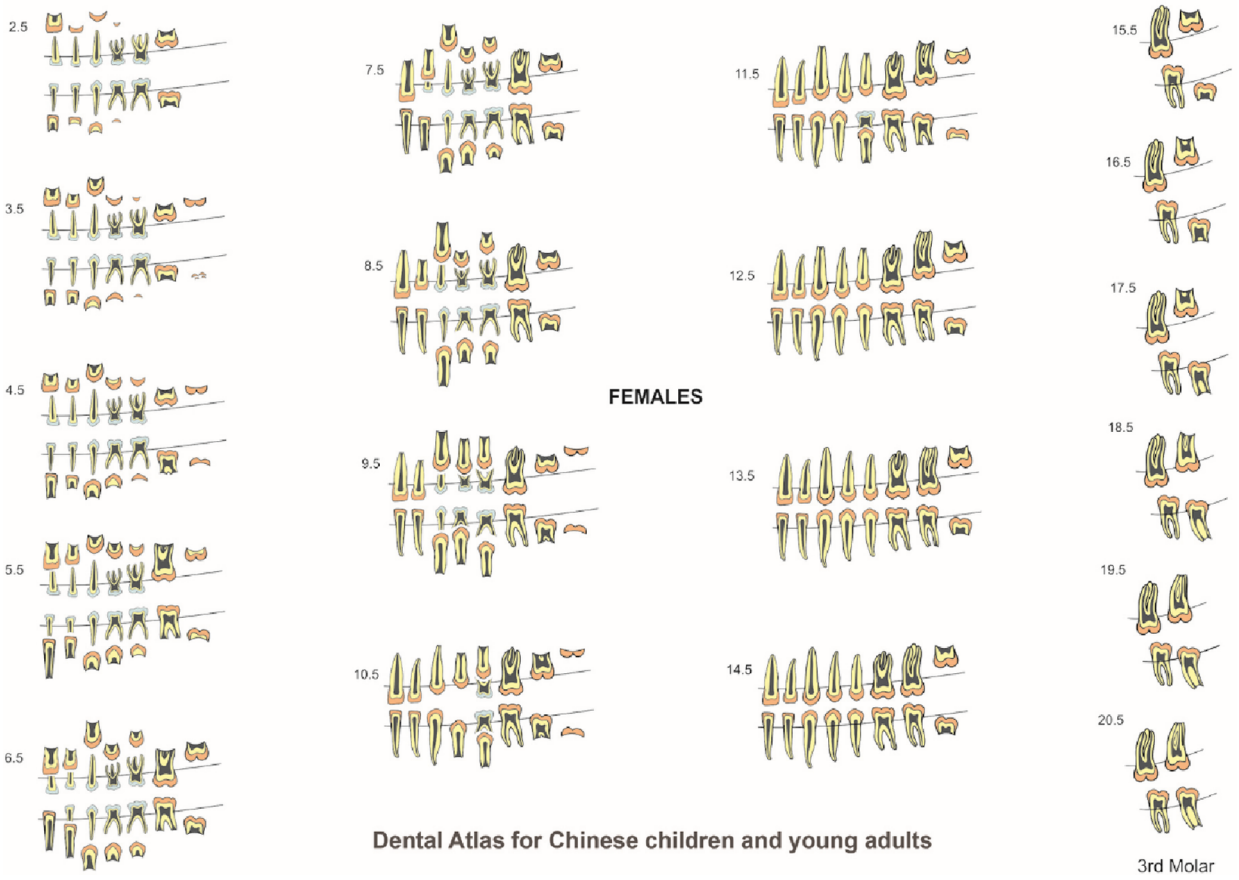


FIGURE 4
Dental atlas for Chinese females based on the formation and eruption of permanent teeth and resorption of primary teeth.

based on clinical observation and hence did not include other aspects of dental development including the resorption of primary teeth and formation pattern of permanent teeth at subsequent years. In our study, all the parameters of tooth formation and eruption were assessed from radiographs. It has been reported that early loss of primary molars delays the eruption of the premolars and conversely, delayed exfoliation results in earlier eruption of the premolars (34). Accelerated eruption of premolars beneath the pulpotomized primary molars have also been reported (35). In addition, trauma (36), odontogenic cysts (37), odontogenic tumors (38), gingival enlargements (39), and supernumerary tooth (40) has been reported to influence dental formation and emergence. Consequently, subjects with severe dental anomalies and other forms of development disorders were excluded from the analysis. It is evident that pathologically affected primary teeth influences the eruption of permanent teeth; however, the relationship between the pathologically involved primary teeth and the stage of formation of permanent teeth has not been established yet (34).

The method in which median stages of dental development analyzed in this study was like a study conducted in the London Atlas study (4). For subjects aged 2 to 14 years, the entire complement of maxillary and mandibular dentition was displayed in the atlas. Since all the teeth had attained complete development by 14 years, for age range of 15 to 20 years, we have presented only maxillary and mandibular third molars. This is like the London Atlas that had full dentition until 15 years followed by third molars in the 16 to 23 years range. Radiographs of subjects used in this study represent a sample population of Chinese ethnic group living in Hong Kong. They are identified by the uniqueness of their name and the family details recorded in the patient files. All the radiographs were primarily taken to assist in clinical diagnosis and were hence re-used in the current study. It is to be noted that panoramic radiographs for young patients below 5 years of age were obtained only following strong indication to assist in diagnosis and treatment planning. Occasionally, they were also taken on uncooperative children who resist to taking conventional intraoral radiographs.

Demirjian's 8 stage method was used in our study considering the reliability and ease in identification of stages. This staging method was like the WITS Atlas study (12), however, The London Atlas study utilized 13 stage method (4). To evaluate initial stages of development of primary teeth, investigators must rely on skeletonized or preserved human remains with known details of birth and death. The London Atlas study comprised of skeletal samples as young as 30 weeks in-utero that were obtained from Maurice Stack collection at

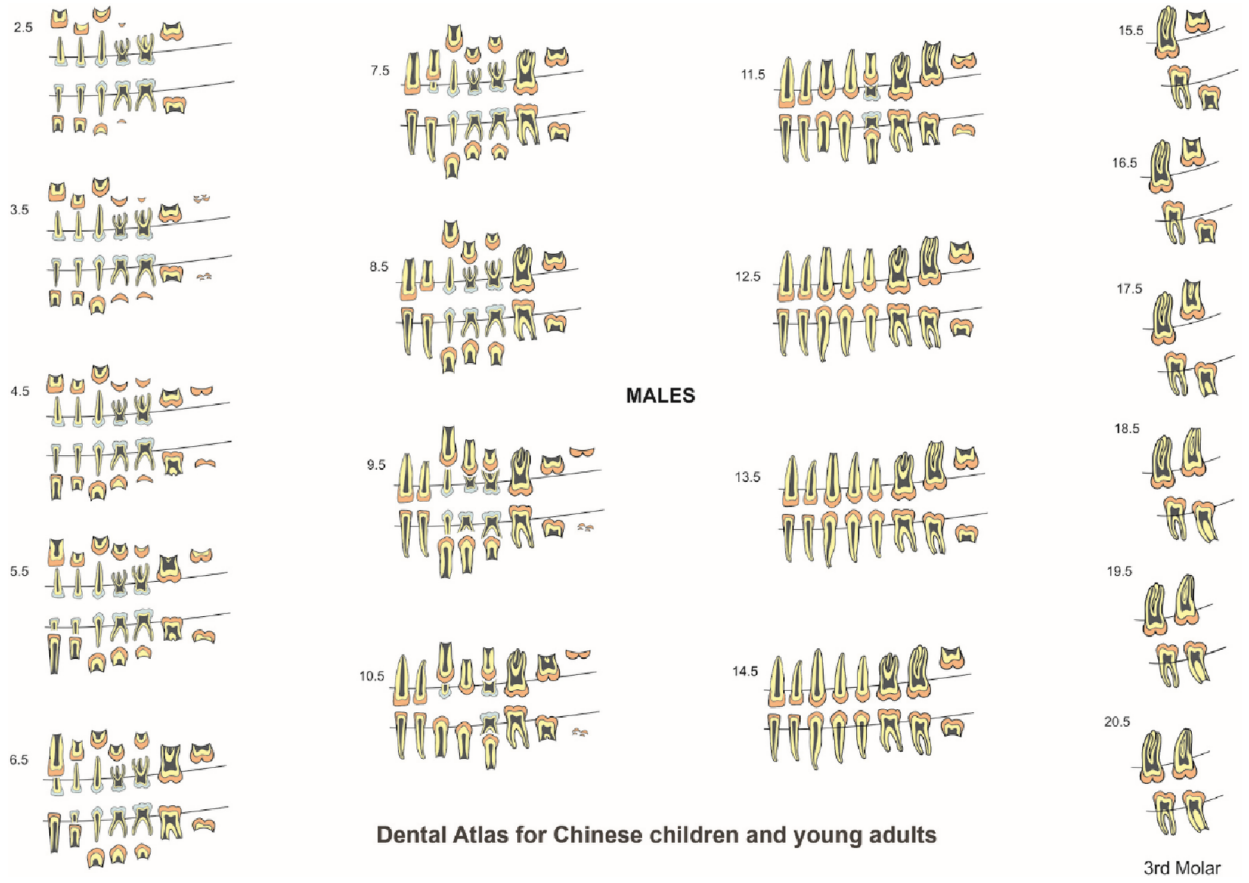


FIGURE 5
Dental atlas for Chinese males based on the formation and eruption of permanent teeth and resorption of primary teeth.

the Royal College of Surgeons of England (4). In current study, archived samples of modern Chinese subjects aged 4 months to 2 years old could not be found and so, it was impossible to present data corresponding to this age. Moreover, it has been shown that the London dental atlas tends to overestimate the age (41). Following this, a recent review questioned the logic of using dental atlas for age estimation. It reviewed five dental atlases and found inconsistency I the study design, statistical procedures and presentation styles (42). This dental atlas should be used with caution for the purpose of dental age estimation as the age is segregated by the mid-point of one year. Moreover, this atlas has not been subjected to blind validation analysis. For accurate estimation of age, it is recommended to use simple average method (SAM) as described in the author's previous article (15).

5 Conclusions

We have presented evidence based dental chart developed from a large sample of children and young adults of Chinese ethnicity. This dental atlas serves as a practical tool for age estimation in forensic investigations, assist in clinical diagnosis and treatment planning as well as indicators of developments in public health. Future research should focus on generating population specific data on dental development as well as integrating newer imaging technologies.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by the study was approved by the University of Hong Kong West Cluster Institutional Review Board (Reference No: UW 12-280). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and institutional requirements. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

JJ: Conceptualization, Data curation, Formal Analysis, Methodology, Software, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Acknowledgments

The author would like to thank Dr. Nigel King, former Professor of Pediatric Dentistry at the University of Hong Kong for reviewing the original draft of the manuscript.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author declares that he is an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fdmed.2024.1434417/full#supplementary-material.

References

1. Demirjian A, Goldstein H, Tanner JM. A new system of dental age assessment. *Hum Biol.* (1973) 45:211–27.

2. Haavikko K. Tooth formation age estimated on a few selected teeth. A simple method for clinical use. *Proc Finn Dent Soc.* (1974) 70:15–9.

3. Moorrees CF, Fanning EA, Hunt EE Jr. Formation and resorption of three deciduous teeth in children. *Am J Physical Anthropol.* (1963) 21:205–13. doi: 10.1002/ajpa.1330210212

4. AlQahtani SJ, Hector MP, Liversidge HM. Brief communication: the London atlas of human tooth development and eruption. *Am J Physical Anthropol.* (2010) 142:481–90. doi: 10.1002/ajpa.21258

5. Bengston RG. A study of the time of eruption and root development of the permanent teeth between six and thirteen years. *Northwest Univ Bull.* (1935) 35:3–9.

6. Schour L, Massler M. The development of the human dentition. *J Am Dent Assoc.* (1941) 28:1153–60.

7. Logan WH, Kronfeld R. Development of the human jaws and surrounding structures from birth to the age of fifteen years. *J Am Dent Assoc.* (1933) 20:379–428.

8. Al-Tuwirqi A, Holcombe T, Seow WK. A study of dental development in a Caucasian population compared with a non-Caucasian population. *Eur Arch Paediatr Dent.* (2011) 12:26–30. doi: 10.1007/BF03262775

9. Jayaraman J, Roberts GJ. Comparison of dental maturation in Hong Kong Chinese and United Kingdom Caucasian populations. *Forensic Sci Int.* (2018) 292:61–70. doi: 10.1016/j.forsciint.2018.09.005

10. McKenna CJ, James H, Taylor JA, Townsend GC. Tooth development standards for South Australia. *Aust Dent J.* (2002) 47:223–7. doi: 10.1111/j.1834-7819.2002.tb00333.x

11. Blenkin M, Taylor J. Age estimation charts for a modern Australian population. *Forensic Sci Int.* (2012) 221:106–12. doi: 10.1016/j.forsciint.2012.04.013

12. Esan TA, Schepartz LA. The WITS atlas: a black southern African dental atlas for permanent tooth formation and emergence. *Am J Physical Anthropol.* (2018) 166:208–18. doi: 10.1002/ajpa.23424

13. Chen J, Zheng H, Bei JX, Sun L, Jia WH, Li T, et al. Genetic structure of the Han Chinese population revealed by genome-wide SNP variation. *Am J Hum Genet.* (2009) 85:775–85. doi: 10.1016/j.ajhg.2009.10.016

14. Lee MM, Low WD, Chang KS. Eruption of the permanent dentition of Southern Chinese children in Hong Kong. *Arch Oral Biol.* (1965) 10:849–61. doi: 10.1016/0003-9969(65)90078-6

15. Jayaraman J, Wong HM, King NM, Roberts GJ. Development of a reference data set (RDS) for dental age estimation DAE) and testing of this with a separate validation set (VS) in a southern Chinese population. *J Forensic Leg Med.* (2016) 43:26–33. doi: 10.1016/j.jflm.2016.07.007

16. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics.* (1977) 33:159–74. doi: 10.2307/2529310

17. Nelson SJ, Ash MM. *Wheeler's Dental Anatomy, Physiology and Occlusion*. 9th ed Missouri: Elsevier Inc (2010). p. 92–205.

18. AlQahtani SJ, Hector MP, Liversidge HM. Accuracy of dental age estimation charts: schour and massler, ubelaker and the London atlas. *Am J Physical Anthropol.* (2014) 154:70–8. doi: 10.1002/ajpa.22473

19. McCloe D, Marion I, da Fonseca MA, Colvard M, AlQahtani S. Age estimation of hispanic children using the London atlas. *Forensic Sci Int.* (2018) 288:332.e1–e6. doi: 10.1016/j.forsciint.2018.04.013

20. Ghafari R, Ghodousi A, Poordavar E. Comparison of the accuracy of the London atlas and smith method in dental age estimation in 5–15.99-year-old iranians using the panoramic view. *Int J Legal Med.* (2019) 133:189–95. doi: 10.1007/s00414-018-1808-6

21. Baylis S, Bassed R. Precision and accuracy of commonly used dental age estimation charts for the New Zealand population. *Forensic Sci Int.* (2017) 277:223–8. doi: 10.1016/j.forsciint.2017.06.011

22. Parner ET, Heidmann JM, Veth M, Poulsen S. A longitudinal study of time trends in the eruption of permanent teeth in Danish children. *Arch Oral Biol.* (2001) 46:425–31. doi: 10.1016/S0003-9969(01)00002-4

23. Leroy R, Bogaerts K, Lesaffre E, Declerck D. The emergence of permanent teeth in flemish children. *Community Dent Oral Epidemiol.* (2013) 31:30–9. doi: 10.1034/j.1600-0528.2003.00023.x

24. Elmes A, Dykes E, Cookson MJ. A cross-sectional survey to determine the ages of emergence of permanent teeth of Caucasian children of the Colchester area of the UK. *Br Dent J.* (2010) 209:E10. doi: 10.1038/sj.bdj.2010.672

25. Pavlovic S, Pereira CP, de Sousa Santos RFV. Age estimation in Portuguese population: the application of the London atlas of tooth development and eruption. *Forensic Sci Int.* (2017) 272:97–103. doi: 10.1016/j.forsciint.2017.01.011

26. Kaul S, Saini S, Saxena B. Emergence of permanent teeth in school-children in Chandigarh, India. *Arch Oral Biol.* (1975) 20:587–93. doi: 10.1016/0003-9969(75)90079-5

27. Short EM. Domestic water and dental caries: vI. The relation of fluoride domestic waters to permanent tooth eruption. *J Dent Res*. (1944) 23:247–55. doi: 10.1177/00220345440230040301

28. Friedlaender JS, Bailit HL. Eruption times of the deciduous and permanent teeth of natives on Bougainville Island, Territory of New Guinea: a study of racial variation. *Hum Biol.* (1969) 41:51–65.

29. Maki K, Morimoto A, Nishioka T, Kimura M, Braham RL. The impact of race on tooth formation. *ASDC J Dent Child*. (1999) 66:353–6.

30. Liversidge HM. Dental maturation of 18th and 19th century British children using Demirjian's method. *Int J Paediatr Dent*. (1999) 9:111–5. doi: 10.1046/j.1365-263x.1999.00113.x

31. Nadler GL. Earlier dental maturation: fact or fiction? *Angle Orthod*. (1998) 68:535–8. doi: 10.1043/0003-3219(1998)068<0535:EDMFOF>2.3.CO;2

32. Cardoso HF, Heuzé Y, Júlio P. Secular change in the timing of dental root maturation in Portuguese boys and girls. *Am J Human Biol.* (2010) 22:791–800. doi: 10.1002/ajhb.21084

33. Jayaraman J, Wong HM, King N, Roberts G. Secular trends in the maturation of permanent teeth in 5 to 6 years old children. *Am J Human Biol.* (2013) 25:329–34. doi: 10.1002/ajhb.22370

34. Fanning EA. Effect of extraction of deciduous molars on the formation and eruption of their successors. *Angle Orthod*. (1962) 32:44–53.

35. Lauterstein AM, Pruzansky S, Barber TK. Effect of deciduous mandibular molar pulpotomy on the eruption of succedaneous premolar. *J Dent Res*. (1962) 41:1367–72. doi: 10.1177/00220345620410061301

36. Gungor H, Pusman E, Uysal S. Eruption delay and sequelae in permanent incisors following intrusive luxation in primary dentition: a case report. *Dent Traumatol.* (2011) 27:156–8. doi: 10.1111/j.1600-9657.2011.00981.x

37. Aleman Navas RM, Martinez Mendoza MG. Congenital eruption **cyst**. *Pediatr Dermatol.* (2010) 27:671–2. doi: 10.1111/j.1525-1470.2010.01335.x

38. Savage NW, Daly CG. Gingival enlargements and localized gingival overgrowths. *Aust Dent J.* (2010) 55:55–60. doi: 10.1111/j.1834-7819.2010.01199.x

39. Varkhede A, Tupkari JV, Sardar M. (Odontogenic tumors: a study of 120 cases in an Indian teaching hospital. *Med Oral Path Oral Cir Bucal*. (2011) 16:e895–9. doi: 10.4317/medoral.17251

40. Omer RS, Anthonappa RP, King NM. Determination of the optimum time for surgical removal of unerupted anterior supernumerary teeth. *Pediatr Dent*. (2010) 32:14–20.

41. Jacometti V, Sato CM, Meireles DA, Silva RHAD. Age estimation using London atlas methodology: a systematic review and meta-analysis. *Forensic Sci Int*. (2023) 342:111532. doi: 10.1016/j.forsciint.2022.111532

42. Roberts G, Lucas VS, Camilleri S, Jayaraman J, Kasper KA, Lewis JM. Questions of logic in atlas methods of dental age estimation. *J Forensic Leg Med*. (2023) 96:102505. doi: 10.1016/j.jflm.2023.102505

frontiers | Frontiers in Dental Medicine

TYPE Correction
PUBLISHED 25 November 2024
DOI 10.3389/fdmed.2024.1504277

OPEN ACCESS

APPROVED BY
Frontiers Editorial Office, Frontiers Media SA, Switzerland

*CORRESPONDENCE
Jayakumar Jayaraman
jayakumar83@hotmail.com

RECEIVED 30 September 2024
ACCEPTED 12 November 2024
PUBLISHED 25 November 2024

CITATION
Jayaraman J (2024) Corrigendum: Development and eruption of human teeth in the Chinese population: a comprehensive dental atlas.
Front. Dent. Med 5:1504277.
doi: 10.3389/fdmed.2024.1504277

Corrigendum: Development and eruption of human teeth in the Chinese population: a comprehensive dental atlas

Jayakumar Jayaraman*

Department of Pediatric Dentistry, Virginia Commonwealth University School of Dentistry, Richmond, VA, United States

KEYWORDS

dental atlas, Chinese, dental development, dental chart, primary teeth, permanent teeth, human dentition, forensics age estimation

A Corrigendum on
Development and eruption of human teeth in the Chinese population: a comprehensive dental atlas

By Jayaraman J. (2024). Front. Dent. Med. 5:1434417. doi: 10.3389/fdmed.2024.1434417

In the published article, there was an error in Figures 4 and 5 as published. The images for these figures did not correspond to the captions: Figure 4 should correspond to dental atlas for Females and Figure 5 should correspond to dental atlas for Males. The correct Figures 4 and 5 and their captions appear below.

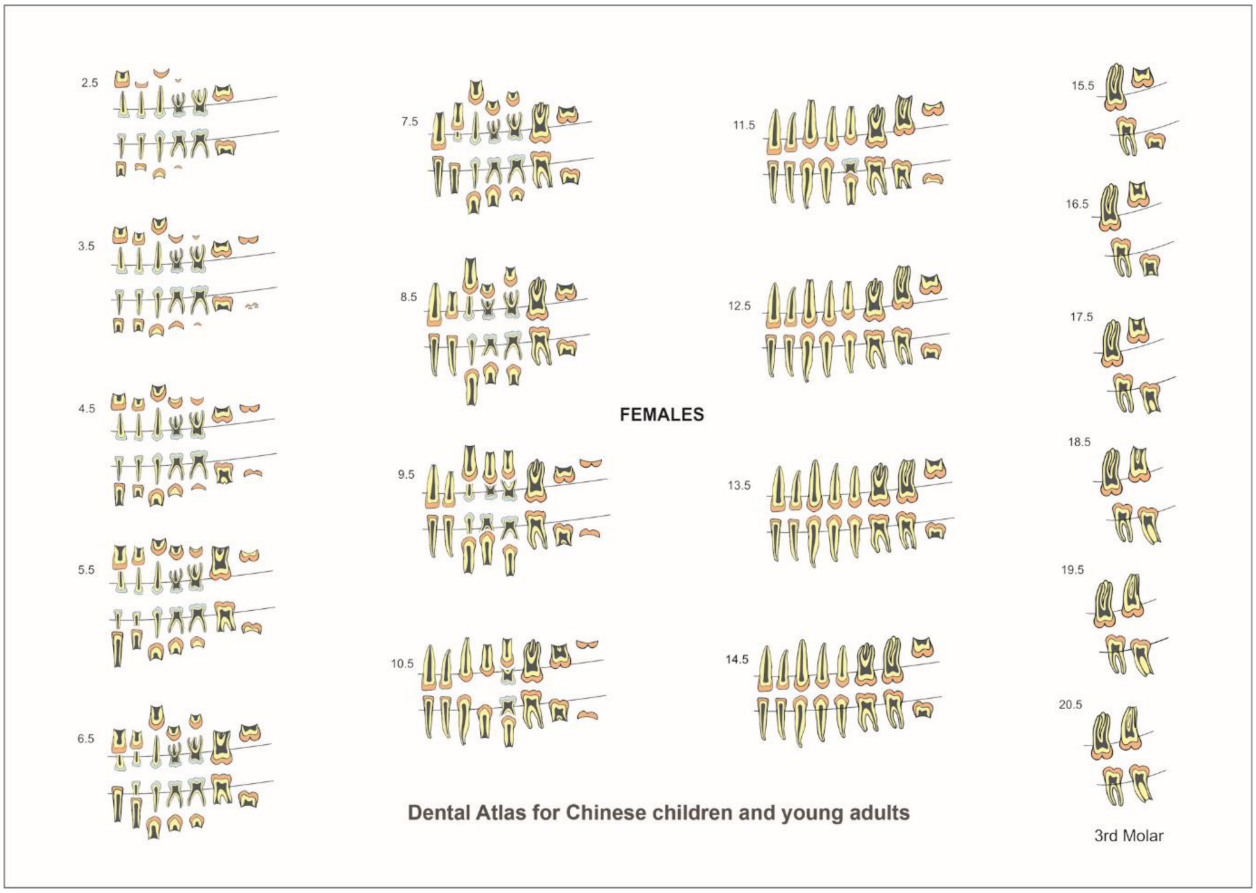


FIGURE 4
Dental atlas for Chinese females based on the formation and eruption of permanent teeth and resorption of primary teeth.

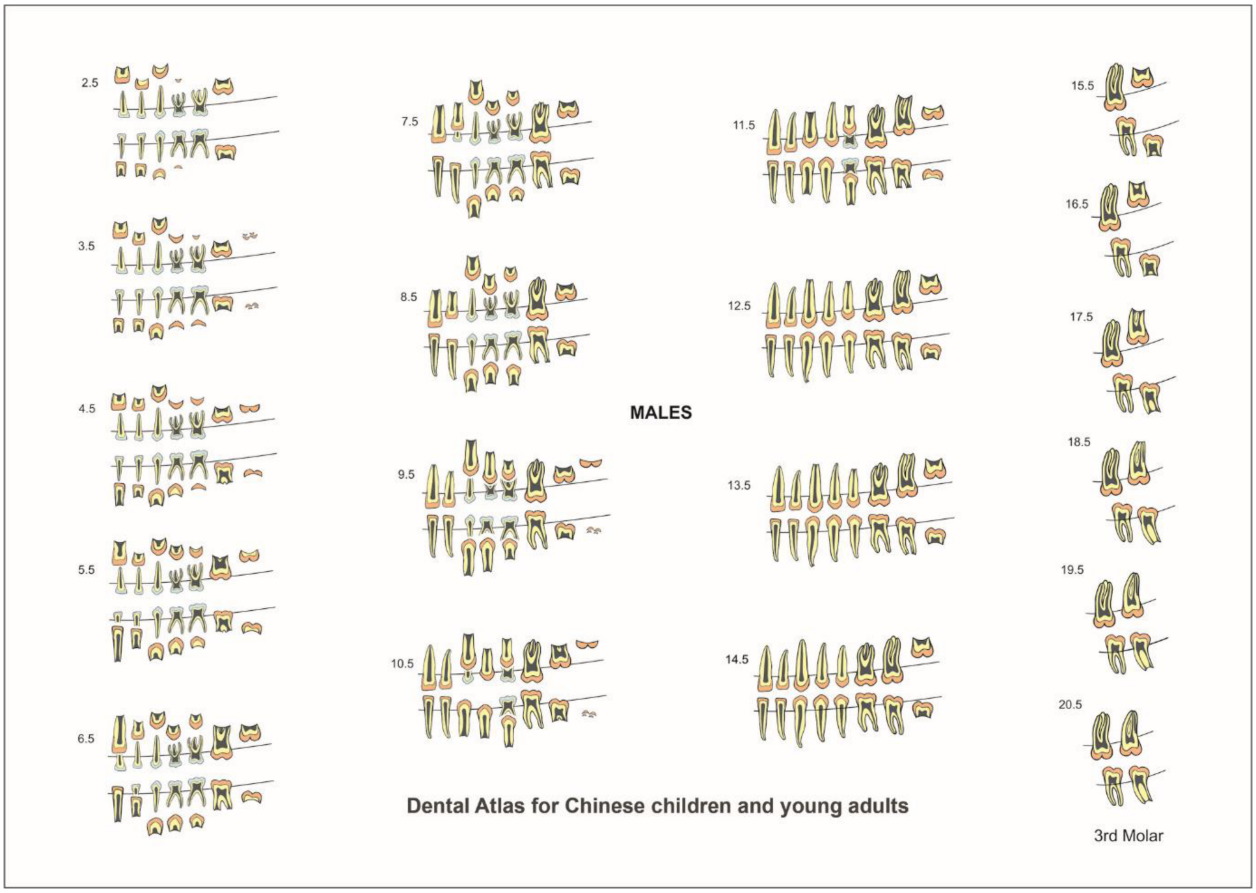


FIGURE 5
Dental atlas for Chinese males based on the formation and eruption of permanent teeth and resorption of primary teeth.

