

Supplementary material

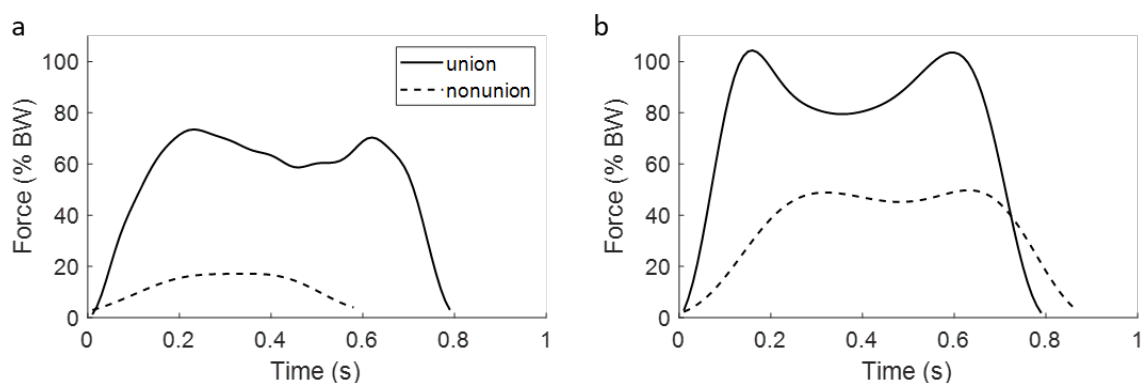


Figure 1. Vertical ground reaction force curves during the stance phase of a patient who showed union and a patient who showed nonunion six weeks (a) and three months (b) after surgery.

Table 1. Gait parameters of patients with union and nonunion at six weeks and three months after surgery. P values < 0.05 are presented in bold.

Gait parameter	Union group at 1 week	Nonunion group at 1 week	Union group at 6 weeks	Nonunion group at 6 weeks	Union group at 3 months	Nonunion group at 3 months
Maximal force (%BW)	13.9 ± 16.5	24.5 ± 19.3	73.2 ± 21.6	35.8 ± 17.9	105.0 ± 14.1	72.8 ± 36.5
Forefoot pressure (%BW/cm ²)	0.5 ± 0.6	0.7 ± 0.8	4.3 ± 2.0	1.4 ± 1.5	7.3 ± 1.6	4.7 ± 2.7
Hindfoot pressure (%BW/cm ²)	1.3 ± 2.1	2.3 ± 2.3	7.5 ± 2.0	3.7 ± 2.9	10.3 ± 1.7	7.2 ± 3.6
Lateral pressure (%BW/cm ²)	0.9 ± 1.6	1.7 ± 1.5	4.4 ± 1.8	2.0 ± 1.5	6.6 ± 0.8	4.4 ± 2.1
Medial pressure (%BW/cm ²)	0.6 ± 0.8	0.9 ± 0.7	3.5 ± 1.3	2.0 ± 0.7	5.3 ± 1.4	3.5 ± 1.6
Lateral forefoot pressure (%BW/cm ²)	0.7 ± 1.0	0.7 ± 0.5	5.2 ± 2.6	1.5 ± 1.8	8.8 ± 2.5	5.7 ± 3.2
Medial forefoot pressure (%BW/cm ²)	0.5 ± 0.6	0.7 ± 1.3	5.4 ± 2.8	1.9 ± 2.1	8.7 ± 2.7	5.4 ± 3.4
Centre of pressure length (AU)	0.21 ± 0.24	0.30 ± 0.21	0.65 ± 0.06	0.44 ± 0.22	0.62 ± 0.05	0.63 ± 0.16