The authors apologize for this error and state that this does not change the scientific conclusions of the article in any way. The original article has been updated.

Publisher's note

frontiers | Frontiers in Pediatrics

TYPE Original Research
PUBLISHED 03 September 2024
DOI 10.3389/fped.2024.1456395

OPEN ACCESS

EDITED BY
Sreekanth Kumar Mallineni,
Tohoku University, Japan

REVIEWED BY
Arlette Setiawan,
Padjadjaran University, Indonesia
Jaya Chandra Bhumireddy,
RIMS Medical College Ongole, India
Merve Erkmen Almaz,
Kırıkkale University, Türkiye
Megha Pradhan,
Kathmandu Medical College Teaching Hospital, Nepal

*CORRESPONDENCE
Mohamad A. Alanbari
✉ mohdanbari91@gmail.com

RECEIVED 28 June 2024
ACCEPTED 21 August 2024
PUBLISHED 03 September 2024

CITATION
Alanbari MA, Hamdan HM, Bawazir OA and Sulimany AM (2024) Association between parental factors and child's behaviors during moderate sedation in pediatric dental care. Front. Pediatr. 12:1456395. doi: 10.3389/fped.2024.1456395

Association between parental factors and child's behaviors during moderate sedation in pediatric dental care

Mohamad A. Alanbari[1,2]*, Hebah M. Hamdan[3], Omar A. Bawazir[1] and Ayman M. Sulimany[1]

[1]Department of Pediatric Dentistry and Orthodontics, College of Dentistry, King Saud University, Riyadh, Saudi Arabia, [2]Pediatric Dentistry Department, Prince Sultan Military Medical City, Riyadh, Saudi Arabia, [3]Department of Periodontics and Community Dentistry, College of Dentistry, King Saud University, Riyadh, Saudi Arabia

Background/Aim: Managing young children with negative behaviors can be challenging in dental settings. Moderate sedation (MS) is often used as a treatment option for such children. However, children's behavior during MS may vary depending on several variables. These variables include parental factors, such as parental anxiety, coping strategies, and pain catastrophizing. However, this area, particularly in Saudi Arabia, remains underexplored. Therefore, this study aimed to assess the association among parental anxiety, coping style, pain catastrophizing, and children's behavior during MS among Saudi children.

Methods: Based on sample size calculation, this cross-sectional observational study included 85 children aged 3–5 years undergoing dental treatment under MS at King Saud University, Riyadh, Saudi Arabia. Parental anxiety, coping styles, and pain catastrophizing were assessed using the Modified Dental Anxiety Scale, Brief Coping Orientation to Problems Experienced Scale, and Pain Catastrophizing Scale. Child behavior was evaluated using the Houpt scale during sedation visits, which was video-recorded and independently analyzed by a single evaluator. Data were analyzed using Pearson's chi-squared test, Mann–Whitney U test, and stepwise multivariate logistic regression analyses.

Results: The results showed no significant association among parental dental anxiety, pain catastrophizing, and child behaviors during MS. Specific parental coping strategies, such as acceptance, were positively associated with positive sedation outcomes ($P = 0.03$), while active coping strategies were linked to less favorable outcomes ($P = 0.03$). Female children had higher sedation failure rates ($P = 0.02$), and the number of dental treatments was positively associated with success rates ($P = 0.03$).

Conclusion: Parental anxiety and pain catastrophizing did not significantly affect the success of sedation. However, acceptance as a coping strategy was significantly associated with sedation success in pediatric dental care under MS, whereas active coping strategies were associated with less favorable outcomes.

KEYWORDS

child behavior, conscious sedation, coping skills, catastrophization, dental anxiety

1 Introduction

The dental care of young children with negative behaviors is challenging, as disruptive behaviors can complicate and prolong routine dental care, thereby requiring extra resources to accomplish effective treatment (1, 2). Children who lack psychological maturity or have unpleasant experiences at dental clinics may be indicated for advanced behavioral guidance techniques (3). In such situations, the use of advanced behavioral guidance techniques, such as moderate sedation (MS), to provide dental rehabilitation can be a valid option (3). The American Academy of Pediatric Dentistry (AAPD) proposes different levels of intended sedation: minimal, moderate, and deep (4). MS is defined as "a drug-induced depression of consciousness during which patients respond purposefully to verbal commands or after light tactile stimulation" (4). MS is an excellent option for reducing fear and anxiety in children, especially when basic behavioral guidance is unsuccessful (3). However, according to Nelson and Xu (5), a number of factors play crucial roles in successful dental rehabilitation under MS (5). During MS, a child's behavior can vary depending on several factors, including medicine and route (6–8), sex (9), age (10, 11), drug regimen (12, 13), and temperament (10, 14). In addition, parental factors, such as anxiety, coping style, and pain catastrophizing, may affect the success of MS (15).

Parental anxiety is positively associated with dental fear and anxiety in children (16, 17). A study conducted in Saudi Arabia on family factors and dental fear found that children of anxious mothers were more fearful than those whose mothers had no dental fear (18). There is a paucity of research on the prevalence of dental anxiety among children in Saudi Arabia (19, 20). Alshuaibi et al. found that 50.4% of boys and 71. 28% of girls in Al Ahsa had high levels of dental anxiety (19). Additionally, another study done in Riyadh revealed that 28.5% of younger individuals and female participants showed increased anxiety levels (20). Dental anxiety and fear are associated with lower oral health-related quality of life in children and oral care neglect, which exacerbates pre-existing dental issues (21, 22). This neglect leads to more complicated and painful treatments and, therefore, worsens the patient's initial anxieties, leading to a cycle of dental care avoidance and worsening of relationships with dental professionals (23–26). Coping strategies are actions that individuals take to deal with the stress, demands, and conflicts in daily life (27). These coping mechanisms are essential for individuals and have a considerable effect on family dynamics, particularly between parents and children. For instance, a study conducted to predict children's responses to invasive medical procedures found an association between parents' coping and distress behaviors and their own coping and distress responses (28). Given the prevalence of dental anxiety in children, understanding the dynamics of parental coping styles is crucial (29). Another factor that demands attention when examining children's behavior during MS in dental settings is parental pain catastrophizing, which is defined as having an exaggerated negative mental set brought to bear during actual or anticipated painful experience (30). It is a multidimensional construct, with several theoretical frameworks explaining its mechanisms (31). Appraisal theory suggests that pain catastrophizing arises from primary appraisals (initial evaluations of stressors) and secondary appraisals (assessments of coping strategies and their potential success) (31). Attention bias theory posits that pain catastrophizers focus excessively on pain-related stimuli, similar to patterns observed in anxiety and depressive disorders (32). This heightened focus aligns with information processing theory, which posits that pain catastrophizing affects how sensory and emotional pain information is processed (31). The communal coping model views pain catastrophizing as a coping strategy to gain emotional or tangible support from others (31, 33). The neural underpinnings of pain catastrophizing involve increased activity in brain regions responsible for processing pain's emotional aspects, such as the anterior cingulate and prefrontal cortex (31). The central nervous system (CNS) mechanisms behind this include changes in processes like enhanced temporal summation and disruptions in the hypothalamic–pituitary–adrenal axis, which exacerbate pain perception (31). Despite extensive research in medical contexts, there is insufficient examination of pain catastrophizing within the dental field. Understanding these mechanisms is crucial, as they can affect how parents perceive and respond to pain, potentially increasing their children's sensitivity to pain and catastrophizing behaviors (34, 35).

De Castro Morais Machado et al. (15) conducted a study in Brazil that examined the effects of specific parental factors, including anxiety, coping style, and parental pain catastrophizing, on the behavior of children during MS. The authors found that parental adaptive coping strategies, specifically acceptance and planning, had a positive effect on the behavior of children with MS. However, parental dental anxiety and pain catastrophizing were not related to MS (15). However, there is a lack of literature evaluating the association between parental factors and the behavior of children during treatment under the standard MS regimen in other societies. Parental factors and its association with child behavior may vary among different cultures and populations. Therefore, this study aimed to evaluate the association between parental anxiety, coping style, and pain catastrophizing and children's behaviors during MS in the Saudi population.

2 Methods

2.1 Ethical approval

This study was approved on December 6, 2022, by the King Saud University (KSU) Institutional Review Board (E-22-7352) and registered at the College of Dentistry Research Center (No. PR 0151), KSU, Riyadh, Saudi Arabia. Informed consent was obtained from the participating parents, including approval for video recording during sedation ensuring transparency and privacy.

2.2 Sample calculation and study population

The G*Power program (version 3.1.9.4) was used to calculate the sample size. With an effect size of 0.325, power of 0.90, and

level of significance of 0.05, the sample size should include at least 83 patients.

The inclusion criteria for this study were Saudi children aged 3–5 years, with American Society of Anesthesiologists (ASA) I physical status as per the ASA classification (36), and displaying negative behavior on the Frankl Rating Scale (37) during screening in the pediatric department at Dental University Hospital (DUH) at KSU, Riyadh, Saudi Arabia. Eligible participants were required to have no more than two dental treatment visits under MS; have parents who could communicate in Arabic and provided consent to their child's participation; meet the MS physical assessment criteria at DUH in KSU in accordance with AAPD (4); possess no prior experience with general anesthesia (GA), deep sedation, or MS related to dental procedures; and not on a GA waiting list. Additionally, children can voluntarily ingest medication without spitting it.

2.3 Study design

This was a cross-sectional observational study of Saudi children who underwent dental treatment for MS between January 2023 and March 2024. This study consisted of two visits, a screening visit and a sedation visit. The screening visit was scheduled at least 1 week before the sedation visit. During the screening visit, a physical assessment was conducted to evaluate the overall health of patients undergoing dental treatment under MS. Subsequently, the questionnaire was distributed to the legal guardians of the children, which consisted of four sections:

(1) Demographic information.

(2) Parental anxiety was assessed using the Arabic version of the Modified Dental Anxiety Scale, which has been validated for assessing dental anxiety (38, 39). This scale assesses anxiety experienced by respondents in response to five different situations faced by patients in the dental clinic: (i) having a dental appointment scheduled for the next day, (ii) being in the waiting area of a dental clinic, (iii) undergoing tooth drilling, (iv) having teeth scaled, and (v) receiving a local anesthetic injection. The total score ranges from 5 to 25 with each question scored using a Likert scale with 5 possible responses: Score 1: not anxious, 2: slightly anxious, 3: fairly anxious, 4: very anxious, and 5: extremely anxious (39). The MDAS has demonstrated good reliability and validity (39).

(3) Parental coping style using the Arabic version of the Brief Coping Orientation to Problems Experienced (Brief COPE), which measures coping strategies, was validated for use in this demographic by Alghamdi (40, 41). This scale comprises 28 items that evaluate how individuals cope with stress in their lives, with each item representing a specific coping strategy, including strategies for dealing with dental problems and noncooperation with their children during dental treatment. Parents were surveyed on their strategies and the frequency of engaging in these behaviors. The scale yields 14 subscale scores, each consisting of two items, covering domains, such as active coping, planning, positive reframing, acceptance, humor, religion, emotional support, instrumental support, self-distraction, denial, venting, substance use, behavioral disengagement, and self-blame. Responses were recorded on a four-point scale.

(4) Pain catastrophizing was assessed using the Arabic version of the Parental Pain Catastrophizing Scale validated by Terkawi et al. (42) to assess pain-related thoughts and feelings (30, 42). This scale contains 13 items and uses a 5-point Likert-type scale (0 = not at all, 1 = to a slight degree, 2 = to a moderate degree, 3 = to a great degree, 4 = all the time) to rank the extent to which parents describe their thoughts and feelings when they are in pain. Higher scores indicate a greater tendency towards pain catastrophizing.

2.4 Sedation visit

Children's health status, vital signs, chest auscultation, and fasting protocols were thoroughly evaluated to ensure safety and suitability for MS prior to the procedure. The patients were orally administered the sedative agent [midazolam 0.7 mg/kg, at a maximum dose of 20 mg (Hikma Midazolam®), Hikma Farmacêutica, Portugal]. The patients were placed in a dental chair after waiting for 10–15 min. A papoose board was used to protect the child, and a nitrous oxide nasal hood was placed over the child's nose at a ratio of 50/50 and lowered downward at the operator's discretion to maintain an optimal level of sedation. The parents were instructed to leave the clinic and wait in the waiting area. The children were monitored according to the AAPD guidelines for monitoring and managing pediatric patients during and after sedation in clinical procedures (4). All dental treatments were provided by pediatric dentistry residents under the supervision of a consultant in pediatric dentistry. After dental treatment, the patients were administered 100% oxygen for a minimum of 5 min and transferred to a recovery room until they were ready for discharge.

Children's behavior was ranked according to the Houpt scale for overall sedation results and intraoperative behavior to evaluate the participants' behavior throughout the sedation process (43). An overall Houpt score of good, very good, or excellent was considered successful sedation, and aborted, poor, or fair was considered failure.

All sedation sessions were recorded using a video camera (Canon HFR 806; Canon Inc., Tokyo, Japan) from the administration of nitrous oxide until the time of nitrous oxide removal, to assess the behavior of the children during the first MS by a single independent evaluator (MA) who was blinded to the scores of parental anxiety, coping scales, and pain catastrophizing. A training session was conducted to calibrate the evaluator and analyze the behaviors recorded during the sedation session. Children's behaviors were assessed consistently by analyzing the videos according to predefined criteria (Houpt scale). Ten videos were rated twice by the same evaluator for the intra-examiner reliability analysis. The kappa test showed that the intra-examiner reliability for the assessment of sedation (overall behavior rating scale) was excellent, with a score of 0.96.

2.5 Statistical analyses

Data were analyzed using SPSS version 20.0 (IBM Corp., Chicago, IL, USA). Descriptive statistical analysis was applied to demographic data. Pearson's chi-squared test was used to examine the association between children's behaviors and categorical variables, specifically age and sex. The Mann–Whitney U test was used to assess the association between children's behaviors and continuous variables, which included the total number of treatments, parental factors, and the duration of sedation. A stepwise multivariate logistic regression model was used to select the best set of variables to assess the effects of parental factors after controlling for possible confounders. Statistical significance was set at $P \leq 0.05$.

3 Results

3.1 Demographics

A total of 85 Saudi children aged 3–5 years and their legal guardians participated in this study. The participants' demographics were closely divided by sex, with 43 (50.59%) girls and 42 (49.41%) boys (Table 1). The age distribution showed a predominance of 5-year-old children, accounting for 44.71% of the participants. Of the 85 participants, 57 (67.06%) were reported to have successful sedation, whereas 28 (32.94%) were considered to have failed sedations. The average number of dental treatments during the sedation visit was 3.64, and the mean duration of sedation was approximately 22.8 min.

3.2 Primary outcomes

The average scores for parental dental anxiety and pain catastrophizing of the participant group were 11.84 ± 4.24 and 16.78 ± 11.46, respectively (Figure 1). Among the various coping strategies utilized by parents, the strategy of planning and active coping were the most favored approaches, with mean scores of 6.34 ± 1.79 and 5.72 ± 1.73, respectively, whereas the least employed coping strategies were denial and substance use, both with mean scores of 2.81 ± 1.27 and 2.81 ± 1.41, respectively.

The results showed no significant association between parental dental anxiety and MS success ($P = 0.28$) or between parental pain catastrophizing and MS success ($P = 0.88$) (Table 2). Regarding coping style, only acceptance demonstrated a statistically significant association with successful sedation outcomes ($P = 0.03$).

TABLE 1 Demographic and treatment characteristics of patients undergoing dental treatment under moderate sedation.

Variables	*N*	%
Sex		
Male	42	49.41
Female	43	50.59
Distribution of children based on age		
3	21	24.70
4	26	30.59
5	38	44.71
Sedation status		
Success	57	67.06
Failure	28	32.94
Variable	**Mean**	**Standard deviation**
Total number of treatments	3.64	1.71
Time of the sedation in minutes	22.8	7.5

3.3 Secondary outcomes

Among child-related factors associated with successful sedation, sex was significantly associated with a higher proportion of sedation failures among females (44.19%) than among males (21.43%) ($P = 0.02$). Age-specific patterns did not show significant differences, indicating that behaviors during sedation were consistent across the 3–5 years age range ($P = 0.50$) (Table 3). The association between treatment-related factors (total number of treatments and time) and sedation success was not significant; however, successful patients received more dental treatments over a longer period.

3.4 Multivariate analysis

The stepwise multiple logistic regression results showed that parents employing acceptance coping strategies had significantly higher odds of having successful sedation compared with others [odds ratio (OR) = 1.77; 95% confidence interval (CI), 1.19–2.63] (Table 4). Conversely, parents applying active coping was significantly associated with a lower likelihood of having successful sedation (OR = 0.64; 95% CI, 0.44–0.95). Additionally, female patients were significantly associated with a lower likelihood of successful sedation (OR = 0.27; 95% CI, 0.09–0.78), whereas the number of treatments provided was positively associated with higher odds of having successful sedation outcome (OR = 1.47; 95% CI, 1.04–2.08).

4 Discussion

Dental treatment of uncooperative children presents considerable challenges for pediatric dentists (44). MS is often employed as a possible option to facilitate dental procedures (3). However, the success of MS is influenced by several factors, including dental (sedation regimen and protocol), childhood (age and sex), and parental factors (15). Given the complexity of parental factors and the limited studies on this topic, this study was conducted to assess the associations among parental dental anxiety, coping styles, and pain catastrophizing in children undergoing dental treatment under MS.

In this study, the results did not show a significant association between parental anxiety and sedation success, which is consistent

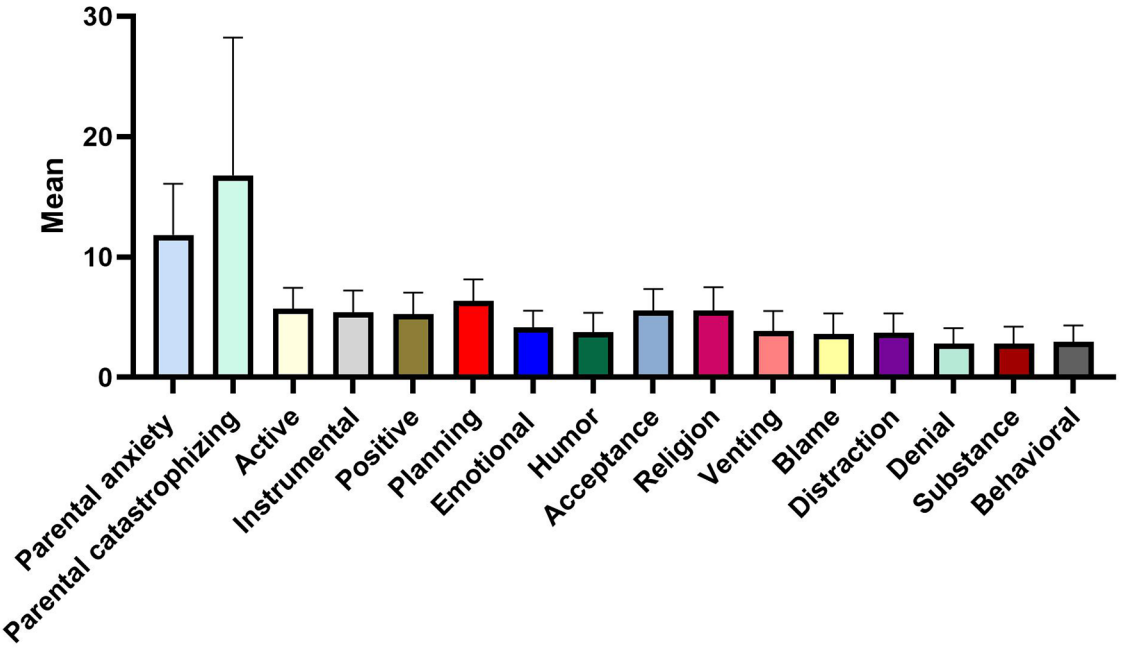


FIGURE 1
Descriptive (parental factors).

TABLE 2 Parent-related factors and their association with sedation status.

Sedation	Success	Failure	*P* value*
	Median [interquartile range (IQR)]	Median (IQR)	
Parental anxiety	11 (6)	11 (9)	0.28
Parental catastrophizing	14 (14)	16.5 (16)	0.88
Acceptance	6 (3.0)	5 (2.0)	0.03
Instrumental support	5 (3.0)	5 (3.5)	0.50
Active	5 (3.0)	6 (3.0)	0.47
Positive reframing	5 (3.0)	5 (2.5)	0.72
Planning	7 (3.0)	6.5 (3.0)	0.39
Emotional support	4 (2.0)	4 (2.0)	0.74
Humor	4 (3.0)	4 (2.0)	0.99
Religion	6 (3.0)	6 (2.0)	0.39
Venting	4 (2.0)	3 (3.0)	0.22
Blame	3 (3.0)	3 (2.0)	0.33
Self-distraction	3 (2.0)	3 (2.5)	0.54
Denial	2 (1.0)	2 (1.5)	0.64
Substance	2 (2.0)	2 (1.5)	0.84
Behavioral disengagement	2 (2.0)	2 (1.0)	0.22

*Calculated using the Mann–Whitney U test.

TABLE 3 Child- and treatment-related factors and their association with sedation status.

Variable	Success	Failure	*P* value
	N (%)	*N* (%)	
Sex			0.02*
Male	33 (78.57)	9 (21.43)	
Female	24 (55.81)	19 (44.19)	
Patients' age			0.50*
3	12 (57.14)	9 (42.86)	
4	19 (73.08)	7 (26.92)	
5	26 (68.42)	12 (31.58)	
Number of treatments	Success	Failure	*P* value
	Median [interquartile range (IQR)]	Median (IQR)	
	4 (3.0)	4 (2.0)	0.10**
Time of the sedation	Success	Failure	*P* value
	Median (IQR)	Median (IQR)	
	24 (8.0)	22 (9.0)	0.12**

*Calculated using the Pearson chi-squared test.
**Calculated using the Mann–Whitney U test.

TABLE 4 Stepwise multiple logistic regression.

Variable	Odds ratio	95% confidence interval	*P* value
Active coping	0.64	(0.44–0.95)	0.03
Acceptance coping	1.77	(1.19–2.63)	0.005
Sex			
Male	Ref	Ref	0.02
Female	0.27	(0.09–0.78)	
Total number of treatments	1.47	(1.04–2.08)	0.03

with the findings of a Brazilian study (15). Previous studies have emphasized the significance of parental anxiety in relation to children's dental fear, pain intensity, and behavior (16–18). This discrepancy may be attributed to the generally low scores of parental dental anxiety reported in this study among the participating parents, indicating that parental anxiety was not a major stressor influencing the child's behavior during MS. Additionally, although parental anxiety may influence the child's

initial response to dental settings, its effect on the child's behavior during sedation may be mediated by other factors.

This study highlights the importance of parental coping techniques in pediatric dental sedation, showing a positive association between acceptance and successful outcomes. This aligns with the results of previous studies suggesting that parents using an acceptance-based approach predict improved behavior in children with MS (15, 45). Acceptance is an emotion-focused coping strategy that aims to alleviate emotional conflicts associated with stressful situations, suggesting its effectiveness in helping children navigate the sedation process more effectively (46). Acceptance as a coping strategy might allow parents to better manage their stress, which in turn creates a calmer environment for the child, helping to reduce the child's anxiety and improve sedation outcomes. Conversely, there is no evidence from prior studies that active coping adversely influences sedation outcomes. The unfavorable influence of active coping methods on successful sedation outcomes found in this study requires further investigation. Although active coping is generally considered helpful in stress management, it may increase the awareness of stressors, potentially leading to unintentional disruptive behavior in children. The effectiveness of coping mechanisms is highly context-dependent, supporting the hypothesis of Lazarus and Folkman (27). Lazarus and Folkman proposed that coping strategies are neither universally effective nor ineffective; instead, their effectiveness depends on the situation in which they are deployed and the individual's appraisal of the situation (27).

This study found no significant association between parental pain catastrophizing and sedation success, similar to the findings of a Brazilian study (15). This could be due to the low incidence of high catastrophizing scores in the sample, suggesting that pain catastrophizing is not a significant factor affecting child's behavior during MS. However, other studies have emphasized its importance in children's health outcomes, especially in the context of chronic pain (34, 35).

The notable role of sex in sedation outcomes, with females exhibiting a higher likelihood of sedation failure than males, is consistent with the results of prior studies demonstrating sex differences in pain perception and behavioral responses to dental procedures (9, 10). Furthermore, evidence suggests that sedation is significantly more successful in male than in female children, underscoring the need for sedation approaches that are responsive to sex-specific characteristics (47, 48). Moreover, clinical trials have shown that males may demonstrate greater sensitivity to specific sedatives or analgesic medications than females (49). This highlights the complexity of sex dynamics in pediatric sedation, suggesting the need for further studies to unravel how sedative pharmacodynamics differ between sexes.

The total number of dental treatments completed during sedation sessions was positively associated with the success of sedation. Successful sedation induces a calm state, reduces disruptive behaviors, and allows dental professionals to provide more dental treatment in one sitting while assuring the child's comfort and minimizing psychological suffering.

In this study, all dental factors influencing MS success were controlled by applying standard sedation protocols and similar doses and routes of administration to all children. In addition, the sex distribution among children was nearly equal, minimizing any bias that could arise from sex imbalances. Additionally, all physical assessments and examinations were performed according to the recommendations of the AAPD guidelines to ensure patient safety and provide optimal treatment conditions. Furthermore, trained examiners assessed child behavior during MS using a reliable scale and video camera to enhance the reliability of the results. However, the findings of this study must be interpreted within the context of its limitations. Conducting the research within a single institution limits the generalizability of the findings. The sample is geographically constrained, which may not account for variations in parental behaviors, coping strategies, and children's responses to sedation across different regions and cultural backgrounds. Therefore, future multi-center studies involving different populations are necessary to validate these findings and provide a more comprehensive understanding of the impact of parental factors on children's behavior during sedation. Additionally, the complexity of behaviors during sedation procedures requires further exploration. Children's reactions to sedation are influenced by multiple factors, including their previous medical experiences, temperament, and even the specific interactions with dental staff on the day of the procedure. Further studies are required to explore other parental factors, such as parental presence in the clinic during sedation. Parental presence might provide comfort and reduce anxiety for some children, while for others, it might cause increased stress or interfere with the dental team's ability to manage the procedure effectively. Investigating the impact of parental presence in future research can offer insights into optimizing sedation practices and improving outcomes. Understanding these dynamics may offer valuable insights for optimizing pediatric dental procedures.

Achieving optimal sedation results in pediatric dentistry requires the recognition that the process is multifactorial, including factors such as parental influence, age of children, children's experiences with medical environments, dental teams, and temperament (50). This suggests that a comprehensive approach that incorporates awareness of these dynamics is essential for improving the effectiveness of sedation and patient outcomes. Promoting acceptance-based coping strategies among parents can have significant practical applications in pediatric dental settings. By encouraging parents to adopt these strategies, dental practitioners can help create a more supportive and calmer environment, which may improve sedation outcomes for children.