Centre of pressure width (AU)	0.11 ± 0.12	0.16 ± 0.11	0.17 ± 0.07	0.13 ± 0.05	0.16 ± 0.04	0.34 ± 0.06
Centre of pressure position AP (AU)	0.51 ± 0.11	0.44 ± 0.17	0.44 ± 0.07	0.45 ± 0.15	0.45 ± 0.05	0.45 ± 0.10
Centre of pressure position ML (AU)	0.45 ± 0.06	0.44 ± 0.09	0.43 ± 0.03	0.46 ± 0.04	0.41 ± 0.03	0.43 ± 0.02
Stance time (%)	30.9 ± 23.1	55.8 ± 22.2	63.7 ± 3.1	50.6 ± 10.1	68.8 ± 2.4	61.3 ± 6.8
Swing time (%)	69.1 ± 23.1	44.2 ± 22.2	36.3 ± 3.1	49.4 ± 10.1	31.2 ± 2.4	38.7 ± 6.8
Stride time (s)	3.31 ± 1.49	2.58 ± 1.06	1.40 ± 0.29	2.11 ± 0.92	1.25 ± 0.12	1.43 ± 0.14
Stride frequency (strides/min)	25.7 ± 10.4	31.9 ± 13.7	55.1 ± 11.5	39.1 ± 14.3	59.8 ± 5.4	51.0 ± 5.1
Maximal acceleration (g)	1.17 ± 0.17	1.34 ± 0.25	2.47 ± 0.99	1.87 ± 0.35	2.45 ± 0.45	2.52 ± 1.02
Maximal angular velocity (°/s)	68.1 ± 30.4	84.4 ± 54.3	330.3 ± 101.0	170.1 ± 111.8	408.9 ± 45.0	288.4 ± 91.1
Asymmetry maximal force (%)	149.6 ± 46.4	106.0	30.9 ± 31.7	97.5 ± 47.2	-11.1 ± 36.7	48.2 ± 57.9
Asymmetry forefoot pressure (%)	163.7 ± 31.4	147.0 ± 41.2	49.8 ± 47.1	139.3 ± 58.7	-0.2 ± 45.9	56.1 ± 75.6
Asymmetry hindfoot pressure (%)	152.1 ± 64.2	110.4 ± 89.4	27.8 ± 34.5	95.6 ± 67.6	-13.9 ± 32.1	42.9 ± 73.8
Asymmetry lateral pressure (%)	151.0 ± 48.8	106.1 ± 81.2	28.9 ± 39.5	105.2 ± 67.4	-13.9 ± 32.1	41.4 ± 63.5
Asymmetry medial pressure (%)	153.7 ± 43.1	121.8 ± 62.8	41.4 ± 41.7	95.3 ± 26.7	1.2 ± 45.2	54.5 ± 58.2
Asymmetry lateral forefoot pressure (%)	164.2 ± 38.0	141.0 ± 47.8	39.3 ± 50.6	139.2 ± 61.9	-7.1 ± 47.4	47.9 ± 77.1

Asymmetry medial forefoot pressure (%)	169.2 ± 36.9	173.5 ± 38.6	52.5 ± 52.5	137.7 ± 63.7	7.9 ± 50.7	64.6 ± 79.3
Asymmetry centre of pressure length (%)	118.7 ± 73.0	80.0 ± 69.7	3.5 ± 8.5	47.7 ± 44.5	4.9 ± 7.0	12.1 ± 29.7
Asymmetry centre of pressure width (%)	90.1 ± 95.9	61.0 ± 82.9	11.7 ± 53.2	56.2 ± 51.3	19.8 ± 28.1	-2.1 ± 23.5
Asymmetry centre of pressure position AP (%)	-1.4 ± 26.0	8.4 ± 28.1	11.5 ± 20.7	19.8 ± 31.7	8.2 ± 16.7	16.2 ± 19.2
Asymmetry centre of pressure position ML (%)	-4.7 ± 13.5	-3.3 ± 15.4	2.2 ± 7.9	-4.1 ± 11.6	2.6 ± 7.1	3.8 ± 6.4
Asymmetry stance time (%)	104.9 ± 58.8	49.4 ± 40.4	12.5 ± 10.7	46.9 ± 24.4	-1.3 ± 11.5	15.4 ± 16.0
Asymmetry swing time (%)	-137.4 ± 43.7	-115.0 ± 39.9	-29.7 ± 30.2	-91.2 ± 47.3	1.4 ± 21.9	-29.1 ± 29.4
Asymmetry stride time (%)	0.1 ± 0.4	0.2 ± 0.3	-0.0 ± 0.1	-0.0 ± 0.1	0.0 ± 0.0	0.0 ± 0.0
Asymmetry maximal acceleration (%)	33.4 ± 15.8	49.7 ± 41.5	6.5 ± 9.9	41.7 ± 17.1	2.5 ± 10.7	13.4 ± 30.9
Asymmetry maximal angular velocity (%)	94.8 ± 36.8	104.1 ± 39.5	13.9 ± 18.5	51.6 ± 43.4	-0.6 ± 11.3	20.7 ± 16.7

AP = anteroposterior; AU = arbitrary units; BW = body weight; ML = mediolateral

Table 2. Gait parameters of the three patient groups at six months after surgery. P values < 0.05 are presented in bold.

Gait parameter	Union	Longitudinal nonunion	Cross-sectional nonunion
Maximal force (%BW)	102.7 ± 14.8	82.4 ± 17.3	94.4 ± 17.7
Forefoot pressure (%BW/cm ²)	6.9 ± 2.2	4.8 ± 2.4	4.2 ± 2.4
Hindfoot pressure (%BW/cm ²)	10.1 ± 2.0	8.2 ± 2.1	8.0 ± 1.6
Lateral pressure (%BW/cm ²)	6.5 ± 1.3	4.9 ± 1.3	5.3 ± 1.4
Medial pressure (%BW/cm ²)	4.9 ± 1.7	3.8 ± 1.2	3.5 ± 0.9
Lateral forefoot pressure (%BW/cm ²)	9.3 ± 3.2	5.3 ± 2.8	5.4 ± 2.3

Medial forefoot pressure (%BW/cm ²)	8.1 ± 3.9	5.8 ± 3.1	4.7 ± 3.0
Centre of pressure length (AU)	0.66 ± 0.02	0.68 ± 0.07	0.62 ± 0.16
Centre of pressure width (AU)	0.20 ± 0.06	0.19 ± 0.04	0.23 ± 0.08
Centre of pressure position AP (AU)	0.46 ± 0.04	0.42 ± 0.07	0.38 ± 0.11
Centre of pressure position ML (AU)	0.40 ± 0.03	0.43 ± 0.04	0.41 ± 0.03
Stance time (%)	67.3 ± 3.9	61.1 ± 3.5	63.5 ± 1.8
Swing time (%)	32.7 ± 3.9	38.9 ± 3.5	36.5 ± 1.8
Stride time (s)	1.16 ± 0.08	1.29 ± 0.10	1.44 ± 0.16
Stride frequency (strides/min)	64.8 ± 4.8	56.7 ± 4.4	61.0 ± 16.6
Maximal acceleration (g)	3.39 ± 1.14	2.76 ± 1.10	2.85 ± 0.88
Maximal angular velocity (°/s)	463.9 ± 48.6	337.1 ± 133.9	225.7 ± 39.4
Asymmetry maximal force (%)	3.2 ± 12.0	21.1 ± 27.7	16.8 ± 14.3
Asymmetry forefoot pressure (%)	16.3 ± 28.5	51.2 ± 50.6	62.4 ± 60.0
Asymmetry hindfoot pressure (%)	5.1 ± 17.8	22.7 ± 18.9	10.8 ± 8.7
Asymmetry lateral pressure (%)	-0.1 ± 10.1	23.7 ± 34.2	14.3 ± 15.8
Asymmetry medial pressure (%)	19.6 ± 30.2	31.3 ± 27.2	34.1 ± 24.7
Asymmetry lateral forefoot pressure (%)	1.2 ± 24.7	56.0 ± 52.3	61.1 ± 52.2
Asymmetry medial forefoot pressure (%)	31.1 ± 46.8	52.4 ± 48.8	68.7 ± 68.9
Asymmetry centre of pressure length (%)	2.4 ± 2.9	3.2 ± 13.0	19.8 ± 30.6
Asymmetry centre of pressure width (%)	-5.0 ± 32.5	28.5 ± 21.7	-8.6 ± 39.0
Asymmetry centre of pressure position AP (%)	8.5 ± 6.9	23.1 ± 16.1	36.6 ± 28.7
Asymmetry centre of pressure position ML (%)	8.0 ± 7.8	-0.9 ± 11.5	0.1 ± 6.3
Asymmetry stance time (%)	3.0 ± 5.5	15.7 ± 7.0	10.3 ± 10.6
Asymmetry swing time (%)	-6.1 ± 11.2	-30.4 ± 12.3	-22.8 ± 25.3
Asymmetry stride time (%)	0.01 ± 0.04	0.01 ± 0.03	-0.08 ± 0.11
Asymmetry maximal acceleration (%)	-2.1 ± 10.9	29.5 ± 11.5	13.4 ± 25.9
Asymmetry maximal angular velocity (%)	4.3 ± 12.5	9.2 ± 13.3	-19.0 ± 37.1

AP = anteroposterior; AU = arbitrary units; BW = body weight; ML = mediolateral

Table 3. Comparison between longitudinally assessed patients showing union and those showing nonunion at one week and three months after surgery. P values and effect sizes of Mann–Whitney U tests; p values < 0.05 are presented in bold.