5 Conclusion

Parental anxiety and pain catastrophizing were not significantly associated with sedation success. However, acceptance as a coping strategy was the only significant factor positively associated with successful sedation outcomes. Conversely, active coping strategies and female sex were associated with less favorable sedation

outcomes. Dental practitioners should focus on pre-sedation preparation and parental support, particularly teaching acceptance-based coping strategies, to improve sedation outcomes and overall dental care for children.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans was approved on December 6, 2022, by the King Saud University (KSU) Institutional Review Board (E-22-7352) and registered at the College of Dentistry Research Center (No. PR 0151), KSU, Riyadh, Saudi Arabia. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' parents.

Author contributions

MA: Investigation, Methodology, Writing – original draft, Writing – review & editing. HH: Data curation, Formal Analysis, Writing – original draft, Writing – review & editing. OB: Conceptualization, Supervision, Writing – original draft, Writing – review & editing. AS: Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing.

Funding

The authors declare that no financial support was received for the research, authorship, and/or publication of this article.

Acknowledgments

Authors would like to thank the College of Dentistry Research Center and Deanship of Scientific Research at King Saud University, Saudi Arabia for supporting this research project (No. PR 0151). We express our gratitude to all participants who completed the questionnaire and to the supervisor in the sedation clinic for his/her support. We thank the residents and nurses for their work and commitment. We would like to thank Editage (www.editage.com) for English language editing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

1. Corkey B, Freeman R. Predictors of dental anxiety in six-year-old children: findings from a pilot study. *ASDC J Dent Child*. (1994) 61:267–71.

2. Brill WA. Child behavior in a private pediatric dental practice associated with types of visits, age and socio-economic factors. *J Clin Pediatr Dent*. (2000) 25:1–7. doi: 10.17796/jcpd.25.1.545025p1g72×730q

3. American Academy of Pediatric Dentistry. *Behavior Guidance for the Pediatric Dental Patient. the Reference Manual of Pediatric Dentistry*. Chicago, IL: American Academy of Pediatric Dentistry (2023). p. 359–77.

4. Coté CJ, Wilson S. Guidelines for monitoring and management of pediatric patients before, during, and after sedation for diagnostic and therapeutic procedures. *Pediatrics*. (2019) 143:32–3. doi: 10.1542/peds.2019-1000

5. Nelson TM, Xu Z. Pediatric dental sedation: challenges and opportunities. *Clin Cosmet Investig Dent*. (2015) 7:97–106. doi: 10.2147/CCIDE.S64250

6. Torres-Pérez J, Tapia-García I, Rosales-Berber MA, Hernández-Sierra JF, de Pozos-Guillén A. Comparison of three conscious sedation regimens for pediatric dental patients. *J Clin Pediatr Dent*. (2007) 31:183–6. doi: 10.17796/jcpd.31.3.e82526q0432375n0

7. Özen B, Malamed SF, Cetiner S, Özalp N, Özer L, Altun C. Outcomes of moderate sedation in paediatric dental patients. *Aust Dent J*. (2012) 57:144–50. doi: 10.1111/j.1834-7819.2012.01673.x

8. Shaat MA, Bakry NS, Elshafie AM, Talaat DM. Intranasal versus sublingual route of dexmedetomidine sedation in paediatric dentistry: a randomized controlled clinical trial. *Int J Paediatr Dent*. (2022) 32:232–9. doi: 10.1111/ipd.12848

9. Fraone G, Wilson S, Casamassimo PS, Weaver J, Pulido AM. The effect of orally administered midazolam on children of three age groups during restorative dental care. *Pediatr Dent*. (1999) 21:235–41.

10. Quinonez R, Santos RG, Boyar R, Cross H. Temperament and trait anxiety as predictors of child behavior prior to general anesthesia for dental surgery. *Pediatr Dent*. (1997) 19:427–31.

11. Kain ZN, MacLaren J, McClain BC, Saadat H, Wang S-M, Mayes LC, et al. Effects of age and emotionality on the effectiveness of midazolam administered preoperatively to children. *Anesthesiology*. (2007) 107:545–52. doi: 10.1097/01.anes.0000281895.81168.c3

12. Shapira J, Kupietzky A, Kadari A, Fuks AB, Holan G. Comparison of oral midazolam with and without hydroxyzine in the sedation of pediatric dental patients. *Pediatr Dent*. (2004) 26:492–6.

13. Chowdhury J, Vargas KG. Comparison of chloral hydrate, meperidine, and hydroxyzine to midazolam regimens for oral sedation of pediatric dental patients. *Pediatr Dent*. (2005) 27:191–7.

14. Isik B, Baygin O, Kapci EG, Bodur H. The effects of temperament and behaviour problems on sedation failure in anxious children after midazolam premedication. *Eur J Anaesthesiol*. (2010) 27:336–40. doi: 10.1097/EJA.0b013e32833111b2

15. De Castro Morais Machado G, Van Wijk A, Van Der Heijden G, Costa LR. Does parental anxiety, coping, and pain catastrophizing influence child behavior during sedation? *Pediatr Dent*. (2018) 40:365–9.

16. Peretz B, Nazarian Y, Bimstein E. Dental anxiety in a students' paediatric dental clinic: children, parents and students. *Int J Paediatr Dent*. (2004) 14:192–8. doi: 10.1111/j.1365-263X.2004.00545.x

17. Karibe H, Aoyagi-Naka K, Koda A. Maternal anxiety and child fear during dental procedures: a preliminary study. *J Dent Child (Chic)*. (2014) 81:72–7.

18. Felemban OM, Alshoraim MA, El-Housseiny AA, Farsi NM. Effects of familial characteristics on dental fear: a cross-sectional study. *J Contemp Dent Pract*. (2019) 20:610–5. doi: 10.5005/jp-journals-10024-2567

19. Alshuaibi AF, Aldarwish M, Almulhim AN, Lele GS, Sanikommu S, Raghunath RG. Prevalence of dental fear and anxiety and its triggering factors in the dental office among school-going children in Al Ahsa. *Int J Clin Pediatr Dent*. (2021) 14:286–92. doi: 10.5005/jp-journals-10005-1925

20. Ashraf MFK, Al-Harbi A, Al-Otaibi F, Al-Qahtani F, Al-Garni A. Dental anxiety at Riyadh Elm University Clinics. *Saudi J Oral Sci*. (2019) 6:101–12. doi: 10.4103/sjos.sjoralsci_33_19

21. Oba AA, Dülgergil CT, Sönmez IS. Prevalence of dental anxiety in 7- to 11-year-old children and its relationship to dental caries. *Med Princ Pract*. (2009) 18:453–7. doi: 10.1159/000235894

22. Winkler CH, Bjelopavlovic M, Lehmann KM, Petrowski K, Irmscher L, Berth H. Impact of dental anxiety on dental care routine and oral-health-related quality of life in a German adult population—a cross-sectional study. *J Clin Med*. (2023) 12:5291. doi: 10.3390/jcm12165291

23. Sohn W, Ismail AI. Regular dental visits and dental anxiety in an adult dentate population. *J Am Dent Assoc*. (2005) 136:58–66; quiz 90. doi: 10.14219/jada.archive.2005.0027

24. Appukuttan DP. Strategies to manage patients with dental anxiety and dental phobia: literature review. *Clin Cosmet Investig Dent*. (2016) 8:35–50. doi: 10.2147/CCIDE.S63626

25. Sukumaran I, Taylor S, Thomson WM. The prevalence and impact of dental anxiety among adult New Zealanders. *Int Dent J*. (2020) 71:122–6. doi: 10.1111/idj.12613

26. Hassan BH, Abd El Moniem MM, Dawood SS, Alsultan AA, Abdelhafez AI, Elsakhy NM. Dental anxiety and oral health-related quality of life among rural community-dwelling older adults. *Int J Environ Res Public Health*. (2022) 19:7643. doi: 10.3390/ijerph19137643

27. Lazarus SR, Folkman S. *Stress, Appraisal, and Coping*. New York: Springer (1984).

28. Salmon K, Pereira JK. Predicting children's response to an invasive medical investigation: the influence of effortful control and parent behavior. *J Pediatr Psychol*. (2002) 27:227–33. doi: 10.1093/jpepsy/27.3.227

29. Fayad MI, Elbieh A, Baig MN, Alruwaili SA. Prevalence of dental anxiety among dental patients in Saudi Arabia. *J Int Soc Prev Community Dent*. (2017) 7:100–4. doi: 10.4103/jispcd.JISPCD_19_17

30. Sullivan MJL, Bishop SR, Pivik J. The pain catastrophizing scale: development and validation. *Psychol Assess*. (1995) 7:524–32. doi: 10.1037/1040-3590.7.4.524

31. Quartana PJ, Campbell CM, Edwards RR. Pain catastrophizing a critical review. *Exp Rev Neurother*. (2009) 9:745–58. doi: 10.1586/ern.09.34

32. Eccleston C, Crombez G. Pain demands attention: a cognitive-affective model of the interruptive function of pain. *Psychol Bull*. (1999) 125:356–66. doi: 10.1037/0033-2909.125.3.356

33. Sullivan MJL, Thorn B, Haythornthwaite JA, Keefe F, Martin M, Bradley LA, et al. Theoretical perspectives on the relation between catastrophizing and pain. *Clin J Pain*. (2001) 17:52–64. doi: 10.1097/00002508-200103000-00008

34. Lynch-Jordan AM, Kashikar-Zuck S, Goldschneider KR. Parent perceptions of adolescent pain expression: the adolescent pain behavior questionnaire. *Pain*. (2010) 151:834–42. doi: 10.1016/j.pain.2010.09.025

35. Lynch-Jordan AM, Kashikar-Zuck S, Szabova A, Goldschneider KR. The interplay of parent and adolescent catastrophizing and its impact on adolescents' pain, functioning, and pain behavior. *Clin J Pain*. (2013) 29:681–8. doi: 10.1097/AJP.0b013e3182757720

36. Doyle DJ, Hendrix JM, Garmon EH. American Society of anesthesiologists classification. In: Garmon EH, editor. *StatPearls*. Treasure Island, FL: StatPearls Publishing (2022). [updated 2022 Dec 4]. Available online at: https://www.ncbi.nlm.nih.gov/books/NBK441940/

37. Frankl S, Shiere F, Fogels H. Should the parent remain with the child in the dental operatory? *J Dent Child*. (1962) 29:150–63.

38. Abu-Ghazaleh SB, Rajab LD, Sonbol HN, Aljafari AK, Elkarmi RF, Humphris G. The Arabic version of the modified dental anxiety scale. Psychometrics and normative data for 15–16 year olds. *Saudi Med J* (2011) 32:725–9

39. Humphris GM, Morrison T, Lindsay SJ. The modified dental anxiety scale: validation and United Kingdom norms. *Community Dent Health*. (1995) 12:143–50.

40. Alghamdi M. Cross-cultural validation and psychometric properties of the Arabic brief cope in Saudi population. *Med J Malaysia*. (2020) 75:502–9.

41. Carver CS. You want to measure coping but your protocol's too long: consider the brief cope. *Int J Behav Med*. (1997) 4:92–100. doi: 10.1207/s15327558ijbm0401_6

42. Terkawi AS, Sullivan M, Abolkhair A, Al-Zhahrani T, Terkawi RS, Alasfar EM, et al. Development and validation of Arabic version of the pain catastrophizing scale. *Saudi J Anaesth*. (2017) 11:S63–70. doi: 10.4103/sja.SJA_130_17

43. Houpt MI, Weiss NJ, Koenigsberg SR, Desjardins PJ. Comparison of chloral hydrate with and without promethazine in the sedation of young children. *Pediatr Dent*. (1985) 7:41–6.

44. Blitz M, Britton KC. Management of the uncooperative child. *Oral Maxillofac Surg Clin North Am*. (2010) 22:461–9. doi: 10.1016/j.coms.2010.08.002

45. Schnider KR, Elhai JD, Gray MJ. Coping style use predicts posttraumatic stress and complicated grief symptom severity among college students reporting a traumatic loss. *J Couns Psychol*. (2007) 54:344–50. doi: 10.1037/0022-0167.54.3.344

46. Carver CS, Scheier MF, Weintraub JK. Assessing coping strategies: a theoretically based approach. *J Pers Soc Psychol*. (1989) 56:267–83. doi: 10.1037/0022-3514.56.2.267

47. Tsinidou KG, Curzon MEJ, Sapsford DJ. A study to compare the effectiveness of temazepam and a chloral hydrate/hydroxyzine combination in sedating paediatric dental patients. *Int J Paediatr Dent*. (1992) 2:163–9. doi: 10.1111/j.1365-263X.1992.tb00030.x

48. Needleman HL, Joshi A, Griffith DG. Conscious sedation of pediatric dental patients using chloral hydrate, hydroxyzine, and nitrous oxide—a retrospective study of 382 sedations. *Pediatr Dent*. (1995) 17:424–31.

49. De Kock MF, Pichon G, Scholtes JL. Intraoperative clonidine enhances postoperative morphine patient-controlled analgesia. *Can J Anaesth*. (1992) 39:537–44. doi: 10.1007/BF03008314

50. Wilson S. *Oral sedation for dental procedures in children*. Berlin. Springer. (2015). doi: 10.1007/978-3-662-46626-1

frontiers | Frontiers in Dental Medicine

TYPE Case Report
PUBLISHED 17 October 2024
DOI 10.3389/fdmed.2024.1481658

OPEN ACCESS

EDITED BY
Sreekanth Kumar Mallineni,
Dr Sulaiman Al Habib Hospital, Saudi Arabia

REVIEWED BY
Alessandro Venditti,
University of Rome Tor Vergata, Italy
Abdulaziz Alsaif,
King Saud University, Saudi Arabia

*CORRESPONDENCE
Yuriko Maruya
yuriko.maruya.c1@tohoku.ac.jp

RECEIVED 16 August 2024
ACCEPTED 01 October 2024
PUBLISHED 17 October 2024

CITATION
Hino R, Chiba Y, Maruya Y, Tadano M, Otake S, Hoshikawa S, Sasahara Y and Saito K (2024) Case Report: Dental treatment under general anesthesia and dental management of a child with congenital ichthyosis.
Front. Dent. Med 5:1481658.
doi: 10.3389/fdmed.2024.1481658

Case Report: Dental treatment under general anesthesia and dental management of a child with congenital ichthyosis

Ryoko Hino[1], Yuta Chiba[1], Yuriko Maruya[1]*, Manami Tadano[1], Shinji Otake[1], Seira Hoshikawa[1], Yoji Sasahara[2] and Kan Saito[1]

[1]Division of Pediatric Dentistry, Department of Oral Health and Development Sciences, Tohoku University Graduate School of Dentistry, Sendai, Japan, [2]Department of Pediatrics, Tohoku University Graduate School of Medicine, Sendai, Japan

Congenital ichthyosis is a disease in which the stratum corneum on the surface of the skin becomes thick from the time of the fetus and the barrier function of the skin is impaired. Congenital ichthyosis is a genetic disorder that causes ectodermal abnormalities and sometimes affects skin, nails, and tooth enamel. Therefore, some patients require special care in their daily life and during dental treatments. Here, the authors report a case of congenital ichthyosis that developed into severe dental caries at two years and nine months of age. The authors performed whole-exome sequencing in his peripheral blood and found that the patient had compound heterozygous mutations in ALOX12B gene (c.159C>G and c.1579G>A), which is responsible for autosomal recessive congenital ichthyosis-2 (MIM#2421000). Mutation of c.159C>G is a nonsense mutation that has never been reported, therefore novel symptoms might have found. The patients exhibited severe caries by hypoplastic teeth. Here, the authors report the treatment of dental caries in a patient with congenital ichthyosis under general anesthesia and its oral management until mixed dentition.

KEYWORDS

congenital ichthyosis, pediatric dentistry, enamel hypoplasia, genetic disorder, caries treatment, general anesthesia

1 Introduction

Congenital ichthyosis is a rare genetic skin disorder that exhibits hereditary patterns, such as autosomal recessive, autosomal dominant, X-linked recessive, and X-linked dominant (1). It is caused by abnormal differentiation of epidermal cells and abnormal production, metabolism, and transport of lipids (2). As a result, they affect the barrier function of the skin and the stratum corneum thickens remarkably. Generally, the prognosis of this disorder is good; however, in severe cases, eyelids and lips roll up, and malformation of the auricle is observed, which leads to death in the newborn and infancy (1–3). The children suffering congenital ichthyosis have difficulty in the control of body temperature because of skin dyskeratosis and dyshidrosis and easily develops hyperthermia when the patients cry (2, 4). Therefore, dental treatment for young non-cooperative patients with congenital ichthyosis may have difficulty, and in such case dental treatment under general anesthesia would be one of the treatment plans (5). Congenital ichthyosis includes the following 4 classifications: (i) Keratinolytic ichthyosis including bullous congenital ichthyosiform erythroderma (BCIE), (ii) Harlequin

ichthyosis, (iii) Autosomal recessive congenital ichthyosis (ARCI) including nonbullous congenital ichthyosiform erythroderma) and lamellar ichthyosis, and (iv) Ichthyosis syndrome with other organ symptoms (IS). The total number of patients with BCIE was estimated to be 55 (4), and only 220 patients are reported to have been treated for ARCI and IS in Japan (6). Thus, congenital ichthyosis is rare. The genes responsible for this disease are *transglutaminase 1* (TGM1), *arachidonate 12-lipoxygenase, 12R type* (ALOX12B), *cytochrome P450 family 4 subfamily F member 22*, *ATP binding cassette subfamily A member 12* (ABCA12), *arachidonate lipoxygenase 3*, and *NIPA like domain containing 4* (NIPAL4) (7–10). The symptoms vary depending on the type of gene mutation. Recently, systemic symptoms including dermatological and ophthalmological defects have gained attention (5, 11). Although protrusion of the lips, an open mouth, and anomalies of the teeth are observed as oral findings (12), oral and dental evaluations are still not well-investigated. Here, the authors report the case of a 2 years and 6 months-old boy with congenital ichthyosis induced by genetic mutations in ALOX12B, who underwent dental treatment under general anesthesia. The case showed severe dental caries and noncooperative behavior because of his young age and intellectual disability, and the authors conducted dental treatment under general anesthesia and obtained good prognosis.

2 Case report

The patient was a Japanese boy with a history of congenital ichthyosis syndrome. He was born at 37 weeks of gestation, and his birth weight and height were 2,562 g and 46.0 cm, respectively. The patient's skin exhibited severe inflammation and scaling. He was diagnosed with suspected Netherton syndrome, and had normal psychomotor development. At 1 year and 7 months of age, he was infected with rotavirus and developed epilepsy, dysphagia, psychomotor developmental delay, cortical blindness, and quadriplegia as aftereffects. In addition, he was allergic to eggs, fish eggs, wheat, soy, and dairy products. Hence, he took four anticonvulsants, four antiallergic agents, a levocarnitine preparation, and a steroid ointment. He had a history of general anesthesia during inguinal hernia surgery at the age of 2 years and cryptorchidism surgery at the age of 2 years and 8 months. After surgery, he developed fever, and discharge was postponed. The patient was one of the fraternal twins. His younger brother was a typical developer, whose congenitally missing teeth were pointed out during a dental health checkup at 2 years and 6 months of age. However, the patient could not undergo a dental health check-up at 2 years and 6 months of age. Instead of undergoing a dental health check-up, he underwent a dental check-up at a dental clinic in a nursing care center, and the dentist pointed out his severe dental caries. At the age of 2 years and 9 months, he was referred to the Pediatric Dental Clinic of Tohoku University Hospital for dental treatment under general anesthesia.

At the first visit, the patient was 78 cm in height (< −3SD) and 9.08 kg in weight (< −3SD). He had flares, scales, dry skin throughout whole body, and a yellow nail on his thumb. The patient was unable to walk independently and used a wheelchair. An oral examination revealed cloudiness and severe caries in the primary teeth. The patient had poor oral hygiene, gingivitis, gingival swelling, xerochilia, and a tongue coat (Figure 1A). In addition, his skin was overstretched and sensitive. He was unable to understand the requirements for dental treatment and declared against dental treatment. The authors discussed this with his parents and decided that his dental treatment would be best provided under general anesthesia. Due to his skin condition, he was at risk of worsening overall status after general anesthesia. Considering this risk, the authors decided to treat him in three settings of general anesthesia for shorter time per treatment. Before starting dental treatment, the patient was checked by a pediatrician, dermatologist, and anesthesiologist to clarify his medical status for general anesthesia. In addition, the authors requested that a pediatrician perform a medical examination before and after general anesthesia.

The authors made the diagnosis using dental radiographs (Figure 1B) and divided them into three blocks for treatment. The first treatment was provided when the patient was three years and two months old, and the second treatment was provided six weeks later. At the age of 3 years 5 months, he was admitted to a nursing center for pneumonia, and the third treatment was postponed. Finally, at the age of 3 years and 8 months, the third treatment was administered. Caries of the maxillary right first primary molar, maxillary right primary canine, and maxillary right primary lateral incisor were diagnosed after reaching the pulp. The carious lesion was excavated and the pulp was removed using H-files with frequent irrigation using oxygenated water and 3% sodium hypochlorite. Canals were dried with cotton plugs and obturated with calcium hydroxide preparation (Vitapex®, Neo Dental Chemical Products Co. Ltd.). Strip crowns (3M ESPE) were used for all the anterior teeth, and prefabricated stainless-steel crowns (3M ESPE) were cemented on the upper and lower bilateral first primary molars because the risk of caries was high. The upper and lower bilateral second primary molars had erupted and were restored with a composite resin because their caries were mild. All dental procedures were completed without any complications, and each operation took approximately 2 h. After treatment, the patient recovered uneventfully from the general anesthesia. The final diagnoses and treatment details are listed in Supplementary Table S1. The patient was discharged the day after general examination. Subsequently, the patient is undergoing monthly follow-up for high caries risk and difficulty in oral care. The gingivitis improved with periodic management. In addition, no caries was found, and the oral condition was much better than that before treatment at 4 years and 7 months of age (Figure 2).

After the topical application of fluoride using 2% acidulated phosphate fluoride (APF) solution, Fluor Dental Jelly 2%® (Bee Brand Medico Dental Co. Ltd.), the patient's skin around the left corner of the mouth became rough. The authors believe that the cause was hypersalivation after fluoride application and that the acidic solution affected the skin. The authors

10.3389/fdmed.2024.1481658

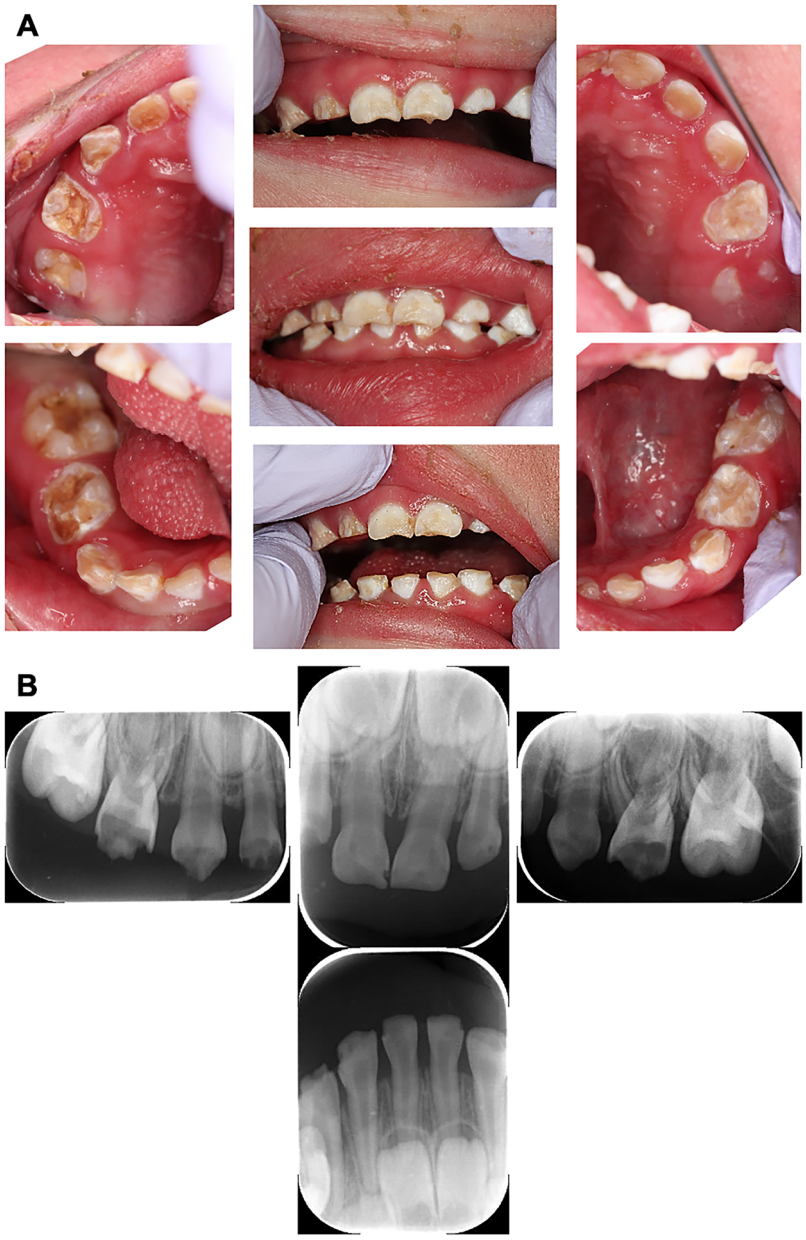


FIGURE 1
Intraoral and dental x-ray photographs at the initial examination (2 years and 9 months-old). **(A)** Intraoral photographs at the initial dental examination. Teeth showed numerous opaque white and brown discolourations and defects, diagnosed as multiple severe caries. **(B)** Pre-treatment dental x-ray image. The mandibular molars were not able to be photographed because the cooperation status of the patient had deteriorated.

switched from 2% APF to the neutral type fluoride, Butler fluodent foam N® (Sunstar Inc.). After switching the fluoride application, the patient's skin condition improved. At 4 years 5 months-old, the patient had white and bumpy lesions on his inner cheeks and gums. On suspicion of candidiasis, an antifungal antibiotic syrup was prescribed to the patient by a pediatrician, and the symptoms resolved. The patient had no caries, and the gingival condition was good after teeth treatments. During the dental checkup at 5 years and 10 months of age, the authors found that the lower primary central incisor showed severe mobility because of the exfoliation period of the deciduous teeth. The patient was at risk of aspiration of the exfoliated teeth, which were removed. The permanent central incisors erupted without complications after four months (Figure 3A). At this time, dental x-ray image was taken for examination and there was no delay in the eruption of permanent teeth or dental caries. (Figure 3B) Since then, the authors have continued to maintain his teeth until mixed dentition, and he has no cavities (Figure 4A). Furthermore, pulpectomy-treated teeth was exfoliated as normally and permanent teeth were erupted (Figures 4B,C).

FIGURE 2
Intraoral photographs at post-treatment (4 years and 7 months old). The patient underwent dental treatment three-times under general anesthesia.

3 Discussion

The genes responsible for congenital ichthyosis depend on the type of disease, and recent studies have revealed many etiological genes such as Keratin1 (K1), K2, K10, TGM1, ABCA12, ALOX12B, and NIPAL4 (7, 8, 13). During the early stage of the present case, Netherton syndrome was suspected as a candidate disease. Netherton syndrome is characterized by congenital ichthyosis-like erythroderma, and almost all patients develop atopic dermatitis or asthma as immune disorders (14). The syndrome also presents systemic symptoms such as growth disorders, aminoaciduria, infectivity, poor body temperature regulation, and dehydration (15). Mutations in *serine peptidase inhibitor Kazal type 5* (SPINK5) gene have been identified in genetic diagnosis (16). Since Netherton syndrome was suspected at the age of 2 years and 8 months, the SPINK5 gene mutation was tested by DNA-sequence. However, no mutation of SPINK5 gene was observed in the coding region. Therefore, the gene mutation in this patient was unclear during this period. Owing to recent advances in genetic analysis, whole-exome sequencing has become available to search for genetic mutations in human patients. Whole exome sequencing was performed at 7 years and 1 month of age. Two mutations in ALOX12B gene (c.1579G>A, p.Val527Met and c.159C>G, p.Try53*) were identified as candidates. Previously, only one case of c.1579G>A and p.Val527Met mutations was reported in China (17). However, c.159C>G, p.Try53* mutation has not been reported. This mutation results in a termination codon and stop-gain amino acids in exon 2. Generally, mutations in ALOX12B are not severe but cause congenital ichthyosiform erythroderma and a kink in the ear helix (9, 18–20). The novel mutation (c.159C>G, p.Try53*) is not synthesized after the 53rd amino acid, which may have caused severe conditions such as epilepsy, tetraplegia, and easy infection. Further studies of this mutation are required to clarify the pathogenesis of congenital ichthyosis.