Gait parameter	P value (effect size) 1 week (n union 11, n nonunion 5)	P value (effect size) 6 weeks (n union 11, n nonunion 4)	P value (effect size) 3 months (n union 7, n nonunion 5)
Maximal force	0.267 (0.38)	0.026 (-0.77)	0.101 (-0.57)
Forefoot pressure	0.583 (0.20)	0.026 (-0.77)	0.181 (-0.48)
Hindfoot pressure	0.320 (0.35)	0.040 (-0.73)	0.138 (-0.52)
Lateral pressure	0.221 (0.42)	0.026 (-0.77)	0.073 (-0.62)
Medial pressure	0.441 (0.27)	0.026 (-0.77)	0.101 (-0.57)
Lateral forefoot pressure	0.510 (0.24)	0.040 (-0.73)	0.100 (-0.57)
Medial forefoot pressure	0.910 (-0.06)	0.056 (-0.68)	0.101 (-0.57)
Centre of pressure length	0.495 (0.24)	0.177 (-0.50)	0.234 (0.43)
Centre of pressure width	0.570 (0.20)	0.177 (-0.50)	0.022 (0.76)
Centre of pressure position AP	0.308 (-0.35)	0.949 (0.05)	1.000 (0.00)
Centre of pressure position ML	0.571 (-0.20)	0.177 (0.50)	0.234 (0.43)
Stance time	0.040 (0.68)	0.003 (-0.96)	0.051 (-0.67)
Swing time	0.040 (-0.68)	0.003 (0.96)	0.051 (0.67)
Stride time	0.440 (-0.28)	0.040 (0.73)	0.035 (0.71)
Stride frequency	0.510 (0.24)	0.056 (-0.68)	0.008 (-0.86)
Maximal acceleration	0.129 (0.52)	0.343 (-0.36)	0.945 (-0.05)
Maximal angular velocity	0.768 (0.12)	0.138 (-0.55)	0.014 (-0.81)
Asymmetry maximal force	0.320 (-0.35)	0.018 (0.82)	0.295 (0.38)
Asymmetry forefoot pressure	0.583 (-0.20)	0.040 (0.73)	0.366 (0.33)
Asymmetry hindfoot pressure	0.377 (-0.31)	0.104 (0.59)	0.101 (-0.57)
Asymmetry lateral pressure	0.221 (-0.42)	0.056 (0.68)	0.073 (0.62)
Asymmetry medial pressure	0.377 (-0.31)	0.040 (0.73)	0.234 (0.43)
Asymmetry lateral forefoot pressure	0.364(-0.31)	0.018 (0.82)	0.295 (0.38)
Asymmetry medial forefoot pressure	1.000 (0.02)	0.104 (0.60)	0.234 (0.43)
Asymmetry centre of pressure length	0.530 (-0.22)	0.078 (0.64)	0.731 (-0.14)
Asymmetry centre of pressure width	0.775 (-0.11)	0.177 (0.50)	0.181 (0.48)
Asymmetry centre of pressure position AP	0.661 (0.16)	0.753 (0.14)	0.534 (0.24)

Asymmetry centre of pressure position ML	0.827 (0.09)	0.280 (-0.41)	0.945 (0.05)
Asymmetry stance time	0.040 (-0.68)	0.010 (0.86)	0.051 (0.67)
Asymmetry swing time	0.371 (0.32)	0.018 (-0.82)	0.051 (-0.67)
Asymmetry stride time	0.679 (0.16)	0.601 (-0.25)	0.775 (-0.12)
Asymmetry maximal acceleration	0.594 (0.20)	0.003 (0.96)	0.295 (0.39)
Asymmetry maximal angular velocity	0.768 (0.12)	0.226 (0.46)	0.035 (0.71)