Several genetic disorders in skin show enamel hypoplasia (21, 22). This is because that skin and teeth are both ectodermal derived organs and have similarity in preferentially expressed genes (23–25). While, there are few detailed reports on the oral symptoms of congenital ichthyosis, and the direct effects of the genes responsible for congenital ichthyosis in teeth are unknown. In some cases, teeth develop normally; however, some patients may have defective teeth and are likely to develop caries. In fact, patients with congenital nonbullous ichthyosiform erythroderma present with corneal involvement, hypotrichosis, anhidrosis, nail hyperkeratosis, and dental dysplasia (26). There are other reports of oral and dental findings in persons with ichthyosis, including gingivitis, periodontitis, enamel hypoplasia, delayed primary and secondary eruptions, bruxism, alveolar ridging, bifid teeth, irregular tooth morphology, hyperkeratotic plaques on the tongue, squamous cell carcinoma, mouth breathing, and xerostomia (3, 26, 27). Although the role of ALOX12B during tooth development have not reported yet, the nonsense mutation of this gene might result in severe phenotype and this patient may also have had hypoplastic teeth. Moreover, the patient easily develops hyperthermia because of skin dyskeratosis and dyshidrosis. In particular, in the summer, attention should be paid to an abnormal rise in body temperature, the patient needs to properly hydrate, and adjust the room temperature and clothing. The patient was consuming ionic beverages to prevent dehydration, and the uptake of ionic beverages seemed to have made the patient's caries more severe.

This patient has received medical treatment at multiple hospitals and departments. Before dental treatment under general anesthesia, the authors consulted each doctor about the previous general anesthesia situation, condition, and considerations. The authors confirmed the following points: (i) Regarding epileptic seizure, the

10.3389/fdmed.2024.1481658

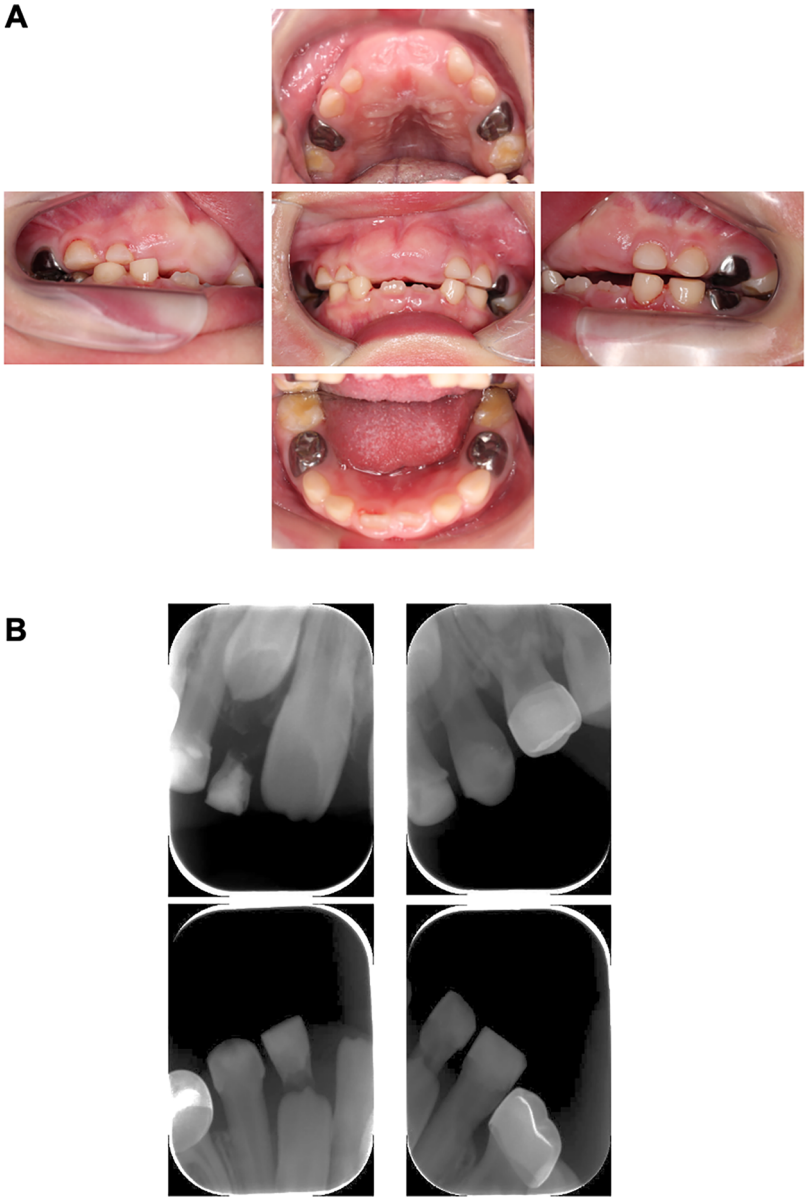


FIGURE 3
Intraoral and dental x-ray photographs at the time of periodic medical check-ups (6 years and 2 months old). **(A)** Intraoral photographs at the time of periodic medical check-up at 6 years and 2 months-old. The lower central incisors have erupted. **(B)** Dental x-ray image at the time of periodic medical check-up at 6 years and 2 months-old.

patient had several stiffnesses with deviation for a few minutes per day. If the patient experienced an epileptic seizure after general anesthesia, the doctor suggested the use of diazepam or dormicum for treatment. (ii) Regarding tube feeding, before beginning the treatment, the patient was introduced to tube feeding for rehydration 1–2 times a day. If the patient could receive fluids through intravenous drops, the doctor suggested to allow him to take anything orally after surgery. Consequently, the patient was given thickened and soft food because of dysphagia. (iii) Regarding skin condition, the doctor suggested using an ointment and moisturizer until the day before surgery. This prevents skin peeling and blistering by fixing the airway tube with medical tape during surgery. However, the use of tape should be minimized. Additionally, the authors commissioned a pediatrician to visit the patient before and after surgery. The patient was discharged without any complications.

During dental maintenance after surgery, the patient experienced some trouble in the mouth, depending on the immune status of the whole body. The patient's skin around the mouth became rough with 2% APF. A less stimulating fluoride preparation should be used and the excess liquid should be wiped off with a gauze after application. During dental treatment, attention should be paid to the skin surrounding the mouth. The patient was prescribed an antifungal antibiotic syrup on suspicion of oral candidiasis. Originally, the patient had a nail abnormality with a yellow nail only on the thumb. Protracted candidiasis causes the nail color to

10.3389/fdmed.2024.1481658

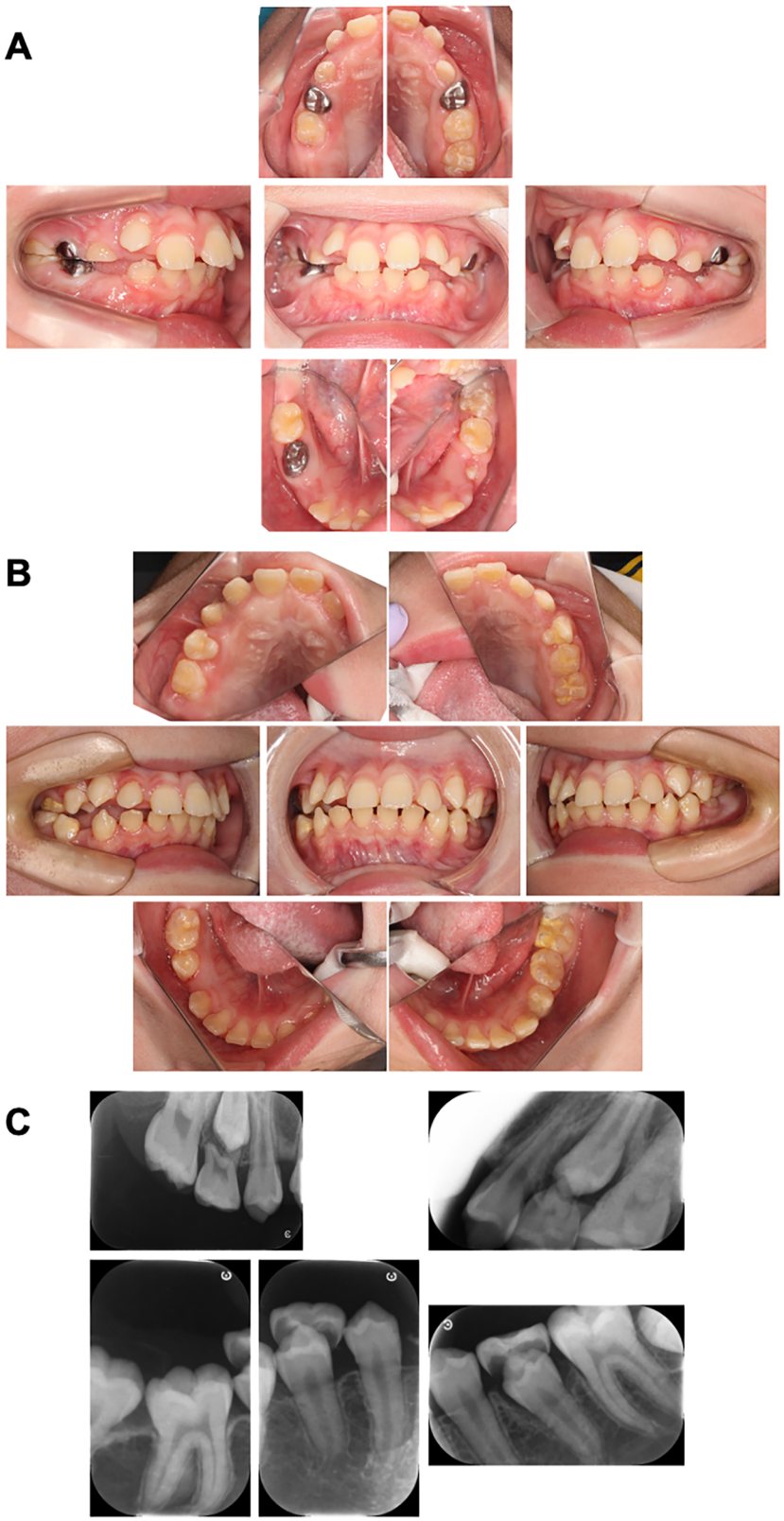


FIGURE 4
Intraoral photographs at the time of periodic medical check-ups. **(A)** Intraoral photographs at the time of periodic medical check-up at 9 years and 6 months-old. There are no caries and the oral hygiene was improved in this case. **(B)** Intraoral photographs at the time of periodic medical check-up at 11 years and 10 months-old. The primary first molars were replaced with permanent teeth. **(C)** Dental x-ray image at the time of periodic medical check-up at 11 years and 10 months-old.

turn yellow or white, resulting in onycholysis. The patient showed an increase in yellow nails and frequent peeling of the nails after oral candida administration (Supplementary Figure S1). These two symptoms may be related. This patient could not sleep because of laughter seizures at night and had an irregular life rhythm. Furthermore, the patient was often hospitalized because of hypothermia. The authors always considered contacting doctors about changes in his general condition. This disorder requires cooperation from medical specialists and early dental intervention because the symptoms persist throughout life in many cases. In addition, regular oral care and prevention of caries after dental treatment are critical. In this case, there were no caries and the gingival condition was good after teeth treatments. Therefore, proper maintenance should be provided to the patients.

4 Conclusion

In this report, the authors present the case of a pediatric patient with congenital ichthyosis who maintained good oral condition after dental treatment under general anesthesia. The case showed noncooperative behavior because of his young age and intellectual disability. For this reason, the case had the risk of hyperthermia during treatment because of congenital ichthyosis and the authors conducted dental treatment under general anesthesia. Medical examination and advise for dental treatment were provided by medical doctor before the treatment and the caries treatments were provided under three times of general anesthesia for shorter time per treatment. Cooperation with other medical specialists, early intervention by dentists, appropriate oral care, and prevention of caries are important for patients with congenital ichthyosis.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Tohoku University Hospital Ethics Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

RH: Conceptualization, Data curation, Formal Analysis, Investigation, Visualization, Writing – original draft, Writing – review & editing. YC: Formal Analysis, Investigation, Visualization, Writing – original draft, Writing – review & editing. YM: Conceptualization, Supervision, Validation, Writing – original draft, Writing – review & editing. MT: Data curation, Validation, Writing – original draft, Writing – review & editing. SO: Data curation, Investigation, Writing – original draft, Writing – review & editing. SH: Data curation, Investigation, Writing – original draft, Writing – review & editing. YS: Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing. KS: Conceptualization, Funding acquisition, Project administration, Supervision, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This work was supported by JSPS KAKENHI JP23K27799 to KS, JP23K16195 to MT, JP24K23606 to SO.

Acknowledgments

We thank Editage (https://www.editage.jp) for English language correction.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fdmed.2024.1481658/full#supplementary-material

References

1. Rodríguez-Pazos L, Ginarte M, Vega A, Toribio J. Autosomal recessive congenital ichthyosis. *Actas Dermosifiliogr*. (2013) 104(4):270–84. doi: 10.1016/j.ad.2011.11.015

2. Elias PM, Williams ML, Feingold KR. Abnormal barrier function in the pathogenesis of ichthyosis: therapeutic implications for lipid metabolic disorders. *Clin Dermatol*. (2012) 30(3):311–22. doi: 10.1016/j.clindermatol.2011.08.017

3. Nair K, Kodhandram GS. Oral manifestations of lamellar ichthyosis: a rare case report. *Indian J Paediatr Dermatol*. (2016) 17:283. doi: 10.4103/2319-7250.184428

4. Kurosawa M, Takagi A, Tamakoshi A, Kawamura T, Inaba Y, Yokoyama K, et al. Epidemiology and clinical characteristics of bullous congenital ichthyosiform erythroderma (keratinolytic ichthyosis) in Japan: results from a nationwide survey. *J Am Acad Dermatol*. (2013) 68(2):278–83. doi: 10.1016/j.jaad.2012.06.044

5. Derelioglu SS, Yılmaz Y, Keles S. Dental treatments under the general anesthesia in a child with keratitis, ichthyosis, and deafness syndrome. *Case Rep Dent*. (2013) 2013:618468. doi: 10.1155/2013/618468

6. Kurosawa M, Uehara R, Takagi A, Aoyama Y, Iwatsuki K, Amagai M, et al. Results of a nationwide epidemiologic survey of autosomal recessive congenital ichthyosis and ichthyosis syndromes in Japan. *J Am Acad Dermatol*. (2019) 81 (5):1086–92.e1. doi: 10.1016/j.jaad.2018.07.056

7. Vahlquist A, Bygum A, Gånemo A, Virtanen M, Hellström-Pigg M, Strauss G, et al. Genotypic and clinical spectrum of self-improving collodion ichthyosis: aLOX12B, ALOXE3, and TGM1 mutations in scandinavian patients. *J Invest Dermatol*. (2010) 130(2):438–43. doi: 10.1038/jid.2009.346

8. Akiyama M, Takizawa Y, Suzuki Y, Ishiko A, Matsuo I, Shimizu H. Compound heterozygous TGM1 mutations including a novel missense mutation L204Q in a mild form of lamellar ichthyosis. *J Invest Dermatol*. (2001) 116(6):992–5. doi: 10.1046/j.0022-202x.2001.01367.x

9. Richard G, et al. Autosomal recessive congenital ichthyosis. In: Adam MP, Feldman J, Mirzaa GM, Pagon RA, Wallace SE, Bean LJH, editors. *GeneReviews*(®). Seattle, WA: University of Washington, Seattle (1993–2024). Available online at: https://www.ncbi.nlm.nih.gov/books/NBK1420/ (Accessed August 12, 2024).

10. Diociaiuti A, Corbeddu M, Rossi S, Pisaneschi E, Cesario C, Condorelli AG, et al. Cross-sectional study on autosomal recessive congenital ichthyoses: association of genotype with disease severity, phenotypic, and ultrastructural features in 74 Italian patients. *Dermatology*. (2024) 240(3):397–413. doi: 10.1159/000536366

11. Choudhary R, Satish V. Dental treatment of a child suffering from non-bullous congenital ichthyosiform erythroderma under general anesthesia. *Int J Clin Pediatr Dent*. (2015) 8(2):157–62. doi: 10.5005/jp-journals-10005-1305

12. Ramar K, Annamalai S, Hariharavel VP, Aravindhan R, Ganesh C, Ieshwaryah K. Oral manifestation of autosomal recessive congenital ichthyosis in a 2-year-old patient. *Case Rep Dent*. (2014) 2014:483293. doi: 10.1155/2014/483293

13. Zhang XB, Wei SC, Li CX, Xu X, He YQ, Luo Q, et al. Mutation of GJB2 in a Chinese patient with keratitis-ichthyosis-deafness syndrome and brain malformation. *Clin Exp Dermatol*. (2009) 34(3):309–13. doi: 10.1111/j.1365-2230.2008.02934.x

14. Saleem HMK, Shahid MF, Shahbaz A, Sohail A, Shahid MA, Sachmechi I. Netherton syndrome: a case report and review of literature. *Cureus*. (2018) 10(7): e3070. doi: 10.7759/cureus.3070

15. Sarri CA, Roussaki-Schulze A, Vasilopoulos Y, Zafiriou E, Patsatsi A, Stamatis C, et al. Netherton syndrome: a genotype-phenotype review. *Mol Diagn Ther*. (2017) 21 (2):137–52. doi: 10.1007/s40291-016-0243-y

16. Chavanas S, Bodemer C, Rochat A, Hamel-Teillac D, Ali M, Irvine AD, et al. Mutations in SPINK5, encoding a serine protease inhibitor, cause netherton syndrome. *Nat Genet*. (2000) 25(2):141–2. doi: 10.1038/75977

17. Li D, Deng M, Liao P, Song Y. Clinical and genetic analysis of a patient with autosomal recessive congenital ichthyosis due to compound heterozygous variants of ALOX12B gene. *Zhonghua Yi Xue Yi Chuan Xue Za Zhi*. (2022) 39 (3):321–4. doi: 10.3760/cma.j.cn511374-20210526-00442

18. Frommherz L, Krause A, Kopp J, Hotz A, Hübner S, Reimer-Taschenbrecker A, et al. High rate of self-improving phenotypes in children with non-syndromic congenital ichthyosis: case series from South-Western Germany. *J Eur Acad Dermatol Venereol*. (2021) 35(11):2293–9. doi: 10.1111/jdv.17524

19. Mohamad J, Samuelov L, Malchin N, Rabinowitz T, Assaf S, Malki L, et al. Molecular epidemiology of non-syndromic autosomal recessive congenital ichthyosis in a middle-eastern population. *Exp Dermatol*. (2021) 30(9):1290–7. doi: 10.1111/exd.14345

20. Hake L, Süßmuth K, Komlosi K, Kopp J, Drerup C, Metze D, et al. Quality of life and clinical characteristics of self-improving congenital ichthyosis within the disease spectrum of autosomal-recessive congenital ichthyosis. *J Eur Acad Dermatol Venereol*. (2022) 36(4):582–91. doi: 10.1111/jdv.17873

21. Hino R, Yamada A, Chiba Y, Yoshizaki K, Fukumoto E, Iwamoto T, et al. Melnick-needles syndrome associated molecule, filamin-A regulates dental epithelial cell migration and root formation. *Pediatric Dental Journal*. (2020) 30(3):208–14. doi: 10.1016/j.pdj.2020.09.003

22. Yamada A, Yoshizaki K, Ishikawa M, Saito K, Chiba Y, Fukumoto E, et al. Connexin 43-mediated gap junction communication regulates ameloblast differentiation via ERK1/2 phosphorylation. *Front Physiol*. (2021) 12:748574. doi: 10.3389/fphys.2021.748574

23. Chiba Y, Yoshizaki K, Saito K, Ikeuchi T, Iwamoto T, Rhodes C, et al. G protein-coupled receptor Gpr115 (Adgrf4) is required for enamel mineralization mediated by ameloblasts. *J Biol Chem*. (2020) 295(45):15328–41. doi: 10.1074/jbc.RA120.014281

24. Rhodes CS, Yoshitomi Y, Burbelo PD, Freese NH, Nakamura T, Chiba Y, et al. Sp6/epiprofin is a master regulator in the developing tooth. *Biochem Biophys Res Commun*. (2021) 581:89–95. doi: 10.1016/j.bbrc.2021.10.017

25. Inada S, Chiba Y, Tian T, Sato H, Wang X, Yoshizaki K, et al. Expression patterns of keratin family members during tooth development and the role of keratin 17 in cytodifferentiation of stratum intermedium and stellate reticulum. *J Cell Physiol*. (2024):e31387. doi: 10.1002/jcp.31387

26. Rathi NV, Rawlani SM, Hotwani KR. Oral manifestations of lamellar ichthyosis: a rare case report and review. *J Pak Assoc Dermatol*. (2016) 23(1):99–102. doi: 10.1136/bcr-2020-235008

27. Caceres-Rios H, Tamayo-Sanchez L, Duran-Mckinster C, de la Luz Orozco M, Ruiz-Maldonado R. Keratitis, ichthyosis, and deafness (KID syndrome): review of the literature and proposal of a new terminology. *Pediatr Dermatol*. (1996) 13 (2):105–13. doi: 10.1111/j.1525-1470.1996.tb01414.x

frontiers | Frontiers in Pediatrics

TYPE Original Research
PUBLISHED 06 December 2024
DOI 10.3389/fped.2024.1478302

OPEN ACCESS

EDITED BY
Sreekanth Kumar Mallineni,
Dr Sulaiman Al Habib Hospital, Saudi Arabia

REVIEWED BY
Burak Buldur,
Cumhuriyet University, Türkiye
Sivakumar Nuvvula,
Narayana Dental College and Hospital, India

*CORRESPONDENCE
Thomas G. O'Connor
✉ Tom_OConnor@URMC.Rochester.edu

RECEIVED 09 August 2024
ACCEPTED 12 November 2024
PUBLISHED 06 December 2024

CITATION
Kopycka-Kedzierawski DT, Ragusa PG, Feng C, Flint K, Watson GE, Wong CL, Gill SR, Billings RJ and O'Connor TG (2024) Psychosocial determinants of oral health outcomes in young children.
Front. Pediatr. 12:1478302.
doi: 10.3389/fped.2024.1478302

Psychosocial determinants of oral health outcomes in young children

Dorota T. Kopycka-Kedzierawski[1], Patricia G. Ragusa[1], Changyong Feng[2], Kim Flint[1], Gene E. Watson[1], Cynthia L. Wong[1], Steven R. Gill[3], Ronald J. Billings[1] and Thomas G. O'Connor[4]*

[1]Department of Oral and Craniofacial Sciences, Eastman Institute for Oral Health, University of Rochester, Rochester, NY, United States, [2]Department of Biostatistics and Computational Biology and Department of Anesthesiology and Perioperative Medicine, University of Rochester, Rochester, NY, United States, [3]Department of Immunology and Microbiology, University of Rochester, Rochester, NY, United States, [4]Departments of Psychiatry, Neuroscience, and Obstetrics and Gynecology, University of Rochester, Rochester, NY, United States

Objective: To examine the social determinants of early childhood caries (ECC), one of the greatest public health risks affecting children, and examine alternative pathways of influence.
Methods: A physically healthy, socio-demographically high-risk sample of initially caries-free children, aged 1–4 years, was prospectively studied for 2 years. At 6-month intervals, assessments were made of caries presence from a standard dental exam; oral microbiology was assayed from saliva samples; oral hygiene behaviors and psychological and psychosocial risk exposure were derived from interviews and questionnaires.
Results: 189 children were enrolled; ECC onset occurred in 48 children over the 2-year study period. A composite measure of psychosocial risk was significantly associated with ECC onset over the course of the study (1.57, 95% CI 1.12–2.20, $p < .001$) and significantly associated with multiple risks for ECC, including poor diet/feeding (.92; 95% CI. 22–1.61, $p < .01$), poor oral hygiene (.39; 95% CI .09–.68), $p < .05$), and higher concentrations *Lactobacilli* (.96; 95% CI .43–1.49, $p < .001$). Multivariable regression analyses provided indirect support for the hypothesis that psychosocial risk exposure predicts ECC onset via behavioral and oral hygiene pathways.
Conclusions: The study provides novel evidence that psychosocial factors influence many of the purported risks for ECC and strong evidence that there are social and psychological determinants of ECC onset.

KEYWORDS

oral health, early childhood caries, social conditions, social determinants of health, International Caries Detection and Assessment System (ICDAS)

Introduction

The expansive research literature on the social determinants of health emphasizes that social-psychological risk exposure early in development predicts diverse health outcomes in adulthood. An important extension of this work, because of its implications for understanding disease mechanisms and timing of clinical intervention, is research

Abbreviations
ECC, early childhood caries; MS, *mutans streptococci*; LB, *Lactobacilli*; GEE, generalized estimating equations; ICDAS, International Caries Detection and Assessment System; CFU, colony forming units; ICC, intra class correlation.

documenting that early risk exposure also predicts clinical health conditions with *childhood onset*. The current study examines psychosocial determinants of early childhood caries (ECC), one of the most prevalent early-onset clinical and public health concerns which has an onset before age 5 years and holds long-term implications for oral and craniofacial health and well-being (1–4).

Evidence of a socio-economic and socio-demographic gradient of ECC has been widely reported: higher rates of ECC are reliably found among children in low income/low resource families and minoritized communities (5, 6). Although often interpreted to imply a social-psychological etiology (e.g., stress), research findings linking socio-demographic context to ECC are confounded by many alternative mechanisms of risk which also show a social-demographic gradient (7–11) and pose compelling alternative explanations and confounds. More direct evidence regarding the role of specific psychological, social and behavioral risk factors for ECC is needed to inform the type and timing of targeted (preventive) interventions to improve child oral health outcomes. That is the aim of the current study, which was designed to test alternative pathways through which social-psychological factors may predict ECC. Leverage for testing social-psychological determinants of ECC derives from (a) a prospective longitudinal follow-up of initially caries-free children for 2 years; (b) collection of oral microbiology that has been causally linked with ECC; and (c) detailed assessment of diet, oral hygiene, and economic and demographic covariates.

Material and methods

Sample

A cohort of confirmed caries-free pre-school children was recruited from a university-based community pediatric dental clinic in the Northeast US; the longitudinal study was conducted between February 2016 and February 2021. Inclusion criteria were: (a) child age of 1–3 years at enrollment, (b) Medicaid and Child Health Plus eligible, (c) primary caregiver age of 18 years or older, (d) sufficient understanding of English to complete study procedures and measures; exclusion criteria were (a) major medical problems and (b) evidence of dental caries at enrollment. Children on antibiotics were not excluded but a study visit was (re-)scheduled to occur at least 30 days from end of the antibiotic exposure (for valid collection of microbiology data). The study was approved by the local Institutional Review Board; written informed consent was obtained from a primary caregiver of participating children; participants were reimbursed for study participation.

Procedure and measures

Children and a primary caregiver were seen at a university-based pediatric community clinic at enrollment and then at 6-month intervals for 2 years (i.e., up to 5 visits in total). Each visit consisted of behavioral assessments, parent-completed questionnaires, saliva collection, and a formal dental exam; each visit lasted approximately 2 h.

Caries status was assessed using the International Caries Detection and Assessment System (ICDAS) (12). At each visit, children were examined by a calibrated pediatric dentist (DKK) using standard protocol and procedures (12); all children had an ICDAS score of 0 at enrollment.

Oral microbiology was assessed from a sample of approximately 2 mL of saliva, which was collected prior to the dental exam at each visit. Microbiological profiles included *mutans streptococci*, *Lactobacilli* (LB), *Candida* species using established microbiological procedures (13). Whole, stimulated, saliva samples were obtained through a disposable saliva ejector attached to a 50 mL sterile centrifuge tube, which in turn was attached to a vacuum pump (14). All salivary samples were processed the same day using an Autoplate Spiral Plating System (Advanced Instruments, Inc.). Saliva samples were evaluated for MS, LB, and Candida species using Mitis Salivarius agar plus bacitracin, Rogosa, and CHROMagar respectively. For dispersion of cell clumps and dechaining of streptococci, a 2 mL aliquot of saliva was sonicated (three 10-s sonic bursts, 100 Watts of peak power). The suspension was serially diluted (10-fold dilutions) in phosphate buffer and 50 µL aliquots uniformly plated on: (i) Mitis Salivarius agar (Becton- Dickinson) supplemented with 20% sucrose and bacitracin (0.2 U/mL), to determine the presence of MS, (ii) Rogosa agar (Oxoid) to evaluate the presence of *Lactobacilli*, (iii) CHROMagar (BBL) supplemented with 0.1 mg/mL chloramphenicol to determine the presence of *Candida* spp., and (iv) tryptic soy agar supplemented with 5% sheep blood to enumerate the total microflora. MS plates were incubated at 37C in a 5% CO_2 atmosphere, Rogosa plates were incubated anaerobically at 37C, CHROMagar plates were incubated aerobically at 37C and duplicated blood agar plates incubated at 37C both under aerobic and anaerobic conditions. All dilutions were plated in triplicates and the plates incubated under the described conditions for 72 h before colonies were counted. The number of *mutans streptococci*, *Lactobacilli*, *Candida* and total microflora were expressed as colony forming units (CFUs) per mL of saliva. Detailed procedures for collection, storage and analysis of oral microflora are well-established and described elsewhere (14). Salivary samples were processed between 1 and 4 h after collection, as there is no significant loss of numbers of total viable flora during the first 24 h (14).

Child and family stress exposures were based on parent-reported measures at each visit from six widely-used inventories assessing several types of child stress exposures: caregiver depression based on the Center for Epidemiologic Studies Depression Scale (15); anxiety and worry based on the Penn State Worry Questionnaire (16); alcohol use from the Alcohol Use Disorders Identification Test (17); stressful life events from a list of standard high-stress conditions [e.g., losses of income, health problems (18)]; household disorganization and confusion was derived from the Confusion, Hubbub, and Order Scale (19); violence exposure was based on the psychological aggression and

physical assault subscales of the Conflict Tactics Scale (20) (following guidelines, this scale was administered yearly rather than at 6-monthly intervals). Following decades of clinical research practice in psychosocial studies (21) and current practice in clinical health studies, e.g., (22), a composite measure from standardized scores of each of the six scales was created at each visit because of the moderate-high correlations between scales, internal consistencies of a composite at each time point, and stability of each measure over the 2-year assessment period (see Supplementary Tables S1, S2).

Oral health behaviors and oral hygiene were assessed using a validated parent questionnaire (23) that includes questions related to the child's eating and drinking habits, snacking choices, sippy cup use, and the type and the amount of beverages and snacks consumed by the children; brushing behaviors; and the children's oral hygiene regimens. Items were combined into three subscales assessing Diet/Feeding (e.g., sippy cup use, having snacks during the day), Oral Hygiene (using fluoridated toothpaste, frequency of brushing), and Tooth Monitoring (e.g., whether or not the child has seen a dentist). These subscales at each assessment are considered as separate variables in the analytic models (see Supplementary Table S1).

Socio-demographic variables. Socio-demographic variables included the child's and parents/primary caregivers' age, race, ethnicity and gender; insurance status; parent/primary caregiver educational attainment and occupation; and income.

Data analysis

Descriptive data and attrition analysis across the two-year assessment period are presented first. The primary psychosocial stress exposure variable is the composite psychosocial measure created by standardizing and summing each of the six measures; this was conducted at each assessment. The three measures of oral microbiology, *S. mutans*, *Candida*, and *Lactobacilli*, were log-transformed prior to analyses, following current practice. Prediction analyses were based on generalized estimating equations (GEE), which employs a regression model framework that accommodates repeated measurement within subject. The psychosocial stress composite was included as a time-varying covariate; several socio-demographic covariates, assessed from baseline (i.e., there was no or little variation in these factors over time), were included on an *a priori* basis: child sex, age, race/ethnicity, education, insurance status; other factors were included as covariates if there was reliable evidence of their association with exposure or outcome variables. Results from unadjusted and adjusted analyses of the association between psychosocial risk status and ECC are reported, followed by results from alternative models: psychosocial risk is included alongside (a) oral health behavioral variables to test the hypothesis that psychosocial risk associates with ECC because of its impact on oral hygiene; (b) oral microbiology to test the hypothesis that psychosocial stress exposure is associated with ECC onset via a link with microbiological risk for caries. The degree to which exposures in models (a) and (b) explained the psychosocial stress effect may be derived from comparing the estimate of psychosocial risk in the minimally adjusted model with the psychosocial risk estimate in alternative models described above. There is a lack of directly applicable prior research for the current analyses, e.g., for *a priori* estimating sample sizes needed to detect a psychosocial prediction of ECC onset. Instead, sample size justification for the current study was based on prior studies of conversion rates in young children (24).

Results

Descriptive and preliminary analyses

A total of 189 confirmed caries-free pre-school children was enrolled. Sample socio-demographic characteristics are displayed in Table 1, which indicate that the participating families are ethnically and racially diverse and at relatively high psychosocial and socio-demographic risk, e.g., based on parental educational attainment and Medicaid eligibility status and clinical measures (e.g., ≥20% above cut-offs scores for clinical measures). Of the $n = 189$ participants at baseline, retention was 72% from initial visit to 1 year and 95% from year 1 to year 2. There was no reliable evidence that demographic, oral hygiene or psychosocial factors in Table 1 predicted retention through the 2-year study period. The Appendix (Supplementary Table S1) provides descriptive data on predictors across the two-year study period. In general, there was minimal evidence of a linear increase or decrease in the study variables over the 2-year study period; stability estimates based on the Intra Class Correlation (ICC)

TABLE 1 Social and demographic characteristics of the sample at enrollment.

	Mean (SD)/*n* (%)
Maternal education	
<High School	17 (9)
High School or GED	105 (55.5)
>High School	62 (32.8)
Marital/cohabiting status	
Single	104 (55)
Married/cohabiting	85 (45)
Employed	108 (57.1)
Smoking in the household (yes)	38/(20)
Number of people/house	4.1 (1.5)
Child sex (female)	91 (48.2)
Child age (months)	29.5 (9.1)
Child race	
Black/African-American	76 (40.2)
White	35 (18.5)
Mixed/other	78 (41.3)
Child ethnicity (Hispanic)	50 (26.5)
Child dental insurance	
Medicaid	143 (75.7)
Child health plus	35 (18.5)
Private	10 (5.3)
None	1 (.5)

Not all *n*'s sum to 189 because of missing response.

varied somewhat across construct; oral microbiology markers were modestly/moderately stable. Preliminary data also indicated that, after accounting for child age, gender, race, and ethnicity, there was no additional prediction of ECC from other socio-demographic factors; as a result, prediction models include only child age, gender, race, and ethnicity as covariates.

Associations between psychosocial risk composite and oral health outcomes

Bivariate associations from GEE models indicated that the psychosocial risk composite was associated with select measures of oral health behaviors and microbiology (Table 2), in particular Diet/feeding [.92 (95% CI .22–1.61), $p < .01$], Oral hygiene [.39 (95% CI .09–.68)], $p < .05$), and higher concentrations *Lactobacilli* [.96 (.43–1.49), $p < .001$]. The psychosocial risk composite also predicted ECC onset over the course of the study (1.57 (95% CI 1.12–2.20, $p < .001$). The magnitude of the bivariate prediction of ECC onset from the psychosocial composite, oral health behaviors, and oral microbiology are provided in Supplementary Table S2.

Table 3 presents Odds Ratio results from alternative GEE prediction models that examine ECC onset over the course of the study; for each model ECC onset is the outcome variable and child age, sex, and race and ethnicity were included as covariates. Model 1 in Table 3 indicates that psychosocial risk status is reliably associated with ECC status after accounting for covariates (OR 1.80, 95% CI 1.20–2.70, $p < .01$). Models 2 and 3 tested the hypothesis that the prediction from the psychosocial risk composite occurred via behavioral/oral health (Model 2) or via oral microbiology (Model 3). There was indirect support for the hypothesis that psychosocial risk exposure predicts ECC onset via behavioral and oral hygiene. Specifically, the prediction from the psychosocial composite was non-significant at $p < .05$ once parent-reported behavioral and oral hygiene factors were considered (from OR 1.80–1.53); the change in the psychosocial exposure estimate was modestly decreased. Additionally, none of the behavioral and oral hygiene measures was reliably associated with ECC with the psychosocial composite included.

TABLE 2 Bivariate associations between psychosocial risk composite and oral health behavior, oral microbiology, and ECC onset across the study period (based on generalized estimating equations).

	Estimate (SE)	95% CI	*p*
Oral health behavior			
Diet feeding	.92 (.35)	.22–1.61	.0098
Oral hygiene	.39 (.15)	.09–.68	.0102
Tooth monitoring	.03 (.06)	−.09–.14	.6543
Oral microbiology			
S. Mutans	.25 (.49)	−.71–1.21	.6117
Lactobacilli	.96 (.27)	.43–1.49	.0004
Candida	−.31 (.21)	−.73–.10	.1391
Early child caries onset	1.57 (.27)	1.12–2.20	.009

Early childhood caries is coded binary (1 = present, 0 = absent).

A different pattern of results was found in the model that included microbiology. As shown in Model 3 in Table 3, *S. mutans*, *Lactobacilli*, and *Candida* all significantly predicted ECC onset (*Lactobacilii* at $p < .06$) in the model that also included the psychosocial risk composite and covariates; as with Model 2, there was a modest decrease in the psychosocial composite prediction. The implication is that the prediction of oral microbiology to ECC operates separately from psychosocial risk.

Supplementary analyses

Several sets of exploratory supplementary analyses were carried out. Additional supplementary analyses categorized the psychosocial composite according to >1 SD above the mean to assess if the findings were different using a more extremes approach to risk exposure; however, results were comparable to the continuous composite rating for oral health behaviors, oral microbiology, and caries onset. Data were also re-analyzed to examine sex differences in risk and health outcomes: models in Table 3 including child sex moderation indicated no reliable evidence that the prediction of ECC from psychosocial risk and covariates differed for boys and girls. Finally, supplementary

TABLE 3 Prediction models of ECC onset: odds ratios from alternative GEE prediction models.

	Model 1 Estimate (SE) 95% CI	Model 2 Estimate (SE) 95% CI	Model 3 Estimate (SE) 95% CI
1. Psychosocial composite			
Psychosocial composite	1.80 (.37)**		
	1.20–2.70		
2. Psychosocial composite + oral hygiene			
Psychosocial composite		1.53 (0.41)	
		0.91–2.58	
Diet/Feeding		0.94 (0.04)	
		0.87–1.02	
Oral Hygiene		1.04 (0.08)	
		0.90–1.21	
Tooth Monitoring		1.29 (0.35)	
		0.70–2.19	
3. Psychosocial composite + oral microbiology			
Psychosocial composite			1.49 (0.39)
			0.89–2.50
S. Mutans			1.09 (0.04)*
			1.00–1.18
Lactobacilli			1.10 (0.06)+
			0.99–1.212
Candida			1.12 (0.06)*
			1.00–1.25
Model prediction accuracy:	58%	59.5%	69.1%

The outcome is the dichotomous measure of ECC onset, where 0 = ECC free and 1 = ECC onset. All models adjust for child age, sex, and race/ethnicity and time. Model 2 also includes Diet/Feeding, Oral Hygiene, Tooth Monitoring measures; Model 3 includes *S. Mutans, Lactobacilli, Candida*. Model prediction accuracy provides a measure of correct classification of ECC onset for models 1, 2, and 3.
** $p < .01$; * $p < .05$.

analyses indicated that there was no individual psychosocial factor that was uniquely associated with ECC and other oral health outcomes: significant associations, for both bivariate and multivariable analyses, were found only with the composite measure that assessed risk across multiple exposures and not when individual factors were considered independently.

Discussion

A long history of research has sought to determine if there are socio-demographic, psychosocial, or behavioral origins of childhood caries (25), in part, to complement (or confound) an oral microbiological model. Indirect evidence for a psychosocial explanation derives from the oral intervention research which repeatedly demonstrates only modest improvements in children's oral health outcomes, e.g., associated with varnish or antibiotics (26, 27). Stronger, but still quite indirect, support derives from many studies showing a socio-economic gradient of ECC onset. Findings from these sets of studies are less clear on two key questions addressed in the current study: is there evidence that *potentially modifiable psychosocial risks exposures* are reliably associated with ECC onset; second, if there is a reliable psychosocial risk prediction, then what is a plausible mechanism of effect? As discussed below, the current study provides firm affirmative evidence for the former and modest evidence regarding the second question.

Associations between specific, measured psychosocial factors and ECC onset has been widely reported (28, 29), including from diverse settings and populations (11, 30, 31), but interpretation of a putative causal role has been pre-empted by research design limitations, such as the reliance on cross-sectional data. In that regard, the 6-monthly assessment of *initially caries-free children* for two years provides important leverage for inferring that psychosocial risk led to subsequent ECC onset. Furthermore, finding a significant prediction after adjusting for socio-demographic covariates (i.e., Model 1 in Table 3), implies that the effects of psychosocial risk exposure on ECC can be distinguished from economic and demographic risk, which also predict ECC onset. Accordingly, the current findings offer considerable and novel support for a psychosocial stress-related account for caries onset in young children. Moreover, each of the factors included in the assessment of psychosocial risk has an established history in developmental and clinical research on children's behavioral health (32, 33), which has been extended more recently to physical health (34–37). Two additional points as regards clinical application warrant discussion. One is that the prediction derived from the psychosocial risk composite and not to any specific exposure in isolation. That is a consistent message in clinical research on child health, which has consistently emphasized the role of cumulative stress exposure across context, type, and time – and the corollary that targeting isolated markers will yield a weaker and a likely mis-specified effect. This observation does not necessarily impugn the possible benefits of targeted interventions (e.g., for parental depression), however, as interventions targeting any of the specific constructs included in the composite might be expected to have broader impact across a range of risks (e.g., parental depression-targeted interventions could be expected to have carry-over effects on family conflict). The second is that comparatively brief psychological-behavioral interventions such motivational interviewing (38) can be effective in reducing ECC, further suggesting that not all areas of risk exposure may need to targeted for an intervention to be effective – even if there is a complex set of risk exposures underlying the clinical condition.

If there is a reliable link between psychosocial risk exposure and ECC, then the subsequent question concerns how. Two leading possibilities were examined in this paper: via oral hygiene behaviors, for example, diet and brushing; or, via the oral microbiology that has a demonstrated causal role in ECC. In bivariate analyses the psychosocial risk composite was associated in several oral hygiene and oral microbiological risks (although not with *S. mutans*, which has the strongest biological claims on ECC). On the other hand, there was not clear evidence of either pathway from the regression models. That is, the psychosocial risk prediction was (only) modestly weaker in models that included a) oral hygiene or b) oral microbiological markers. The implication is that there is a modest confound between psychosocial risk and behavioral and oral hygiene factors in the prediction of ECC onset. On the other hand, the finding that each of the oral microbiological markers was a significant predictor of ECC onset when adjusting for psychosocial risk implies that these biological processes for ECC are not dependent on a psychosocial risk or stress biology marker associated with these risks.

The study has several limitations. First, the sample was selectively chosen to include very young children at greatest risk for ECC onset; the findings may not generalize to other populations. Similarly, the findings are based on a US sample; the findings obtained here may be particular to the health care context and patterns of oral health risks, which may differ widely across socio-cultural settings within and between countries, e.g., (39). Second, two of several possible mechanisms by which psychosocial risk may be associated with ECC onset were examined in detail. Further research is needed to replicate and integrate the current findings alongside alternative explanations concerning, for example, parental oral health and health care access, and the oral microbiome (40–42). Third, the follow-up period of two years was long enough to identify ECC onset in a sizable subsample, but likely the more severe cases; the current findings may not apply to later onset ECC. Finally, additional factors with potential relevance for ECC (e.g., sleep problems) were not systematically assessed or included in the analyses. Set against these limitations were several strengths of the paper, including a prospective assessment of initially caries-free children and extensive assessment of psychosocial risk exposure on multiple occasions.

There has been a major policy and clinical directive toward greater understanding of ECC and precision in specifying the mechanisms of ECC – in order to broaden and strengthen the types of intervention that may be needed. The current findings provide strong evidence that psychosocial risk is a contributor to

ECC onset and add to a growing evidence base indicating a social and behavioral context that warrants attention in efforts to promote children's oral health.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, pending IRB approval.

Ethics statement

The studies involving humans were approved by University of Rochester Research Subjects Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by participants and/or the participants' legal guardians/next of kin.

Author contributions

DK-K: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – review & editing. PR: Data curation, Project administration, Writing – review & editing. CF: Formal Analysis, Methodology, Writing – review & editing. KF: Data curation, Project administration, Supervision, Writing – review & editing. GW: Data curation, Methodology, Project administration, Supervision, Writing – review & editing. CW: Data curation, Project administration, Validation, Writing – review & editing. SG: Validation, Writing – review & editing. RB: Conceptualization, Supervision, Writing – review & editing. TO: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. Funding was provided by NIH DE024985; the NIH had no role in the design and conduct of the study.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fped.2024.1478302/full#supplementary-material

References

1. Kirthiga M, Murugan M, Saikia A, Kirubakaran R. Risk factors for early childhood caries: a systematic review and meta-analysis of case control and cohort studies. *Pediatr Dent*. (2019) 41(2):95–112.

2. Kim Seow W. Environmental, maternal, and child factors which contribute to early childhood caries: a unifying conceptual model. *Int J Paediatr Dent*. (2012) 22 (3):157–68. doi: 10.1111/j.1365-263X.2011.01186.x

3. Boyce WT, Den Besten PK, Stamperdahl J, Zhan L, Jiang Y, Adler NE, et al. Social inequalities in childhood dental caries: the convergent roles of stress, bacteria and disadvantage. *Soc Sci Med*. (2010) 71(9):1644–52. doi: 10.1016/j.socscimed.2010.07.045

4. Casamassimo PS, Thikkurissy S, Edelstein BL, Maiorini E. Beyond the DMFT: the human and economic cost of early childhood caries. *J Am Dent Assoc*. (2009) 140 (6):650–7. doi: 10.14219/jada.archive.2009.0250

5. Bilal S, Abdulla AM, Andiesta NS, Babar MG, Pau A. Role of family functioning and health-related quality of life in pre-school children with dental caries: a cross-sectional study. *Health Qual Life Outcomes*. (2021) 19(1):192. doi: 10.1186/s12955-021-01828-3

6. Tinanoff N, Baez RJ, Diaz Guillory C, Donly KJ, Feldens CA, McGrath C, et al. Early childhood caries epidemiology, aetiology, risk assessment, societal burden, management, education, and policy: global perspective. *Int J Paediatr Dent*. (2019) 29(3):238–48. doi: 10.1111/ipd.12484

7. Finlayson TL, Siefert K, Ismail AI, Sohn W. Psychosocial factors and early childhood caries among low-income African-American children in Detroit. *Community Dent Oral Epidemiol*. (2007) 35(6):439–48. doi: 10.1111/j.1600-0528.2006.00352.x

8. Tang C, Quinonez RB, Hallett K, Lee JY, Whitt JK. Examining the association between parenting stress and the development of early childhood caries. *Community Dent Oral Epidemiol*. (2005) 33(6):454–60. doi: 10.1111/j.1600-0528.2005.00249.x

9. Harris R, Nicoll AD, Adair PM, Pine CM. Risk factors for dental caries in young children: a systematic review of the literature. *Community Dent Health*. (2004) 21(1 Suppl):71–85.

10. Marie-Mitchell A, O'Connor TG. Adverse childhood experiences: translating knowledge into identification of children at risk for poor outcomes. *Acad Pediatr*. (2013) 13(1):14–9. doi: 10.1016/j.acap.2012.10.006

11. Buldur B, Guvendi ON. Conceptual modelling of the factors affecting oral health-related quality of life in children: a path analysis. *Int J Paediatr Dent*. (2020) 30(2):181–92. doi: 10.1111/ipd.12583

12. Ismail AI, Sohn W, Tellez M, Amaya A, Sen A, Hasson H, et al. The international caries detection and assessment system (ICDAS): an integrated system for measuring dental caries. *Community Dent Oral Epidemiol*. (2007) 35(3):170–8. doi: 10.1111/j.1600-0528.2007.00347.x

13. Kopycka-Kedzierawski DT, Scott-Anne K, Ragusa PG, Cvetanovska M, Flint K, Feng C, et al. Social, psychological, and behavioral predictors of salivary bacteria, yeast in caries-free children. *JDR Clin Trans Res*. (2022) 7(2):163–73.

14. Mundorff SA, Eisenberg AD, Leverett DH, Espeland MA, Proskin HM. Correlations between numbers of microflora in plaque and saliva. *Caries Res*. (1990) 24(5):312–7. doi: 10.1159/000261289

15. Radloff LS. The CES-D scale: a self-report depression scale for research in the general population. *Appl Psychol Meas*. (1977) 1:385–401. doi: 10.1177/014662167700100306

16. Meyer TJ, Miller ML, Metzger RL, Borkovec TD. Development and validation of the Penn state worry questionnaire. *Behav Res Ther*. (1990) 28(6):487–95. doi: 10.1016/0005-7967(90)90135-6

17. Babor TF, Higgins-Biddle JC, Saunders JB, Monteiro MG. *The Alcohol use Disorders Identification Test: Guidelines for Use in Primary Care*. Geneva: World Health Organization (2001).

18. Compas BE, Howell DC, Phares V, Williams RA, Giunta CT. Risk factors for emotional/behavioral problems in young adolescents: a prospective analysis of adolescent and parental stress and symptoms. *J Consult Clin Psychol*. (1989) 57 (6):732–40. doi: 10.1037/0022-006X.57.6.732

19. Matheny AP, Wachs TD, Ludwig JL, Phillips K. Bringing order out of chaos: psychometric characteristics of the confusion, hubbub, and order scale. *J Appl Dev Psychol*. (1995) 16(3):429–44. doi: 10.1016/0193-3973(95)90028-4

20. Straus MA, Hamby SL, Boney-McCoy S, Sugarman DB. The revised conflict tactics scales: development and preliminary psychometric data. *J Fam Issues*. (1996) 17(3):283–316. doi: 10.1177/019251396017003001

21. Rutter M, Cox A, Tupling C, Berger M, Yule W. Attainment and adjustment in two geographical areas. I–the prevalence of psychiatric disorder. *Br J Psychiatry*. (1975) 126:493–509. doi: 10.1192/bjp.126.6.493

22. Santosa A, Rosengren A, Ramasundarahettige C, Rangarajan S, Gulec S, Chifamba J, et al. Psychosocial risk factors and cardiovascular disease and death in a population-based cohort from 21 low-, middle-, and high-income countries. *JAMA Netw Open*. (2021) 4(12):e2138920. doi: 10.1001/jamanetworkopen.2021.38920

23. Kressin NR, Nunn ME, Singh H, Orner MB, Pbert L, Hayes C, et al. Pediatric clinicians can help reduce rates of early childhood caries: effects of a practice based intervention. *Med Care*. (2009) 47(11):1121–8. doi: 10.1097/MLR.0b013e3181b58867

24. Javed F, Feng C, Kopycka-Kedzierawski DT. Incidence of early childhood caries: a systematic review and meta-analysis. *J Investig Clin Dent*. (2017) 8(4):e12238. doi: 10.1111/jicd.12238

25. Leverett DH, Featherstone JD, Proskin HM, Adair SM, Eisenberg AD, Mundorff-Shrestha SA, et al. Caries risk assessment by a cross-sectional discrimination model. *J Dent Res*. (1993) 72(2):529–37. doi: 10.1177/00220345930720021001

26. Manchanda S, Sardana D, Liu P, Lee GH, Li KY, Lo EC, et al. Topical fluoride to prevent early childhood caries: systematic review with network meta-analysis. *J Dent*. (2022) 116:103885. doi: 10.1016/j.jdent.2021.103885

27. Marinho VC, Worthington HV, Walsh T, Clarkson JE. Fluoride varnishes for preventing dental caries in children and adolescents. *Cochrane Database Syst Rev*. (2013) 2013(7):CD002279. doi: 10.1002/14651858.CD002279.pub2

28. Almutairi S, Scambler S, Bernabe E. Family functioning and dental caries among preschool children. *J Public Health Dent*. (2022) 82(4):406–14. doi: 10.1111/jphd.12475

29. Duijster D, Verrips GH, van Loveren C. The role of family functioning in childhood dental caries. *Community Dent Oral Epidemiol*. (2014) 42(3):193–205. doi: 10.1111/cdoe.12079

30. Kateeb E, Lim S, Amer S, Ismail A. Behavioral and social determinants of early childhood caries among Palestinian preschoolers in Jerusalem area: a cross-sectional study. *BMC Oral Health*. (2023) 23(1):152. doi: 10.1186/s12903-023-02809-2

31. Jain M, Namdev R, Bodh M, Dutta S, Singhal P, Kumar A. Social and behavioral determinants for early childhood caries among preschool children in India. *J Dent Res Dent Clin Dent Prospects*. (2015) 9(2):115–20. doi: 10.15171/joddd.2014.023

32. Murray L, Arteche A, Fearon P, Halligan S, Goodyer I, Cooper P. Maternal postnatal depression and the development of depression in offspring up to 16 years of age. *J Am Acad Child Adolesc Psychiatry*. (2011) 50(5):460–70. doi: 10.1016/j.jaac.2011.02.001

33. Ramchandani PG, O'Connor TG, Evans J, Heron J, Murray L, Stein A. The effects of pre- and postnatal depression in fathers: a natural experiment comparing the effects of exposure to depression on offspring. *J Child Psychol Psychiatry*. (2008) 49(10):1069–78. doi: 10.1111/j.1469-7610.2008.02000.x

34. Janicke DM, Marciel KK, Ingerski LM, Novoa W, Lowry KW, Sallinen BJ, et al. Impact of psychosocial factors on quality of life in overweight youth. *Obesity (Silver Spring)*. (2007) 15(7):1799–807. doi: 10.1038/oby.2007.214

35. O'Connor TG, Wang H, Moynihan JA, Wyman PA, Carnahan J, Lofthus G, et al. Observed parent-child relationship quality predicts antibody response to vaccination in children. *Brain Behav Immun*. (2015) 48:265–73. doi: 10.1016/j.bbi.2015.04.002

36. O'Connor TG, Willoughby MT, Moynihan JA, Messing S, Vallejo Sefair A, Carnahan J, et al. Early childhood risk exposures and inflammation in early adolescence. *Brain Behav Immun*. (2020) 86:22–9. doi: 10.1016/j.bbi.2019.05.001

37. Aris IM, Perng W, Dabelea D, Padula AM, Alshawabkeh A, Velez-Vega CM, et al. Neighborhood opportunity and vulnerability and incident asthma among children. *JAMA Pediatr*. (2023) 177(10):1055–64. doi: 10.1001/jamapediatrics.2023.3133

38. Colvara BC, Faustino-Silva DD, Meyer E, Hugo FN, Hilgert JB, Celeste RK. Motivational interviewing in preventing early childhood caries in primary healthcare: a community-based randomized cluster trial. *J Pediatr*. (2018) 201:190–5. doi: 10.1016/j.jpeds.2018.05.016

39. Solis-Riggioni A, Gallardo-Barquero C, Chavarria-Bolanos D. Prevalence and severity of dental caries in foster-care children and adolescents. *J Clin Pediatr Dent*. (2018) 42(4):269–72. doi: 10.17796/1053-4628-42.4.5

40. Kopycka-Kedzierawski DT, Feng C, Billings RJ, Watson GE, Ragusa PG, Flint K, et al. Psychosocial risk exposure limits routine pediatric oral health care. *AJPM Focus*. (2024) 3(2):100191. doi: 10.1016/j.focus.2024.100191

41. Buldur B. Pathways between parental and individual determinants of dental caries and dental visit behaviours among children: validation of a new conceptual model. *Community Dent Oral Epidemiol*. (2020) 48(4):280–7. doi: 10.1111/cdoe.12530

42. Grier A, Myers JA, O'Connor TG, Quivey RG, Gill SR, Kopycka-Kedzierawski DT. Oral Microbiota composition predicts early childhood caries onset. *J Dent Res*. (2021) 100(6):599–607. doi: 10.1177/0022034520979926

frontiers | Frontiers in Dental Medicine

TYPE Original Research
PUBLISHED 24 December 2024
DOI 10.3389/fdmed.2024.1489074

OPEN ACCESS

EDITED BY
Sivakumar Nuvvula,
Narayana Dental College and Hospital, India

REVIEWED BY
Burak Buldur,
Cumhuriyet University, Türkiye
Jaya Chandra Bhumireddy,
Government Dental college and Hospital, India

*CORRESPONDENCE
Satish Vishwanathaiah
✉ svishwanathaiah@jazanu.edu.sa

RECEIVED 26 September 2024
ACCEPTED 29 November 2024
PUBLISHED 24 December 2024

CITATION
Vishwanathaiah S (2024) Comparison of volumetric analysis between conventional and rotary files in the preparation of root canals in primary molars—an *in vitro* study.
Front. Dent. Med 5:1489074.
doi: 10.3389/fdmed.2024.1489074

Comparison of volumetric analysis between conventional and rotary files in the preparation of root canals in primary molars—an *in vitro* study

Satish Vishwanathaiah*

Division of Pediatric Dentistry, Department of Preventive Dental Sciences, College of Dentistry, Jazan University, Jazan, Saudi Arabia

Background: To compare and evaluate the efficacy of canal preparation and volumetric filling of primary molars instrumented by conventional hand K-file, ProAF baby rotary file and Kedo-S square file using cone beam computed tomography.
Materials and methods: Thirty freshly extracted human primary second molars were randomly divided into 3 groups of 10 teeth each. After access opening and working length determination, preoperative volume analysis was done using cone beam computed tomography (CBCT). The canals were then instrumented by either hand K-files, Pro AF Baby rotary files and Kedo-S square rotary files. Post operative volume analysis was performed using CBCT. All the canals were obturated using Metapex and scanned again using CBCT. Mean values of the pre- and post-operative canal volumes were analyzed using one-way ANOVA. Inter- and intra- group volumetric changes were analyzed statistically by *post hoc* test.
Results: The mean difference in volume after canal preparation and obturation was the highest in the hand K-file group, followed by Pro AF Baby Gold group and the least in the Kedo-S square group. Inter and intra group comparison showed statistically significant differences for all the file groups used.
Conclusion: Kedo- S square showed the least difference in preparation volume and better obturating volume compared to Pro AF baby gold file systems.