AP = anteroposterior; ML = mediolateral

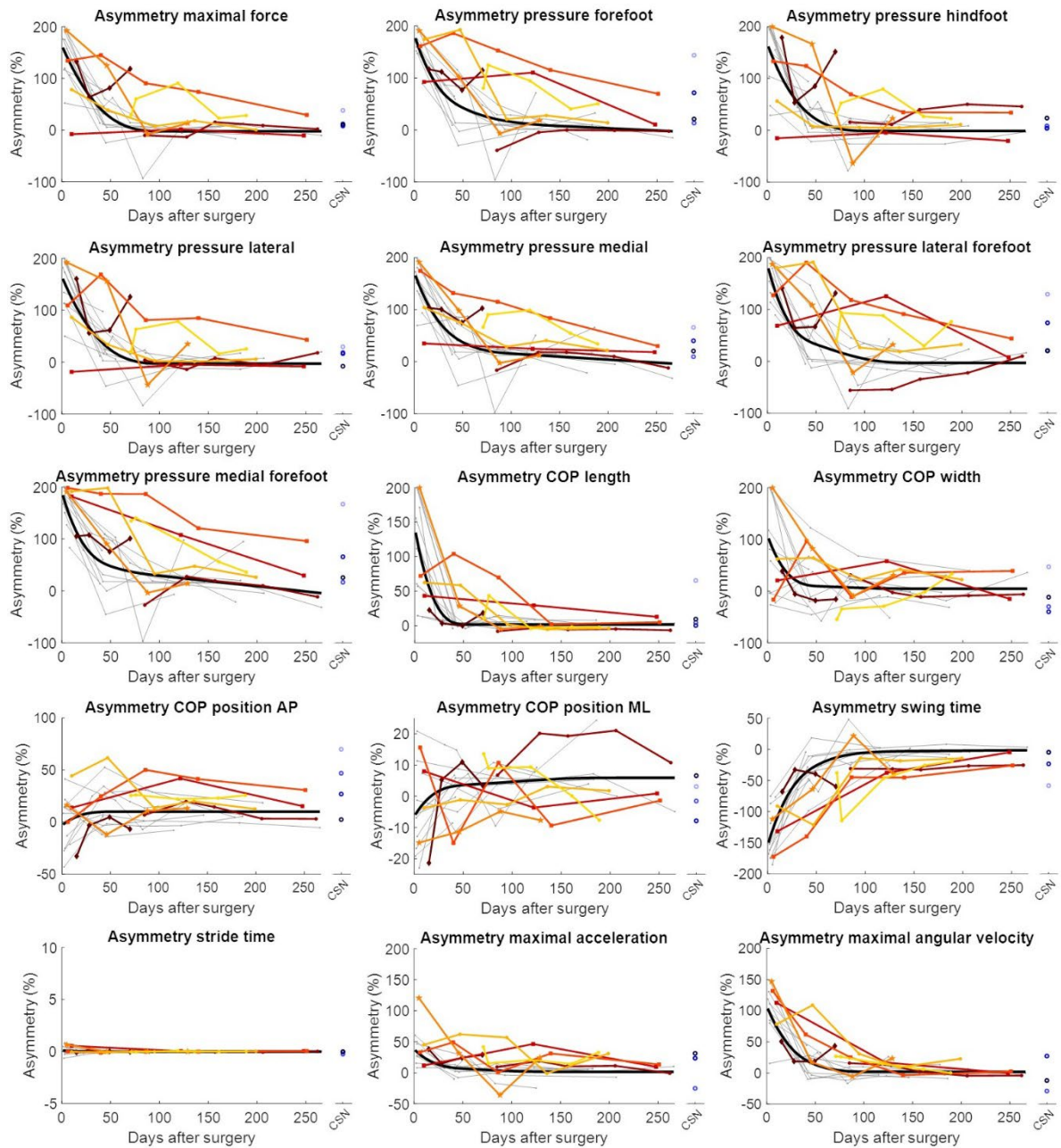


Figure 2. Gait parameters throughout the healing phase of tibial fractures that are less suitable for detecting patients at risk of developing nonunion. Each patient showing union is represented by a grey line. For visualization purposes, the optimal fit for patients who showed union is represented by the thick black line. Longitudinally assessed patients showing nonunion are represented by coloured lines, and cross-sectionally assessed patients showing nonunion (CSN) are represented by blue circles. The datapoints represented with squares represent the two longitudinally assessed patients with diabetes who exhibited nonunion, the dark red diamond-shaped datapoints represent the patient who exhibited nonunion caused by an infection, and the mid-

orange pentagram-shaped data points represent the patient whose implant screws broke between the third and fourth measurements and exhibited nonunion. The gait parameters with the greatest effect sizes throughout healing are represented: a. maximal force; b. maximal pressure on the forefoot; c. maximal pressure on the lateral side of the foot; d. swinging time; e. maximal angular velocity; and f. asymmetry of the stance time. BW = body weight.