KEYWORDS

Kedo-S square, pediatric rotary files, Pro AF baby gold, primary molar, volume

1 Introduction

The success of pulpectomy depends on both mechanical and chemical disinfection of the canal space of primary molars. Barr et al.'s endodontic revolution in pediatric dental practice had made a paradigm shift in performing pulpectomy in primary teeth (1, 2). Apart from iatrogenic errors, rotary NiTi files in pediatric endodontic practice had reduced the time spent on canal preparation with better cleansing of infected or necrosed pulp contents and efficient canal preparation which are curved and tortuous. Such canal systems make pulpectomy simple, quick, and cost effective without tiring the dental team, thereby restoring the tooth's integrity and function (3, 4).

Barr's contributions to endodontic files revolutionized root canal preparation by advancing rotary endodontics with nickel-titanium (NiTi) files. These files, known for the flexibility and adaptability to curved canals, enable efficient shaping while minimizing risks such as transportation, perforation, and excessive dentin removal. The

variably varied tapered designs further improved canal preparation, reducing treatment time, and enhancing precision. Additionally, Barr's focus on minimally invasive endodontics (ME) emphasized preserving pericervical dentin, ensuring the long-term integrity of treated teeth, His innovations in file design aligned with contemporary approaches prioritizing conservation and efficiency, setting new standards for safety and clinical predictability in root canal therapy (5).

Effective and efficient preparation of canal space involves complete elimination of bacterial contents, with minimal removal of contaminated dentin and preserving the remaining dentin (6). This can be achieved by preserving the canal anatomy using file systems that maintain canal centering ability. Rotary file systems are designed specifically for these purposes which vary by length, cross sections, and flexibility (7).

ProAF baby comprises five file sequences and is made of heat-treated nickel titanium-controlled memory wire. They maintain a constant taper of 4% and 6% depending on the file sequence used. These files were designed to be similar to the file sequence used for permanent teeth (8). Kedo-S square consists of a single file system and is made of heat-treated Ni-Ti M-wire with titanium oxide coating. They have variably variable taper with a working length of 16 mm (9). The variably variable taper design of the Kedo-S Square file system refers to the taper variation within the file. This design addresses the unique anatomical challenges of primary teeth, including curved and tapering root canals, ensuring precise and efficient canal shaping. The taper changes along its length with varied taper between 4%-8%. The coronal segment has a larger taper to enhance debris removal and irrigation, the middle segment features a moderate taper for controlled shaping, and the apical segment employs a smaller taper to preserve dentin and reduce the risk of perforation or structural compromise. This design ensures better adaptation to canal anatomy, minimizes dentin removal, and reduces the risk of procedural errors such as canal transportation or file separation. Additionally, the enhanced taper in the coronal region facilitates debris evacuation and irrigation flow, improving the overall efficiency and safety of the procedure (9).

The study's rationale centers around these recently implemented file systems, which evolved to obtain optimal conditions for a pulpectomised tooth. This *in vitro* study aimed to compare and assess the efficacy of canal preparation and volumetric filling of primary molars instrumented with traditional hand K-files, ProAF baby rotary files, and Kedo S square files utilizing cone beam computed tomography. The null hypothesis postulated that rotary file systems were less effective than hand file systems in preparing the canals of primary molars.

2 Materials and methods

The study design was analysed and obtained from the institutional scientific review board of the College of Dentistry, Jazan University, Jazan. (CODJU-1706I). Forty freshly extracted human primary second molars were obtained from the out-patient pediatric dentistry clinic. A signed written informed consent was obtained from the parents or guardians regarding the use of the extracted tooth for research purposes which was also approved by the institutional ethical committee. The teeth were extracted due to the following reasons: non restorable crown structure, severe extraoral swelling and when parents were not willing to preserve the tooth by performing pulp therapies. According to the study's inclusion criteria, teeth had to have no or minimum physiological root resorption, which is specifically described as up to one-third of the root length from the apex. Teeth with calcified canals or those with root resorption greater than two-thirds of the root length were removed. The selection strategy was carefully designed to minimize confounding factors that might influence the study's findings, particularly those linked to notable root resorption or anatomical abnormalities.

The clinical significance of root resorption thresholds is particularly essential in endodontic therapy. Teeth exhibiting resorption exceeding one-third of the root length may possess inadequate structural integrity to facilitate effective root canal therapy, jeopardizing the procedure's long-term success. Excessive resorption might hinder the formation of an adequate seal in the root canal system, thereby elevating the risk of treatment failure or premature tooth loss.

2.1 Sample size estimation

$$\text{Sample Size } (n) = \frac{2S_p^2\,[Z_{1-\alpha/2} + Z_{1-\beta}]^2}{\mu_d^2}$$

$$S_p^2 = \frac{S_1^2 + S_2^2}{2}$$

where,

Z (1-α/2) = 1.64 for 90% confidence interval;

$Z_{1-\beta}$ = 0.84 for 80% power;

S_1 = 2.26 (standard deviation in Hand file group);

S_2= 0.57 (standard deviation in Rotary file group);

μ_d = 1.57(difference in mean ratio scores between two groups).

By substituting these values, the sample size was estimated to be fifteen (10) in each group. The study sample size was derived from an *in vitro* study by Singh et al. (9) with 95% power using G Power analysis. The total sample size was determined to be 45 teeth.

2.2 Preparation of the teeth samples

After the cleansing process using ultrasonic scalers, the teeth were stored in 0.5% sodium hypochlorite solution until its use in the *in vitro* study. For standardization of the samples for canal preparation, only mesiobuccal root of the primary second molars were considered for the study. The mesiobuccal root was used because it was one of the intact roots with minimal resorption. A total of forty-five teeth were collected, numbered and randomly divided into 3 groups of 15 teeth each. Access opening of the primary second molars were performed using a small round

carbide bur in a high-speed handpiece. Any remnant necrotic coronal pulp was amputated using a spoon excavator. A size #10 K-file was used to determine the patency of the mesiobuccal canal. After confirming the patency of the canals, the canals were irrigated using 0.9% normal saline through a 31-gauge irrigation needle. The working length was established by subtracting 1 mm from visible length seen at the root apex.

2.3 Mounting of samples and pre-operative volumetric analysis

Preoperative volumetric analysis was done using cone beam computed tomography (CBCT) (Figure 1). All the samples were mounted in a vinyl polysiloxane impression material *(3M ESPE, GERMANY)* to form a template that was prepared for reciprocating the position both in the pre- and post-operative volumetric analysis. To maintain uniformity of the samples, the samples were arranged to make sure that the mesial surface of the teeth was on the right side as similar to the methodology performed from the previous study (11, 12). The samples were then subjected to light speed plus SCT scanner *(GE electricals. Wilwaukee, USA)* in an axial, coronal, and sagittal plane by an experienced operator who was blinded of the instrumentation sequence (Figure 2). Volume rendering and multiple planar volume reconstruction for root canal measurement were done using Advantage Windows Workstation Version V (GE System, Milwaukee, WI, USA). A constant thickness of 0.65 mm per slice and a constant spiral or table speed of 0.75 and 120 KVP was used. The volume of all the samples was calculated from the canal orifice to 1 mm short of apical foramen.

2.4 Root canal instrumentation

The instrumentation of the selected teeth was conducted by a single experienced investigator who routinely treats pediatric

FIGURE 1
Pre-operative volumetric analysis.

FIGURE 2
Mounting of the samples.

patients and hold expertise in utilizing manual and rotary instrumentation techniques.

Group A: The teeth samples were prepared using hand K-files (Mani, Tochigi, Japan). These hand K-files have an ISO standardized 2% constant taper with a working length of 21 mm. The canals were prepared till the determined working length of each sample using no. 15, 20, 25 and 30 size hand K-files in consecutive sequences. The files were regularly wiped using wet gauze to remove tissue debris. With every increase in file size, the canals were irrigated using 0.9% normal saline and 1% sodium hypochlorite to flush out the dentinal debris. Canal recapitulation was performed after the use of each file.

Group B: The teeth samples were prepared using Pro AF Baby Gold rotary files at 300 rpm at 2 N/Cm torque. Number 15 size hand K-file (Mani, Tochigi, Japan) was used to check patency upto working length. Bo file was used to instrument the first 3 mm beyond the orifice. B1 and B2 files were then used to complete the canal instrumentation up to the determined working length of the samples. Irrigation was performed using 0.9% normal saline followed by 1% sodium hypochlorite to flush out the dentinal debris.

Group C: The teeth samples were prepared using Kedo-S square rotary files (Kedo Dental, India) that has a variably variable (VV) taper at 250 rpm at 2.2 N/Cm torque. Number 15 size hand K-file (Mani, Tochigi, Japan) was used to check patency upto working length. Kedo-S square P1 (0.30/VV taper) file was used for instrumenting the canals up to the determined working length of the samples. Irrigation was performed using 0.9% normal saline followed by 1% sodium hypochlorite to flush out the dentinal debris.

2.5 post-operative volumetric analysis

All the canals were then dried using paper points before subjecting to CBCT (Figure 3). The samples in all the groups were again placed in the same template in the same position and scanned similar to the pre-operative volumetric analysis. Pre-operative volumetric analysis, the canal volume for each sample was measured from the canal orifice to 1 mm short of apex.

2.6 Obturation and post-obturation volumetric analysis

All the canals were obturated using Metapex (MetaBioMed) and entrance filling was provided using glass ionomer cement. The samples were placed back in the template and the final scanning was done. CBCT evaluation of all the samples in the pre-operative, post-operative and post-obturation analyses was done by an experienced radiograph analyst with 8 years of expertise in the field, who was blinded from the methodology that was used in the present study.

2.7 Statistical analysis

Mean values of the pre- and post-operative canal volumes after canal preparation, post-operative canal volumes after obturation and the differences in canal volume of all the samples were analyzed using one-way ANOVA. Inter- and intra- group volumetric changes were analyzed statistically by Tukey's *post hoc* test. A *p*-value of less than 0.05 was considered statistically significant. All the statistical analysis was done using Statistical Package for Social Studies (SPSS) v.22 produced by IBM, Illinois, Chicago, USA.

3 Results

The mean difference in volume after canal preparation was the highest in the hand K-file group, followed by Pro AF Baby Gold group and the least in the Kedo-S square group. Comparison within the groups showed statistically significant differences for all the file groups used (Hand K—$p = 0.022$; Pro AF Baby Gold—$p = 0.034$; Kedo-S square—$p = 0.001$) (Table 1). Inter-group comparison showed statistically significant differences between hand-K group and ProAF Baby Gold group ($p = 0.025$), ProAF Baby Gold group and Kedo-S square group ($p = 0.011$) & highly statistically significant differences between hand-K group and Kedo-S square group ($p = 0.000$) (Table 2). The mean difference in volume after obturation was the highest in the hand K-file group, followed by Pro AF Baby Gold group and the least in the

FIGURE 3
Post volumetric analysis.

TABLE 1 Mean pre- and post-operative volumes before obturation and difference in volumes of canals prepared under each group of files used in the present study.

Files Group	Pre-Operative Volume Mean ± SD (cm^3)	Post-Operative Volume (before obturation) Mean ± SD (cm^3)	Volume Difference Mean ± SD (cm^3)	*p*-value
Hand-K	0.0051 ± 0.00042	0.0082 ± 0.00026	0.0031 ± 0.00012	0.022*
ProAF Baby Gold	0.0056 ± 0.00028	0.0078 ± 0.00047	0.0022 ± 0.00034	0.034*
Kedo-S square	0.0053 ± 0.00017	0.0071 ± 0.00015	0.0018 ± 0.00083	0.001*

*Statistically significant differences by Tukey's *post hoc* test.

TABLE 2 Intergroup comparison of mean difference in volumes of canals prepared before obturation.

Comparison between groups (before obturation)	*p*-value
Hand-K vs. ProAF Baby Gold	0.025*
Hand-K vs. Kedo-S square	0.000*
ProAF Baby Gold vs. Kedo-S square	0.011*

*Statistically significant differences by paired *t*-test.

Kedo-S square group. Comparison within the groups showed statistically significant differences for all the file groups used (Hand K—$p = 0.017$; Pro AF Baby Gold—$p = 0.025$; Kedo-S square—$p = 0.000$) (Table 3). Inter-group comparison showed highly statistically significant differences between hand-K group and Kedo-S square group ($p = 0.000$) & statistically significant differences between hand-K group and ProAF Baby Gold group ($p = 0.046$) and ProAF Baby Gold group and Kedo-S square group ($p = 0.023$) (Table 4).

4 Discussion

The results of the present study suggest that rotary files had more preparatory canal volume when compared to the hand file system. Kedo-SG Blue file system had better canal preparation volume than ProAF Baby Gold file system. Post-obturation analysis also suggested a superior obturating volume in rotary file systems, especially with Kedo-SG Blue, when compared to the conventional hand file system.

The results showed that primary root canal space had minimal preparation using both the rotary files compared to conventional hand file systems. This is because of the tip diameter, the Pro AF baby system used upto B2 file which has a 0.25 daumeter; Kedo S square cross section in the apical portion is thinner with a tip diameter of 0.28 whereas hand file's tip diameter of size 30 is 0.30. This result was similar to other studies who have reported that minimal preparation of canals was noticed using rotary file systems (13–15). Kedo-S square had the least mean difference in the canal preparation volume compared to Pro AF Baby Gold file system. This result was supported by the study done by Mohamed et al., who concluded that Kedo-S square had minimal dentin removal and preparatory volume (15). This was because Kedo S-square had two cross sections with minimal diameter and a variably variable taper design. This tended to minimally prepare the canals (16). This result was contradicted by study done by Swaminathan et al, who concluded that more dentin removal using Kedo-S file system as compared to MTwo file system (17). The taper design of the file can influence the preparation of the canal (18). Kedo-S rotary file systems using a VV taper (4%–8%) aided in improved coronal enlargement thereby facilitating a straight-line access and better flow of obturating material (3). More specifically, the utilization of a 0.25 tip with a 4% taper file proves essential for achieving adequate canal preparation in the apical and middle thirds. Simultaneously, the use of a 6% taper file in the coronal one-third enhances the overall preparation of the canal (12, 18). This could be the reason for better preparation in the Kedo-SG blue group. Post-obturation analysis showed that Kedo-S square had minimal obturation volume when compared to the other file systems used. This result was similar to the studies (19–21) who concluded that optimal obturation volume was obtained using Kedo-S square. This was due to the similar reason of two different cross sections and more taper in the coronal aspect that effectively provided a slight coronal flare to enhance the flow of the obturating paste through orifice (22).

Radiographic evaluation of canal preparation using hand or rotary instruments is essential to provide information on the efficiency of the instruments used. Such a non-invasive, cost-effective technique is by using CBCT which takes multiple two-dimensional images at different angulations to reconstruct a three-dimensional visual representation (23). This would be essential for a comprehensive assessment of the canal preparation for the operator to assess at ease. Earlier studies have proven that CBCT is an essential tool for measurements of before and after

TABLE 3 Mean pre- and post-operative volumes after obturation and difference in volumes of canals prepared under each group of files used in the present study.

Files Group	Pre-Operative Volume Mean ± SD (cm^3)	Post-Operative Volume (after obturation) Mean ± SD (cm^3)	Volume Difference Mean ± SD (cm^3)	*p*-value
Hand-K	0.0052 ± 0.00034	0.0084 ± 0.00023	0.0032 ± 0.00016	0.017*
ProAF Baby Gold	0.0055 ± 0.00017	0.0080 ± 0.00046	0.0025 ± 0.00026	0.025*
Kedo-S square	0.0051 ± 0.00084	0.0074 ± 0.00074	0.0023 ± 0.00065	0.000*

*Statistically significant differences by Tukey's *post hoc* test.

TABLE 4 Intergroup comparison of mean difference in volumes of canals prepared after obturation.

Comparison between groups (after obturation)	*p*-value
Hand-K vs. ProAF Baby Gold	0.046*
Hand-K vs. Kedo-S square	0.000*
ProAF Baby Gold vs. Kedo-S square	0.023*

*Statistically significant differences by paired *t*-test.

root canal preparation (24, 25). A recent systematic review on comparing CBT and micro-CT showed that there were no significant differences between both and CBCT can be as accurate as micro-CT in terms of assessment canal morphology (26).

No clear guidelines or design have been provided by any professionals for its use in primary teeth (1). Rotary file systems for permanent teeth have been redesigned for use in primary teeth. Pro AF Baby Gold file systems followed the regular 4% and 6% ISO standard taper that were commonly used for canal preparation in permanent teeth. The only difference was that the length of the file was 16 mm and the active cutting length was around 12 mm. Kedo-S brand was the first rotary file system designed specifically for its use in preparing canals of primary teeth. With variably variable taper design and cutting length of the file designed specifically to the length of primary teeth, the Kedo-S file system tends to be an ideal rotary system for mechanical disinfection of root canals (27). Kedo-S square have two cross sections combined into a single file which are both heat treated, and titanium oxide coated (20). Such patented designs would require assessment for efficient canal preparation for its clinical usage. Thus, a CBCT analysis was performed to evaluate the efficacy of both the rotary file systems. Obturating the prepared canal space will prevent the re-entry of contaminants and provide a 3-dimensional fluid tight seal thus providing long term success of the endodontic treatment (28, 29). Hence the assessment of the obturation volume was one of the objectives of the present study.

Chemo mechanical preparation is the most practiced achieving complete disinfection of canal space with elimination of microorganisms and thereby preventing the infection to peri radicular tissues. This protocol involves both mechanical filing and intermittent use of mitigating solutions to successfully perform pulpectomy that favours periapical healing (30). Although irrigants play a vital role, this study is more inclined towards the mechanical systems used for cleansing the canal space. Conventional hand instruments that have been used for decades for biomechanical preparation of root canals have had its own drawbacks. Ribbon shaped, curved and tortuous canals of primary teeth are left underprepared due to stiffness of the hand file systems that compromises the complete disinfection of the canal anatomy (31). Ledge formations and canal transportations along the coronal concavity and along the radicular convexity are commonly noticed when curved canals are intervened using stiff hand files (20) With the protocol put forward by Barr et al., and Priyadarshini et al., these complications were avoided by using rotary file systems in primary teeth (31, 32). The current study was thus designed to inspect the effectiveness and volumetric changes using hand files and two pediatric rotary file systems designed for primary teeth suggest that Kedo-S square could help in preservation of dentin with minimal canal preparation thereby avoiding thinner dentin regions commonly seen at the furcation.

Utilizing a conservative preparation volume in primary teeth is essential for safeguarding dental structure, upholding tooth integrity, and securing best long-term results for the developing dentition. Deciduous teeth, characterized by weaker enamel and dentin, are susceptible to fractures if an excessive amount of tooth structure is extracted. Moreover, their enlarged pulp chambers render them vulnerable to pulpal exposure, perhaps leading to inflammation, infection, or requiring more invasive procedures such as pulpectomy. A conservative approach preserves the functional and structural integrity of these teeth, which are crucial for mastication, speech development, and facilitating the appropriate eruption of permanent teeth. Conservative preparations also reduce microleakage by maintaining natural anatomical shapes, enhancing the fit of restorations, and diminishing the risk of secondary caries. Maintaining crown structure is essential for arch stability and provides sufficient room for the eruption of permanent teeth, hence preventing malocclusion. Moreover, minimally invasive procedures improve the child's comfort and participation, hence diminishing oral anxiety and the necessity for sophisticated behavior control strategies. Conservative preparations enhance the endurance and efficacy of restorations by necessitating less restorative material, hence promoting the overall oral and systemic health of young patients.

The limitation of the present study is that the results derived are commonly attributed to the *in vitro* setup used in the present study. However clinical trials and *in vivo* assessment of the quality of obturation could provide us with an insight over the clinically relevant aspects. Apart from preparation and obturation volume analysis, canal centering ability, transportation, uninstrumented regions, microcracks can also be assessed for obtaining further knowledge in the mechanical aspects. Use of different tapers of the file systems used could provide an overt expression of the results towards the more tapered file system. Also, the curvature of the roots was not standardized before the start of the study. This could also have had an influence as the more curved canals could have had a minimal preparation and obturation volume due to unavoidable human errors. Hence further studies are recommended keeping the above limitations to obtain a proper method for measuring the volumetric changes.

5 Conclusion

The present study suggests minimal preparation volume and obturation volume using rotary file systems compared to hand-K file system. Kedo-S square showed the least difference in preparation volume and better obturating volume compared to Pro AF Baby Gold file systems.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding authors.

Ethics statement

'The study design was analysed and obtained from the institutional scientific review board of the College of Dentistry, Jazan University, Jazan. (CODJU-1706I) Forty freshly extracted human primary second molars were collected from the out-patient pediatric dental department. A signed written informed consent was obtained from the parents or guardians regarding the use of the extracted tooth for research purposes which was also approved by the institutional ethical committee.

Author contributions

SV: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Resources, Validation, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

Publisher's note

References

1. Deshpande AN, Joshi NH, Naik KS. *In Vitro* comparative evaluation of cleaning efficacy and volumetric filling in primary molars: cone beam computed tomography evaluation. *Contemp Clin Dent*. (2017) 8(1):33–37. doi: 10.4103/0976-237X.205064

2. Jeevanandan G. Kedo-S paediatric rotary files for root canal preparation in primary teeth—case report. *J Clin Diagn Res*. (2017) 11(3):ZR03–ZR05. doi: 10.7860/JCDR/2017/25856.9508

3. Kalita S, Agarwal N, Jabin Z, Anand A. Comparative evaluation of cleaning capacity and efficiency of kedo-S pediatric rotary files, rotary ProTaper, and hand K files in primary molar pulpectomy. *Int J Clin Pediatr Dent*. (2021) 14(3):383–387. doi: 10.5005/jp-journals-10005-1958

4. Schachter D, Blumer S, Sarsur S, Peretz B, Tunis TS, Fadela S, et al. Exploring a paradigm shift in primary teeth root canal preperation: AN Ex Vivo Micro-CT study. *Children*. (2023) 10(5):792. doi: 10.3390/children10050792

5. Esentürk G, Akkas E, Cubukcu E, Nagas E, Uyanik O, Cehreli ZC. A micro-computed tomographic assessment of root canal preparation with conventional and different rotary files in primary teeth and young permanent teeth. *Int J Paediatr Dent*. (2020) 30(2):202–208. doi: 10.1111/ipd.12587

6. Chugh VK, Patnana AK, Chugh A, Kumar P, Wadhwa P, Singh S. Clinical differences of hand and rotary instrumentations during biomechanical preparation in primary teeth-A systematic review and meta-analysis. *Int J Paediatr Dent*. (2021) 31(1):131–142. doi: 10.1111/ipd.12720

7. Shah HS, Patil VM, Kamath AP, Mathur AA. Comparative evaluation of instrumentation time, obturation time, and radiographic quality of obturation using two rotary systems and manual technique for primary molar pulpectomies—i*n vivo* study. *Contemp Clin Dent*. (2021) 12(1):55–62. doi: 10.4103/ccd.ccd_83_20

8. Lakshmanan L, Jeevanandan G, Maganur PC, Vishwanathaiah S. Fracture incidence of kedo-S square pediatric rotary files: a prospective clinical study. *Eur J Dent*. (2022) 16(3):594–598. doi: 10.1055/s-0041-1735935

9. Singh P, Saha S, Tripathi AM, Yadav G, Dhinsa K. Cone-beam computed tomographic analysis of deciduous root canals after instrumentation with different filing systems: an *in vitro* study. *Int J Clin Pediatr Dent*. (2022) 15(S1):S22–S29. doi: 10.5005/jp-journals-10005-2126

10. Pragadeesh AP, Prathima GS, Nandakumar S. Comparative evaluation of kedo-'S'square files with manual instrumentation in primary molars: an invitro study. *Int J Life Sci Pharma Res*. (2023) 13(4):55–62. doi: 10.22376/ijlpr.2023.13.4.P81-P86

11. Jeevanandan G, Thomas E. Volumetric analysis of hand, reciprocating and rotary instrumentation techniques in primary molars using spiral computed tomography: an *in vitro* comparative study. *Eur J Dent*. (2018) 12(1):21–26. doi: 10.4103/ejd.ejd_247_17

12. Srinivas A, Jeevanandan G, Govindaraju L, Subramanian EMG. Comparative evaluation of the efficacy of rotary file system (kedo-S) vs hand K-files in root canal preparation of primary teeth using cone beam computed tomography (CBCT)—an *in vitro* study. *Braz Dent Sci*. (2019) 22(2):197–202. doi: 10.14295/bds.2019.v22i2.1705

13. Tofangchiha M, Ebrahimi A, Adel M, Kermani F, Mohammadi N, Reda R, et al. *In vitro* evaluation of Kedo-S and RaCe rotary files compared to hand files in preparing the root canals of primary molar teeth. *Front Biosci (Elite Ed)*. (2022) 4 (2):14. doi: 10.31083/j.fbe1402014

14. Nabeeh PK, Peedikayil FC, Premkumar CT, Kottayi S, Narasimhan D. Comparison of volumetric changes in primary molar root canals by four different file systems: a cone-beam computed tomography study. *J South Asian Assoc Pediatr Dent*. (2021) 4(2):112–116. doi: 10.5005/jp-journals-10077-3085

15. Mohamed RH, Abdelrahman AM, Sharaf AA. Evaluation of rotary file system (kedo-S-square) in root canal preparation of primary anterior teeth using cone beam computed tomography (CBCT)-*in vitro* study. *BMC Oral Health*. (2022) 22 (1):13. doi: 10.1186/s12903-021-02021-0

16. Swaminathan K, Rakkesh KM, Haridoss S. Computed tomographic assessment of remaining dentin and risk of perforation after kedo-S and mtwo rotary instrumentation in root canals of primary teeth: an *In Vitro* study. *Int J Clin Pediatr Dent*. (2022) 15(S1):S87–S91. doi: 10.5005/jp-journals-10005-2217

17. Panchal V, Jeevanandan G, Subramanian EMG. Comparison of instrumentation time and obturation quality between hand K-file, H-files, and rotary Kedo-S in root canal treatment of primary teeth: a randomized controlled trial. *J Indian Soc Pedod Prev Dent*. (2019) 37(1):75–79. doi: 10.4103/JISPPD.JISPPD_72_18

18. Kumar D, Ravindran V. Comparison of quality of obturation and instrumentation time using manual hand-K files and rotary Kedo-S square files for pulpectomy in primary molars: a double blinded randomised controlled trial. *J Popul Ther Clin Pharmacol*. (2023) 30(10):46–53. doi: 10.47750/jptcp.2023.30.10.008

19. Durairaj BA, Shivashankarappa PG, Muthukrishnan K, Ezhumalai G, Ramassamy E. Clinical efficacy of Kedo S square files versus manual K files in root canal preparation of deciduous molars: a randomised clinical trial. *J Clin Diagn Res*. (2023) 17(11):ZC01–ZC05. doi: 10.7860/JCDR/2023/65065.18656

20. Lakshmanan L, Ramakrishnan M, Jeevanandan G. Comparison of obturation quality, instrumentation time and post-operative pain using manual K-files and pediatric rotary files in primary molars a double blinded randomised clinical trial. *Braz Dent Sci*. (2023) 26(2):e3497. doi: 10.4322/bds.2023.e3497

21. Hargreaves KM. *Cohen's Pathways of the Pulp: South Asia Edition E-Book*. India: Elsevier Health Sciences (2021).

22. Kurthukoti AJ, Sharma P, Swamy DF, Shashidara R, Swamy EB. Computed tomographic morphometry of the internal anatomy of mandibular second primary molars. *Int J Clin Pediatr Dent*. (2015) 8(3):202–207. doi: 10.5005/jp-journals-10005-1313

23. Barbosa-Ribeiro M, Albergaria SJ, Malvar MFG, Crusoé-Rebello IM, Gomes BPF, Carvalho FB. Canal transportation and centering ability of curved root canals prepared using rotary and reciprocating systems. *Braz J Oral Sci*. (2015) 14 (3):214–218. doi: 10.1590/1677-3225v14n3a08

24. Alamri HM, Sadrameli M, Alshalhoob MA, Sadrameli M, Alshehri MA. Applications of CBCT in dental practice: a review of the literature. *Gen Dent*. (2012) 60(5):390–400.

25. Borges CC, Estrela C, Decurcio DA, Pécora JD, Sousa-Neto MD, Rossi-Fedele G. Cone-beam and micro-computed tomography for the assessment of root canal morphology: a systematic review. *Braz Oral Res*. (2020) 34:e056. doi: 10.1590/1807-3107bor-2020.vol34.0056

26. Jeevanandan G, Govindaraju L. Clinical comparison of Kedo-S paediatric rotary files vs manual instrumentation for root canal preparation in primary molars: a double blinded randomised clinical trial. *Eur Arch Paediatr Dent*. (2018) 19(4):273–278. doi: 10.1007/s40368-018-0356-6

27. Vaishali Naidu D, Sharada Reddy J, Patloth T, Suhasini K, Hema Chandrika I, Shaik H. Cone-beam computed tomographic evaluation of the quality of obturation using different pediatric rotary file systems in primary teeth. *Int J Clin Pediatr Dent*. (2021) 14(4):542–547. doi: 10.5005/jp-journals-10005-2000

28. Samadi F, Jaiswal J, Saha S, Garg N, Chowdhary S, Samadi F, et al. A comparative evaluation of efficacy of different obturation techniques used in root canal treatment of anterior teeth: an *in vitro* study. *Int J Clin Pediatr Dent*. (2014) 7 (1):1–5. doi: 10.5005/jp-journals-10005-1224

29. Rangappa KG, Hegde J, Chikkamallaiah C, Rashmi K. Comparative evaluation of the sealing ability of different obturation systems used over apically separated rotary nickel-titanium files: an *in vitro* study. *J Conserv Dent*. (2013) 16(5):408–12. doi: 10.4103/0972-0707.117502

30. Waly AS, Yamany I, Abbas HM, Alsairafi MAA, Bazzaz RMF, Bogari DF, et al. Comparison of two pediatric rotary file systems and hand instrumentation in primary molar: an ex vivo cone-beam computed tomographic study. *Niger J Clin Pract*. (2021) 24(10):1492–1498. doi: 10.4103/njcp.njcp_563_20

31. Barr ES, Kleier DJ, Barr NV. Use of nickel-titanium rotary files for root canal preparation in primary teeth. *Pediatr Dent*. (2000) 22(1):77–8.

32. Priyadarshini P, Jeevanandan G, Govindaraju L, Subramanian EMG. Clinical evaluation of instrumentation time and quality of obturation using paediatric hand and rotary file systems with conventional hand K-files for pulpectomy in primary mandibular molars: a double-blinded randomized controlled trial. *Eur Arch Paediatr Dent*. (2020) 21(6):693–701. doi: 10.1007/s40368-020-00518-w

frontiers | Frontiers in Dental Medicine

TYPE Review
PUBLISHED 10 February 2025
DOI 10.3389/fdmed.2025.1495025

OPEN ACCESS

EDITED BY
Ali Mentes,
Marmara University, Türkiye

REVIEWED BY
Rosa Helena Wanderley Lacerda,
Federal University of Paraíba, Brazil
Alessandro Venditti,
University of Rome Tor Vergata, Italy

*CORRESPONDENCE
Sreekanth Kumar Mallineni
✉ drmallineni@gmail.com

RECEIVED 11 September 2024
ACCEPTED 03 January 2025
PUBLISHED 10 February 2025

CITATION
Mallineni SK, Anthonappa RP, Jayaraman J and King NM (2025) Radiographic localization of supernumerary teeth: a narrative review. Front. Dent. Med 6:1495025. doi: 10.3389/fdmed.2025.1495025

Radiographic localization of supernumerary teeth: a narrative review

Sreekanth Kumar Mallineni[1]*, Robert Prashanth Anthonappa[2], Jayakumar Jayaraman[3] and Nigel Martyn King[2]

[1]Pediatric Dentistry, Dr. Sulaiman Al Habib Medical Group, Ar Rayyan, Riyadh, Makkah Province, Saudi Arabia, [2]School of Dentistry, The University of Western Australia, Nedlands, WA, Australia, [3]Department of Pediatric Dentistry, Virginia Commonwealth University School of Dentistry, Richmond, VA, United States

Objectives: To conduct a narrative review of the published literature on the localization techniques to identify the best technique for the localization of supernumerary teeth.
Methods: An extensive search of literature published in English between January 1966 and May 2024 was conducted using the "Medline via PubMed" and "Cochrane database" databases. The keywords included in the search were "localization" "radiographs", and "impacted teeth", or "un-erupted teeth", or "supernumerary teeth" or "supernumerary tooth". The citation lists from the included articles were examined to identify additional reports and a hand search was also conducted. Kappa statistics were used for intra-examiner reliability.
Results: The initial search yielded 4,864 citations, subsequently examined and supplemented by a hand search to find additional studies. Commonly used techniques for the localization of supernumerary teeth are the horizontal tube shift technique, vertical tube shift technique, vertex occlusal technique, and cone-beam computerized tomography.
Conclusion: The most commonly used localization techniques for supernumerary teeth are horizontal tube shift, vertex occlusal, vertical tube shift, and cone-beam computerized tomography. Conventional radiographs only provide two-dimensional views of 3-dimensional structures. Three-dimensional imaging alone can provide accurate data on impacted supernumerary teeth but, the need for this film has to be justified because of the higher radiation exposure.

KEYWORDS
localization, radiographs, impacted teeth, supernumerary teeth, CBCT

1 Introduction

Supernumerary teeth are defined as "any tooth or odontogenic structure that is formed from a tooth germ in excess of the usual number for any given region of the dental arch" (1). They may be single or multiple, unilateral or bilateral in distribution, and can occur in both dental arches, and either in the primary mixed or permanent dentitions. The mesiodens is the most commonly occurring supernumerary tooth followed by mandibular premolars, which are the supernumerary teeth of the supplemental type (2–4). Males are more commonly affected than females, at a ratio of 2:1 (5, 6). Several hypotheses have been proposed to explain the occurrence of supernumerary teeth, but their etiology remains unclear (1, 7). According to one systematic review, the prevalence of supernumerary teeth ranges from 1.5% to 3% in the general population with a

predilection to the mongoloid racial group (8). Early identification and appropriate management are critical to either limit or prevent the consequences of supernumerary teeth, which range from crowding to cyst formation. Clinical diagnosis is the primary and most important aid in the diagnosis of an impacted tooth (9, 10). Clinical localization includes visual inspection and palpation, while radiographic localization is based on different combinations of radiographs (11). Localization of supernumerary teeth plays a major role in diagnosis and treatment planning, especially if surgical intervention is required (12). Although early intervention can potentially prevent later complications, several authors have been cited as having anecdotally suggested that this approach is harmful due to the possible risk of damage to the developing tooth germs (1, 2). The location of supernumerary teeth can be confirmed by using a variety of imaging techniques. The interpretation principle "SLOB" (Same Lingual Opposite Buccal) rule is the most commonly used one when applying the concept of parallax (13). Localization of an un-erupted tooth is based on a combination of clinical and radiographic assessment (14). The more exact the localization of supernumerary teeth, potentially the less invasive the surgical procedure; therefore, the purpose of this paper was to conduct a narrative review of the available literature and to identify the best technique for the localization of supernumerary teeth.

2 Materials and methods

An extensive search of literature published in English between January 1966 and May 2024 was conducted using the "Medline via PubMed" and "Cochrane database" databases. The keywords included in the search were "localization" and "radiographs", and "impacted teeth", "un-erupted teeth", or "supernumerary teeth" or "supernumerary tooth". The citation lists from the included references were subsequently examined, in addition hand searching was performed in an attempt to identify additional papers. Kappa statistics were used for intra-examiner reliability.

3 Results

The initial search yielded 4,873 citations from PubMed Medline and 27 from Cochrane database, which were subsequently examined and supplemented by a hand search to find additional studies. Eighteen articles were available for final analysis on the localization of supernumerary teeth five related to horizontal tube shift technique (HTST) (5), six each related to vertical tube shift technique (VTST) and cone beam computerized tomography (CBCT) (6), and one related to computerized tomography (CT). No literature was evident for panoramic radiographs alone and magnetic resonance imaging (MRI) for the localization of supernumerary teeth. The most commonly used techniques for the localization of supernumerary teeth are Clark's technique (13), vertex occlusal (15), and Keur's technique (16), all of which involve the use of conventional radiographs (Table 1). Three-dimensional radiographs for localization and dimensional evaluation include CBCT, CT, MRI, Spiral computerized tomography (SCT), Scanora, and dental magnetic resonance imaging (dMRI), of which CBCT is most often used for the localization of un-erupted impacted/supernumerary teeth in the anterior region of the maxilla (Table 1). Only one reviewer was involved in the literature search and Kappa statistics showed good intra-examiner reliability (K = 0.89). Various localization techniques have been described in the literature (9, 11, 13, 15–42). The most commonly used ones for the localization of supernumerary teeth (13, 15–17), and all the other techniques used for localization of impacted teeth have been summarized in Table 2. The most frequently used localization techniques are described in detail in the text.

3.1 Horizontal tube shift technique (HTST)

Classically, this technique requires three periapical radiographs, one on the tooth of interest followed by one mesial and another distal to the first radiograph (13) see Figure 1. However, over the years, there has been a reduction in the number of films used for this technique, so presently only two periapical films are routinely used. While maintaining the same horizontal plane, a tube shift of 20° to 30° is made between each film. This technique is commonly referred to as Clark's technique and employs the principle of parallax to delineate the spatial relationships of an object.

3.2 Vertex occlusal

Localization of an impacted tooth by radiographic means is dependent on the presence of fixed points apparent both visibly and radiographically (15). To obtain the accurate location of an impacted tooth, the central ray of the x-ray beam must be directed along the long axis of those teeth in the dental arch, which is to be used as reference points. An intraoral intensifying screen may be used to reduce the radiation dose. This technique is not recommended when the voltage of the dental x-ray set is less than 65 kV (43), and it is not acceptable when a long exposure time is needed. These results in a high patient dose and a film of low diagnostic quality because of fogging from scattered radiation see Figure 2. An alternative technique was proposed for the benefit of patients and clinicians, this involved an erect Potter Bucky diaphragm or a fine stationary radiographic grid that can be employed along with the occlusal film (35). However,

TABLE 1 Commonly used methods for the localization of supernumerary teeth.

Authors	Year	Method	Radiographs
Clark (13)	1910	Horizontal technique	3 PA
Hitchin (15)	1951	Vertex occlusal	AO
Keur (16)	1986	Vertical tube shift	PAN and AO
Mozzo et al. (17)	1998	CBCT	

PA, periapical radiograph; AO, anterior occlusal radiograph; PAN, panoramic radiograph; CBCT, cone beam computerised tomography.

TABLE 2 Different combinations of radiographs used for the localization of impacted teeth.

Authors	Year	Methods	Radiographs
Mackenzie Davidson (18)	1898	Stereoscopy	2 PA or 2 AO
Bosworth (19)	1934	Multiple exposures	1PA
Donovan (20)	1952	Occlusal radiography	AO
Richards (21)	1952	Buccal object rule	2PA
Broadway and Gould (22)	1960	Ballard suggestion for localization	LC and PAC
Seward (23)	1963	Radiology in general practice	Apex PA, VO, PA skull, ROL of jaws, and lateral exposure of sinus
Rayne (9)	1969	Localization of canine	PA and AO
Wraith (24)	1969	Radiographic assessment canines	PA skull, LC and 2 PA
Turk and Katzenell (25)	1970	Panorex	PAN
Hounsfield (26)	1973	Computerized tomography	
Ostrofsky (27)	1976	Magnification technique	PAN
Beeching (28)	1981	Parallax with Panorex	PAN, VO of upper jaw or AO of the lower jaw
Coupland (29)	1984	LC skull and PAN	LC and PAN
Keur (16)	1986	Keur technique	2AO
Ericson and Kuroll (30)	1986	Polytomography	
Southall and Gravely (31)	1989	Vertical parallax radiology	OO and PAN
Miller et al. (32)	1990	Cross-sectional tomography	
Jensen (33)	1990	Free-focus radiography	PAN
Tammisalo et al. (34)	1992	Scanora	
Ong (35)	1994	Alternative to VO	AO
Felice and Lombardi (36)	1995	Water's view	Water's view and PAN
Gray et al. (37)	1996	MRI	
Preda et al. (38)	1997	Spiral CT	
Jacobs (11)	1999	Right angle technique	PAN and AO
Jacobs (39)	2000	Cross- sectional occlusal radiography	AO and PAN
Kim et al. (40)	2003	SLUOBD method	PAN and PA
Tony and Alfred (41)	2010	Tangential radiography	PAN and AO
Tymofiyeva et al. (42)	2010	dMRI	

PA, periapical radiograph; AO, anterior occlusal; VO, vertex occlusal; OO, oblique occlusal; LC, lateral cephelogram; PA skull, posteroanterior view of skull; PAN, panoramic radiograph.

this technique is not recommended for Class II division 2 malocclusion patients (44), where the retroclination of the maxillary incisors results in the frontal bone obscuring the incisor region. However, probably because of the dosage issues and the quality of the poor image, this method is no longer favored.

3.3 Vertical tube shift technique (VTST)

This method was introduced with the combination of panoramic and occlusal radiographs to localize an unerupted tooth in the anterior region of the maxilla (16). To obtain the panoramic radiography, the tube is positioned behind the patients' head at an angle of −7° to the occlusal plane, and the film is placed in front of the head. Nevertheless, to aid the interpretation of tube shift, the tube can be considered to be in front of the patients' head at an effective angle of +7°, and the anterior occlusal radiograph is taken at an angle of +60° to 65° to the occlusal plane (Figure 3). Although a VTST using the PR and OR is usually not as easy to interpret, the PR-OR combination is traditionally preferred. This is because the PR, which contains information about all the teeth in both arches as well as about the jaws and surrounding structures, is often already available; it is usually taken as an initial radiograph, so only one additional exposure is required (anterior occlusal). Eventually, modifications were made in the angulations of VTST; the difference in the positioning of the tube for illustrations for occlusal radiographs 60^0 and 70^0 has been demonstrated. However, the recommendation is to increase the tube angle from 60^0 to 65^0 and 70^0 to 75^0 (11, 39). In a panoramic radiograph, the relationship between the images of the un-erupted ST with the reference objects is unaltered if the x-ray tube is considered to be on the facial side of the arches rather than on the lingual or buccal. The larger the distance between the impacted tooth and the image of an impacted tooth with a given x-ray tube movement, results in the easier determination of its position. Both the positions of the crown and of the root apex should be checked to gain a full picture of the position of the impacted tooth. Furthermore, it has been stated that this combination of radiographs should provide the clinician with a good diagnostic yield for the radiation dose given (44).

3.4 Cone beam computerized tomography [CBCT]

The CBCT respectively offers 3D- imaging of the maxillofacial region, providing the opportunity to study objectives in all standard plans with 3D reconstruction in multi-section views (17). The exact localization of supernumerary teeth is often difficult to assume by using conventional radiological techniques like PVTSAN or intra-oral dental films. A preoperative radiological investigation using CBCT on patients who are prepared to undergo surgery for impacted and supernumerary teeth in the frontal maxilla can more certainly indicate the nature of the pathology and hence enhance the surgical safety (Figure 4).

4 Discussion

A combination of clinical and radiological assessments is necessary for the diagnosis of supernumerary teeth. Most often, clinicians will take radiographs based on clinical information to confirm the diagnosis of supernumerary teeth. The localization of supernumerary teeth from radiographs is an important diagnostic adjunct to clinical assessment, diagnosis, and treatment planning. This is most important when surgical

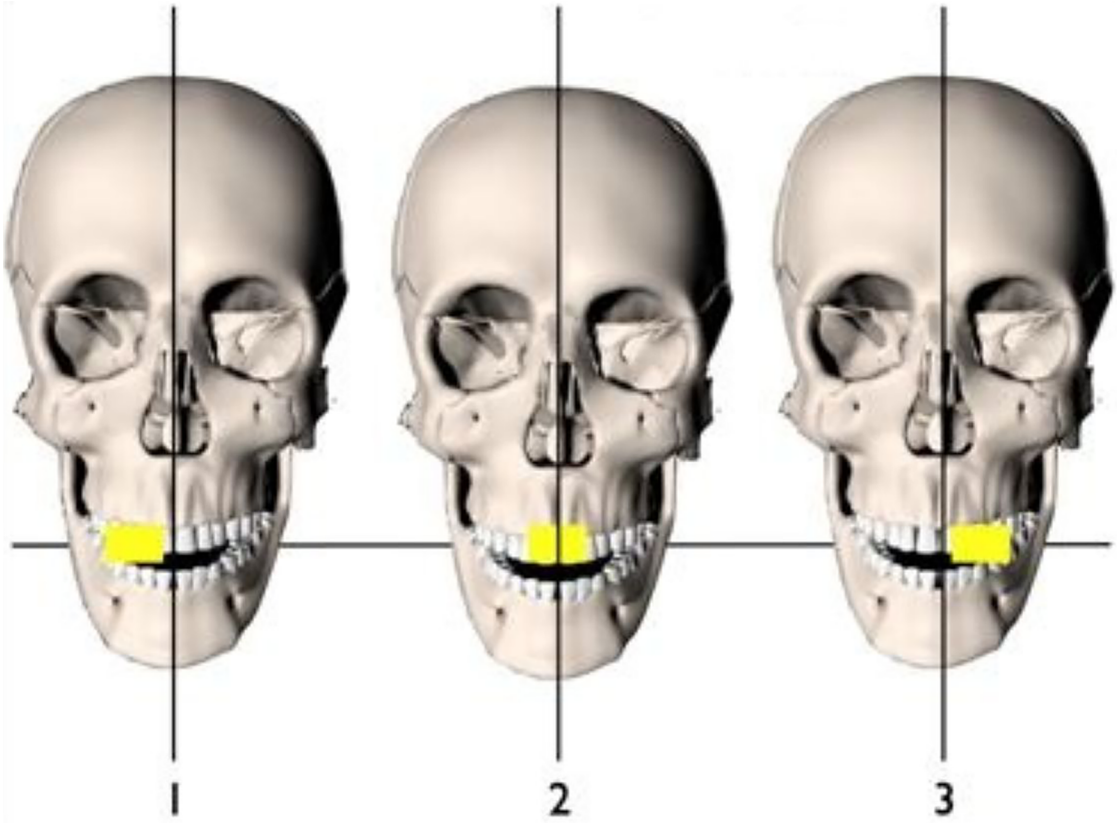


FIGURE 1
Schematic illustration of Clark's technique using horizontal tube shift.

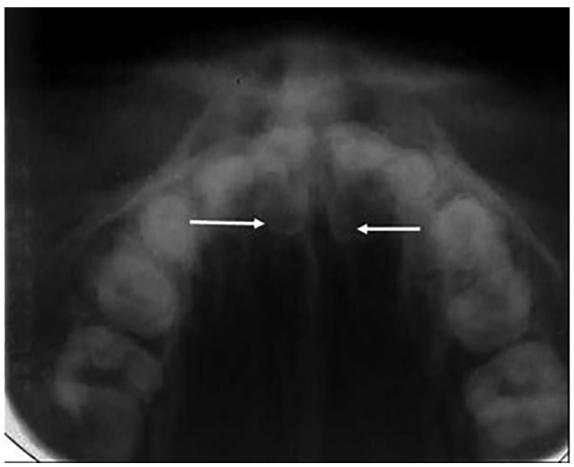


FIGURE 2
Two palatally located supernumerary teeth [arrows] on a vertex occlusal film, note the lack of clarity of images.

intervention is required. To evaluate the position and orientation of supernumerary teeth, the most commonly obtained radiographs are periapical, occlusal, panoramic, and lateral cephalograms. By localizing the supernumerary teeth, the site and extension of the flap margins and the amount of bone removal can be planned prior to surgical intervention. Although periapical, occlusal, and panoramic radiographs are usually able to provide the required information, these modalities do not always provide sufficient information concerning the 3-dimensional [3D] relationship of the supernumerary teeth and the surrounding structures for surgical planning (45, 46). One of the limitations of a single radiograph is its relative inability to demonstrate the relationship between two objects that are either side by side or superimposed (47). It is difficult to determine whether both are in the middle of the bone or buccal or lingual to each other. Furthermore, numerous alternative localization strategies have been articulated as a principle for interpreting buccal and lingual relationships in serial images produced from different techniques. However, different imaging modalities, ranging from intra-oral and extra-oral radiographs to computed tomography (CT) have been used for the evaluation of supernumerary teeth. The most frequently used localization techniques are the horizontal (13) and vertical tube shift (16) techniques using conventional radiographs. Stereoscopic methods (18) were used to localize the foreign bodies, such as bullets and impacted teeth prior to Clark's horizontal tube shift technique (13). Subsequently, based on this principle, various tube shift techniques have been proposed in the literature. However, the interpretation of both techniques enables the

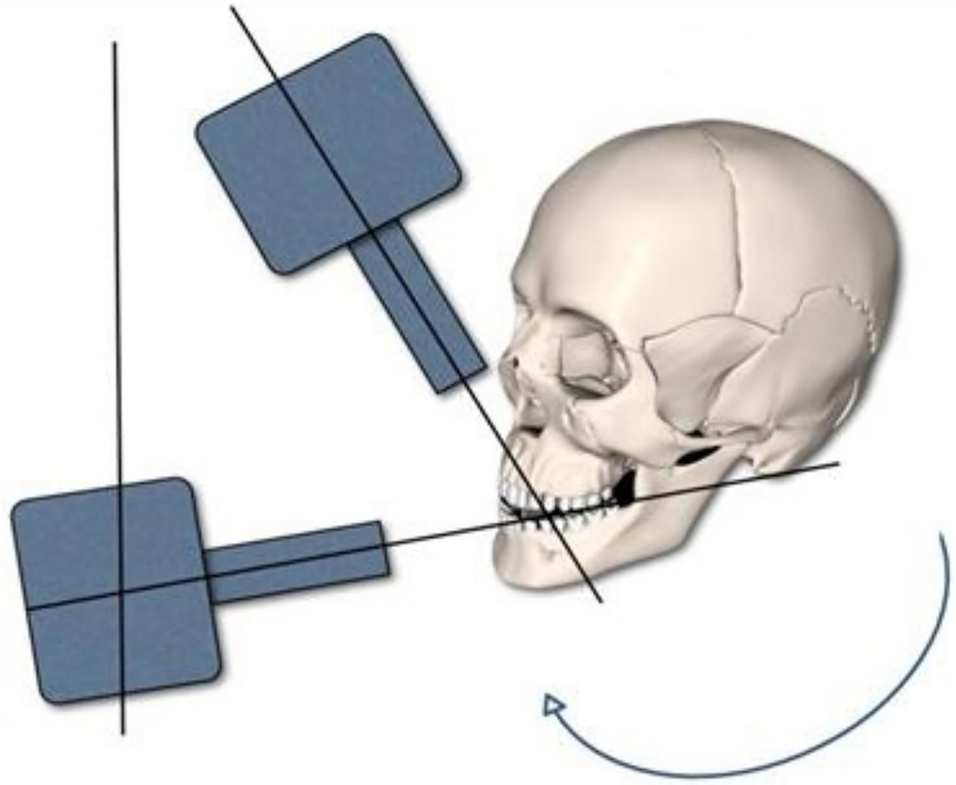


FIGURE 3
Schematic diagram of the vertical tube shift technique.

clinician to determine the relative position of the displaced tooth (48). The clinical signs provide preliminary information that later is confirmed by radiographic examination.

The treatment decisions have traditionally been based on planar 2-dimensional radiographs such as intraoral and extraoral radiographs (49). Although many localization techniques have been proposed using different combinations of radiographs, they just provide a 2-dimensional view of 3-dimensional structures. The introduction of cone-beam computerized tomography [CBCT] in dentomaxillofacial radiology has created new diagnostic possibilities, which includes evaluating supernumerary teeth (50). However, currently, CBCT has limited usage due to its high cost, low vertical resolution, and high radiation dosage (51). CBCT can be used to provide a 3-dimensional visualization of the oral maxillofacial complex, which aids in the formation of the treatment plan (52). This new imaging technique provides a rapid 3D volumetric image, with low radiation exposure than conventional CT. Using CBCT, the clinician can view the data in axial, sagittal, and coronal sections in three dimensions. Besides, it is possible to obtain periapical, panoramic, occlusal, and lateral cephalograms from a single cone beam scan. CBCT provides a 3-dimensional view with more detailed and accurate imaging compared to conventional and digital radiographs. Nevertheless, the clinician should determine the risks and benefits of imaging for each individual. Furthermore, some significant factors need to be considered; when deciding whether to purchase a CBCT device or to refer patients to imaging centers which include cost, the time required to generate images, training, data transmission and storage, knowledge about software, and accountability for the interpretation and review of the pathology. Many published studies and case reports have accepted the use of CBCT images in oral maxillofacial surgery, dental implantology, orthodontics, and pediatric dentistry because of measurement accuracy, comparisons between 2-D and 3-D images for diagnosis and treatment planning, and the clinical use of native 3-D information. The exposure dose for CBCT devices is typically in the range between 40 and 135 μSV, and the scan time generally from 5.7 to 40 s. The effective absorbed radiation dose for a complete cone beam volume tomographic image of the maxillofacial area is within the range for a full-mouth set of periapical films (53). There is controversy over the prophylactic removal of unerupted supernumerary teeth, which do not have any apparent pathological complications. It has been suggested that early removal prevents space loss and avoids extensive orthodontic treatment in the future (52). Alternatively, studies have reported an eruption rate of approximately 80% for supernumerary teeth positioned normally (54, 55). Accurate localization of supernumerary teeth is required to make a comprehensive diagnosis, determine the appropriate surgical access, and treatment planning. For a pediatric patient, knowing the exact position of supernumerary teeth is paramount to avoiding potential complications. The risk of problems associated with the supernumerary teeth in the anterior maxillary region, early

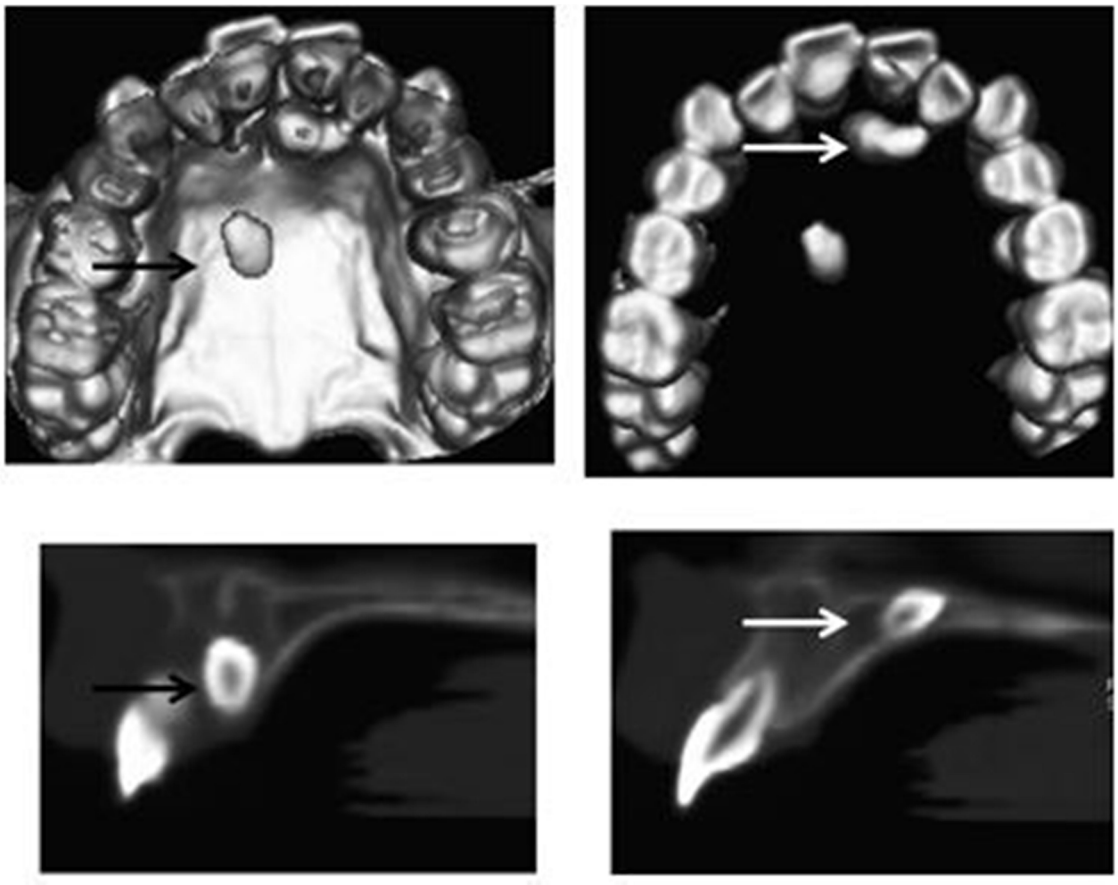


FIGURE 4
Cone beam computerized tomography 3D images are used for the localization of supernumerary teeth [arrows].

diagnosis of disturbances, and proper management are considered to be important in factors growing children (56). A recent revolution of artificial intelligence (AI) when used in dentistry has given new scope for the identification of supernumerary teeth using various AI tools (57–59). The AI technologies, especially in dental imaging, enhance accuracy and efficiency to identification, and hence management of dental anomalies (57). The incorporation of artificial intelligence in dental practices is through enhancing diagnostic accuracy and making tailored treatment strategies possible. AI systems such as Diagnocat analyze, dental images used to identify supernumerary teeth and offer a comprehensive treatment planning option that demonstrates AI's capability to improve diagnostic accuracy and efficiency in dentistry (59). AI-powered tools that use deep learning neural networks are excellent at identifying and numbering teeth on panoramic x-rays, that is necessary for identifying supernumerary teeth (60, 61).

Although, CBCT and traditional radiographs are equally effective for the initial diagnosis of pathology. CBCT provides more information on the location of pathology and the presence of root resorption, which is crucial for treatment planning (62, 63). However, there has been limited research on various conventional radiographic methods for localizing impacted teeth (59, 62–64). Most of the reports in the literature focus on the localization of impacted canines and third molars, with only a few studies reporting on the localization of supernumerary teeth (65, 66). A recent study revealed that VTST outperforms HTST in accurately locating supernumerary teeth in the anterior region of the maxillary arch (65). However, the results are not statistically significant. The CBCT is better than traditional radiography because it offers accurate and authentic anatomical information with excellent surgical predictability without distortion or artifacts. It reduces costs and surgical challenges, enabling faster surgery completion (66). Researchers have reported no significant difference in localizing dilacerations, supernumerary teeth, and impacted incisors in the anterior region of the maxilla using a periapical film instead of an anterior occlusal film (2, 40). Most recently, several studies focused on using 3D imaging for the identification of the supernumerary teeth (61, 67). Toureno et al. (67) proposed a guideline for the identification and localization of supernumerary teeth in both two and three dimensions. The guideline aimed to minimize treatment errors and enhance communication among healthcare professionals and third-party administrators. CBCT provides clear 3D images that help doctors accurately locate missing teeth and other structures in the area (66–68). This is important for planning effective treatment and surgeries. Studies

have shown that CBCT is more accurate at diagnosing than 2D radiographs, with an accurate preoperative finding rate (68–70). Recently various epidemiological studies used CBCT to report the prevalence of supernumerary teeth. It was truly evident that the trends of shifting from two-dimensional imaging to CBCT can better assess the number, location, shape, and position of supernumerary teeth, providing a comprehensive evaluation that is beneficial for preventing complications (69–72). Nevertheless, in situations involving multiple supernumerary teeth or when precise positioning is crucial, CBCT remains the preferred choice (72, 73). Even though CBCT excels in numerous facets, two dimensionals radiographs certain their significance in preliminary evaluations because of their economical nature and lower radiation risk (74). The is narrative review evaluates the available localization techniques when used to locate the position of impacted teeth, particularly supernumerary teeth.

5 Conclusion

The most commonly used localization techniques for supernumerary teeth are horizontal tube shift, vertex occlusal, vertical tube shift, and cone-beam computerized tomography. Unfortunately, conventional radiographs are only able to provide two-dimensional views of three-dimensional structures. Nevertheless, three-dimensional imaging alone can provide precise and accurate data on impacted supernumerary teeth however, the need for this film has to be justified because of the higher radiation exposure. The paper also describes the trends in the use of other various techniques for the localization of supernumerary teeth.

Author contributions

SM: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. RA: Conceptualization, Funding acquisition, Investigation, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing. JJ: Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. NK: Funding acquisition, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

Publisher's note

References

1. Omer RS, Anthonappa RP, King NM. Determination of the optimum time for surgical removal of unerupted anterior supernumerary teeth. *Pediatr Dent*. (2010) 32:14–20.

2. Seehra J, Mortaja K, Wazwaz F, Papageorgiou SN, Newton JT, Cobourne MT. Interventions to facilitate the successful eruption of impacted maxillary incisor teeth due to the presence of a supernumerary: a systematic review and meta-analysis. *Am J Orthod Dentofacial Orthop*. (2023 May) 163(5):594–608. doi: 10.1016/j.ajodo.2023.01.004

3. King NM, Lee AM, Wan PK. Multiple supernumerary premolars: their occurrence in three patients. *Aust Dent J*. (1993) 38:11–6. doi: 10.1111/j.1834-7819.1993.tb05445.x

4. Khalaf K, Brook AH, Smith RN. Genetic, epigenetic and environmental factors influence the phenotype of tooth number, size and shape: anterior maxillary supernumeraries and the morphology of mandibular incisors. *Genes*. (2022) 13(12):2232. doi: 10.3390/genes13122232

5. Brook AH. Dental anomalies of number, form and size: their prevalence in British schoolchildren. *J Int Assoc Dent Child*. (1974) 5:37–53.

6. Anthonappa RP, Omer RS, King NM. Characteristics of 283 supernumerary teeth in southern Chinese children. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. (2008) 105:48–54. doi: 10.1016/j.tripleo.2008.01.035

7. Anthonappa RP, King NM, Rabie AB. Aetiology of supernumerary teeth: a literature review. *Eur Arch Paediatr Dent*. (2013) 14:279–88. doi: 10.1007/s40368-013-0082-z

8. Anthonappa RP, King NM, Rabie AB. Prevalence of supernumerary teeth based on panoramic radiographs revisited. *Pediatr Dent*. (2013) 35:257–61.

9. Rayne J. Impacted upper canines. *Dent Cadmos*. (1969) 37:1130–52.

10. Williams BH. Diagnosis and prevention of maxillary cuspid impaction. *Angle Orthod*. (1981) 51:30–40.

11. Jacobs SG. Radiographic localization of unerupted maxillary anterior teeth using the vertical tube shift method. The history and application of the method with some case reports. *Am J Orthod Dentofac Orthop*. (1999) 116:415–23. doi: 10.1016/S0889-5406(99)70226-X

12. Anthonappa RP, King NM, Rabie AB, Mallineni SK. Reliability of panoramic radiographs for identifying supernumerary teeth in children. *Int J Paediatr Dent*. (2012) 22:37–43. doi: 10.1111/j.1365-263X.2011.01155.x

13. Clark C. A method of ascertaining the position of unerupted teeth by means of film radiographs. *Proc R Soc Med*. (1910) 3:87–90.

14. Counihan K, Al-Awadhi EA, Butler J. Guidelines for the assessment of the impacted maxillary canine. *Dent Update*. (2013) 40:770–7. doi: 10.12968/denu.2013.40.9.770

15. Hitchin AD. The impacted maxillary canine. *Dent Pract Dent Rec*. (1951) 2:100–3.

16. Keur JJ. Radiographic localization techniques. *Aust Dent J*. (1986) 31:86–90. doi: 10.1111/j.1834-7819.1986.tb02566.x

17. Mozzo P, Procacci C, Tacconi A, Martini PT, Andreis IAB. A new volumetric CT machine for dental imaging based on the cone-beam technique: preliminary results. *Eur Radiol*. (1998) 8:1558–64. doi: 10.1007/s003300050586

18. Davidson JM. Roentgen rays and localisation: an apparatus for exact measurement and localisation by means of roentgen rays. *Br Med J*. (1898) 1:10–3. doi: 10.1136/bmj.1.1931.10

19. Bosworth LL. Multiple exposure technique. *Dent Cosmos*. (1934) 76( ):589.

20. Donovan MH. Occlusal radiography of the mandibular third molar. *Dent Radiogr Photogr*. (1952) 25:53–5.

21. Richards AG. Roentgenographic localization of the mandibular canal. *J Oral Surg*. (1952) 10:325–9.

22. Broadway RT, Gould DG. Surgical requirements of the orthodontist. *Br Dent J*. (1960) 108( ):1187–90.

23. Seward GR. Radiology in general dental practice: unerupted maxillary canines, central incisors and supernumeries. *Br Dent J*. (1963) 115:85–9.

24. Wraith KW. Methods of repositioning the misplaced canine. *Dent Pract Dent Rec*. (1969) 19:387–93.

25. Turk MH, Katzenell J. Panoramic localization. *Oral Surg Oral Med Oral Pathol Endod*. (1970) 29:212–5. doi: 10.1016/0030-4220(70)90084-8

26. Hounsfield GN. Computerised transverse axial scanning [tomography]. *Br J Radiol*. (1973) 46:1016–22. doi: 10.1259/0007-1285-46-552-1016

27. Ostrofsky MK. Localization of impacted canines with Status-X radiography. *Oral Surg Oral Med Oral Pathol*. (1976) 42:529–33. doi: 10.1016/0030-4220(76)90301-7

28. Beeching BW. Parallax with the panorex. *Br Dent J*. (1981) 151:369–73. doi: 10.1038/sj.bdj.4804707

29. Coupland MA. Localisation of misplaced maxillary canines: orthopantomograph and P.A. Skull views compared. *Br J Orthod*. (1984) 11:27–32. doi: 10.1179/bjo.11.1.27

30. Ericson S, Kurol J. Radiographic assessment of maxillary canine eruption in children with clinical signs of eruption disturbance. *Eur J Orthod*. (1986) 8:133–40. doi: 10.1093/ejo/8.3.133

31. Southall PJ, Gravely JF. Vertical parallax radiology to localize an object in the anterior part of the maxilla. *Br J Orthod*. (1986) 16:79–83. doi: 10.1179/bjo.16.2.79

32. Miller CS, Nummikoski PV, Barnett DA, Langlais RP. Cross-sectional tomography. A diagnostic technique for determining the buccolingual relationship of impacted mandibular third molars and the inferior alveolar neurovascular bundle. *Oral Surg Oral Med Oral Pathol*. (1990) 70:791–7. doi: 10.1016/0030-4220(90)90023-L

33. Jensen TW. Fine-detail panoramic radiography by free-focus radiography. A clinical demonstration of diagnostic radiographs. *Oral Surg Oral Med Oral Pathol*. (1990) 70:502–15. doi: 10.1016/0030-4220(90)90219-I

34. Tammisalo E, Hallikainen D, Kanerva H, Tammisalo T. Comprehensive oral x-ray diagnosis: scanora multimodal radiography. A preliminary description. *Dentomaxillofac Radiol*. (1992) 21:9–15. doi: 10.1259/dmfr.21.1.1397455

35. Ong A. An alternative technique to the vertex/true occlusal view. *Am J Orthod Dentofacial Orthop*. (1994) 106:621–6. doi: 10.1016/S0889-5406(94)70087-7

36. Di Felice R, Lombardi T. Ectopic third molar in the maxillary sinus: case report. *Aust Dent J*. (1995) 40:236–7. doi: 10.1111/j.1834-7819.1995.tb04802.x

37. Gray CF, Redpath TW, Smith FW. Pre-surgical dental implant assessment by magnetic resonance imaging. *J Oral Implantol*. (1996) 22:147–53.

38. Preda LA, La Fianza A, Di Maggio EM, Dore R, Schifino MR, Campani R, et al. The use of spiral computed tomography in the localization of impacted maxillary canines. *Dentomaxillofac Radiol*. (1997) 26:236–41. doi: 10.1038/sj.dmfr.4600258

39. Jacobs SG. Radiographic localization of unerupted teeth: further findings about the vertical tube shift method and other localization techniques. *Am J Orthod Dentofacial Orthop*. (2000) 118:439–47. doi: 10.1067/mod.2000.108782

40. Kim JD, Lee CY, You CH. The radiographic localization of unerupted maxillary incisors and supernumeraries. *Korean J Oral Maxillofac Radiol*. (2003) 33:217–21.

41. Tony A. Localization of impacted maxillary anterior tooth with tangential radiograph. *H K Dent J*. (2009) 6:46–8.

42. Tymofiyeva O, Rottner K, Jakob PM, Richter EJ, Proff P. Three-dimensional localization of impacted teeth using magnetic resonance imaging. *Clin Oral Investig*. (2010) 14:169–76. doi: 10.1007/s00784-009-0277-1

43. McNicol A, Stirrups DR. Radiation dose during the dental radiographic techniques most frequently used during orthodontic treatment. *Eur J Orthod Dentomaxillofac Radiol*. (2012) 41:444–9. doi: 10.1259/dmfr/19442214

44. Langlais RP, Langland OE, Morris CR. Radiographic localization techniques. *Dent Radiogr Photogr*. (1979) 52:69–77.

45. Gavel V, Dermaut L. The effect of changes in tooth position of unerupted canines on cephalograms. *Eur J Orthod*. (2003) 25:49–56. doi: 10.1093/ejo/25.1.49

46. Frederiksen NL. Guidelines for prescribing dental radiographs. United states food and drug administration. *Tex Dent J*. (1995) 112:63–7.

47. Schulze D, Heiland M, Thurmann H, Adam G. Radiation exposure during midfacial imaging using 4- and 16-slice computed tomography, cone beam computed tomography systems, and conventional radiography. *Dentomaxillofac Radiol*. (2004) 33:83–6. doi: 10.1259/dmfr/28403350

48. Ludlow JB, Davies-Ludlow LE, Brooks SL. Dosimetry of two extraoral direct digital imaging devices: NewTom cone beam CT and orthophos plus DS panoramic unit. *Am J Orthod Dentofacial Orthoped*. (2005) 128:418–23. doi: 10.1016/j.ajodo.2004.04.033

49. Howerton WB Jr, Mora MA. Advancements in digital imaging: what is new and on the horizon? *J Am Dent Assoc*. (2008) 139:20–4. doi: 10.14219/jada.archive.2008.0354

50. Mah JK, Danforth RA, Bumann A, Hatcher D. Radiation absorbed in maxillofacial imaging with a new dental computed tomography device. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. (2003) 96:508–13. doi: 10.1016/S1079-2104(03)00350-0

51. Ludlow LE, Brooks SL, Howerton WB. Dosimetry of 3 CBCT devices for oral and maxillofacial radiology: CB Mercuray, NewTom 3G, and i-CAT. *Dentomaxillofac Radiol*. (2006) 35:219–26. doi: 10.1259/dmfr/14340323

52. Mallineni SK, Alassaf A, Almulhim B, Alghamdi S. Dental anomalies in primary dentition among Arabian children: a hospital-based study. *Children*. (2024) 11(3):366. doi: 10.3390/children11030366

53. Kau CH, Richmond S, Palomo JM, Hans MG. Three-dimensional cone beam computerized tomography in orthodontics. *J Orthod*. (2005) 32:282–3. doi: 10.1179/146531205225021285

54. Pescia R, Kiliaridis S, Antonarakis GS. Spontaneous eruption of impacted maxillary incisors after surgical extraction of supernumerary teeth: a systematic review and meta-analysis. *Clin Oral Investig*. (2020) 24(11):3749–59. doi: 10.1007/s00784-020-03369-3

55. Mallineni SK, Aldhuwayhi S, Deeban Y, Almutairi KS, Alhabrdi SN, Almidaj MA, et al. Prevalence, occurrence, and characteristics of supernumerary teeth among the Saudi Arabian population using panoramic radiographs. *Diagnostics*. (2024) 14(22):2542. doi: 10.3390/diagnostics14222542

56. Brinkmann JC, Martínez-Rodríguez N, Martín-Ares M, Sanz-Alonso J, Marino JS, Suárez García MJ, et al. Epidemiological features and clinical repercussions of supernumerary teeth in a multicenter study: a review of 518 patients with hyperdontia in Spanish population. *Eur J Dent*. (2020) 14(3):415–22. doi: 10.1055/s-0040-1712860

57. Hayashi-Sakai S, Nishiyama H, Hayashi T, Sakai J, Shimomura-Kuroki J. Deep learning with convolution neural network detecting mesiodens on panoramic radiographs: comparing four models. *Odontology*. (2025) 113(1):448–55. doi: 10.1007/s10266-024-00980-8

58. Kaya E, Güneç HG, Ürkmez EŞ, Aydın KC, Fehmi H. Deep learning for diagnostic charting on pediatric panoramic radiographs. *Int J Comput Dent*. (2024 Oct 15) 27(3):225–33. doi: 10.3290/j.ijcd.b4200863

59. Mladenovic R, Arsic Z, Velickovic S, Paunovic M. Assessing the efficacy of ai segmentation in diagnostics of nine supernumerary teeth in a pediatric patient. *Diagnostics*. (2023) 13(23):3563. doi: 10.3390/diagnostics13233563

60. Mine Y, Iwamoto Y, Okazaki S, Nakamura K, Takeda S, Peng TY, et al. Detecting the presence of supernumerary teeth during the early mixed dentition stage using deep learning algorithms: a pilot study. *Int J Paediatr Dent*. (2022) 32(5):678–85. doi: 10.1111/ipd.12946

61. Katheria BC, Kau CH, Tate R, Chen JW, English J, Bouquot J. Effectiveness of impacted and supernumerary tooth diagnosis from traditional radiography versus cone beam computed tomography. *Pediatr Dent*. (2010) 32:304–49.

62. Henninger E, Friedli L, Makrygiannakis MA, Zymperdikas VF, Papadopoulos MA, Kanavakis G, et al. Supernumerary tooth patterns in non-syndromic white European subjects. *Dent J*. (2023) 11(10):230. doi: 10.3390/dj11100230

63. Hadziabdic N, Haskic A, Mujkic A, Hasic-Brankovic L, Dzankovic A, Korac S, et al. Epidemiological, clinical and radiographic features of supernumerary teeth in nonsyndromic Bosnian and Herzegovinian population: a monocentric study. *Med Arch*. (2022) 76(5):348–53. doi: 10.5455/medarh.2022.76.348-353

64. He L, Que G, Yang X, Yan S, Luo S. Prevalence, clinical characteristics, and 3-dimensional radiographic analysis of supernumerary teeth in Guangzhou, China: a retrospective study. *BMC Oral Health*. (2023) 23(1):351. doi: 10.1186/s12903-023-03032-9

65. Mallineni SK, Anthonappa RP, King NM. Reliability of horizontal and vertical tube shift techniques in the localisation of supernumerary teeth. *Eur Arch Paediatr Dent*. (2016) 17(6):455–60. doi: 10.1007/s40368-016-0253-9

66. Ziegler CM, Klimowicz TR. A comparison between various radiological techniques in the localization and analysis of impacted and supernumerary teeth. *Indian J Dent Res*. (2013) 24(3):336–41. doi: 10.4103/0970-9290.117998

67. Toureno L, Park JH, Cederberg RA, Hwang EH, Shin JW. Identification of supernumerary teeth in 2D and 3D: review of literature and a proposal. *J Dent Educ*. (2013) 77(1):43–50. doi: 10.1002/j.0022-0337.2013.77.1.tb05441.x

68. Jiang Y, Ma X, Wu Y, Li J, Li Z, Wang Y, et al. Epidemiological, clinical, and 3-dimentional CBCT radiographic characterizations of supernumerary teeth in a non-syndromic adult population: a single-institutional study from 60,104 Chinese subjects. *Clin Oral Investig*. (2020) 24(12):4271–81. doi: 10.1007/s00784-020-03288-3

69. Ma X, Jiang Y, Ge H, Yao Y, Wang Y, Mei Y, et al. Epidemiological, clinical, radiographic characterization of non-syndromic supernumerary teeth in Chinese children and adolescents. *Oral Dis*. (2021) 27(4):981–92. doi: 10.1111/odi.13628

70. Liu X, Ren Q, Bai J, Kang P, Ren G, Li X, et al. Imaging analysis of 1 138 supernumerary teeth by using cone-beam computed tomography. *Hua Xi Kou Qiang Yi Xue Za Zhi*. (2023) 41(6):671–7.

71. Gurler G, Delilbasi C, Delilbasi E. Investigation of impacted supernumerary teeth: a cone beam computed tomograph (CBCT) study. *J Istanb Univ Fac Dent*. (2017) 51(3):18–24.

72. Gurgel CV, Costa AL, Kobayashi TY, Rios D, Silva SM, Machado MA, et al. Cone beam computed tomography for diagnosis and treatment planning of supernumerary teeth. *Gen Dent*. (2012) 60(3):e131–5.

73. Kapila SD, Nervina JM. CBCT In orthodontics: assessment of treatment outcomes and indications for its use. *Dentomaxillofac Radiol*. (2015) 44(1):20140282. doi: 10.1259/dmfr.20140282

74. MacDonald D, Telyakova V. An overview of cone-beam computed tomography and dental panoramic radiography in dentistry in the community. *Tomography*. (2024) 10(8):1222–37. doi: 10.3390/tomography10080092

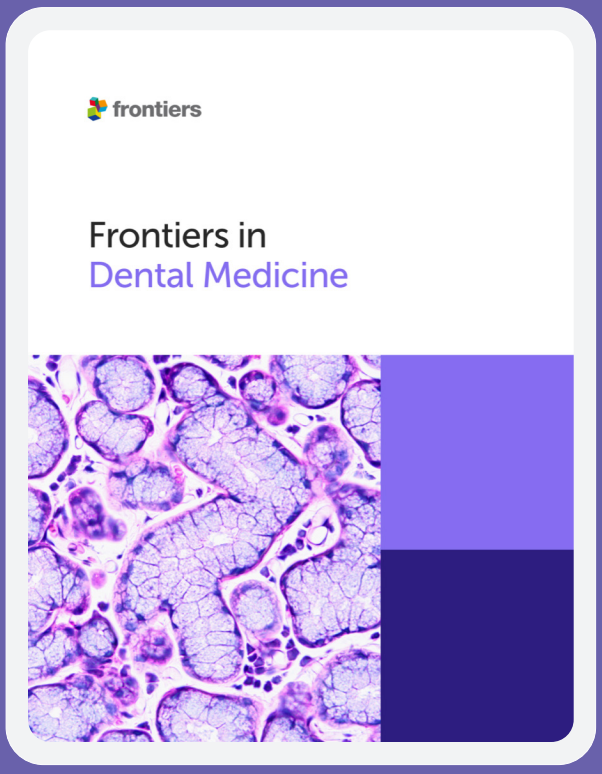
Frontiers in
Dental Medicine

Explores how dental health and disease impacts overall health

An interdisciplinary journal that investigates how dental, oral and craniofacial health and diseases are understood in the context of the whole body. Its goal is to improve oral and overall health outcomes for all communities.

Discover the latest Research Topics

See more →



Frontiers

Avenue du Tribunal-Fédéral 34
1005 Lausanne, Switzerland
frontiersin.org

Contact us

+41 (0)21 510 17 00
frontiersin.org/about/contact