

Reference

Ravari, R. ¹, Lewicke², J., Vette^{2,3,4}, A. H., & Hebert^{2,4,5}, J. S.

Changes in the Biomechanical Gait Characteristics of a Bilateral Prosthesis User After Unilateral Transfemoral Osseointegration: A 2-Year Case Study.

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Products

Osseointegration with C-Leg 4 + Trias

Major Findings

For osseointegration (OI) compared to the baseline (BL) socket-suspended prosthesis (both prostheses with C-Leg and Trias):

→ **Improved self-reported function (prosthetic mobility and prosthetic use after OI)**

- Higher Q-TFA Score 6 months after OI compared to BL.

→ **Improved functional mobility prediction after OI**

- Amputee Mobility Predictor (AMP) score increased from 26.0 points (K1 level) at BL to 29.0 points (K2 level) at 6 months post-OI.

→ **Increased functional mobility shown by improvement in timed walking tests after OI**

- Timed up and Go (TUG) performance improved from 39.9 s at BL to 36.2 s (+9.3%) at 12 months after OI and 28.9 s (+27.6%) at 18 months after OI.
- L-Test performance improved from 71.8 s at BL to 63.0 s at 12 months post-OI (+13.6%) and to 53.3 s at 18 months post-OI (+25.0%).

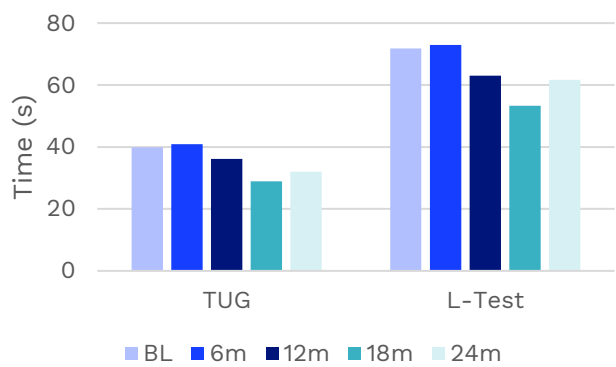


Figure 1. TUG and L-Test times (s) for all time points (m = months post OI).

→ **Partially improved time distance parameter after OI**

- Highest improvements in walking speed, cadence and double support times were found at 18 months after OI indicating improved dynamic stability.
- Details see Table 1

Table 1. Percentual differences for time-distance parameters between 6 and 24 months (m) relative to BL

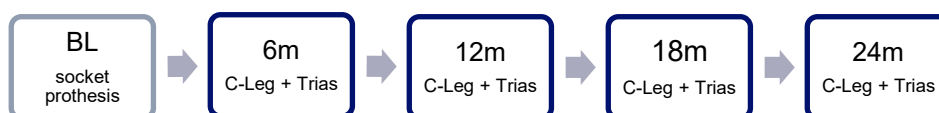
Parameter	6m	12m	18m	24m
Walking speed (m/s)	-6,3 %	-10,4 %	+4,2 %	-8,3 %
Stride length (m)	-11,2 %	-9,2 %	-3,1 %	-9,2 %
Cadence (steps /min)	+5,4 %	-3,0 %	+5,9 %	+0,2 %
Step width (m)	+14,3 %	+35,7 %	+14,3 %	+21,4 %
Right Double Support (% GC)	+10,9 %	+1,9 %	-3,2 %	+5,3 %
Left Double Support (% GC)	+11,6 %	-0,8 %	-1,6 %	+7,1 %

Population

Subjects:	1 female
Amputation level:	bilateral amputation (left: transfemoral, right: transtibial)
Previous prosthesis:	C-leg + trias as socket suspended prosthesis system
Amputation causes:	traumatic
age:	31 years
time since amputation:	10 years
MFCL:	K1

Study Design

longitudinal single-case study with repeated measurements



m = months post OI

At each timepoint measures of gait-biomechanics (Analysis of 3 walking trials at usual speed using 3-D motion capture with 8 markers at 120 Hz), functional mobility (TUG, L-Test, AMP), and satisfaction (Q-TFA) were performed.

Results

Functions and Activities								Participation	Environment
Level walking	Stairs	Ramps, Hills	Uneven ground, Obstacles	Cognitive demand	Metabolic Energy Consumption	Safety	Activity, Mobility, ADLs	Preference, Satisfaction, QoL	Health Economics

Category	Outcomes	Results for C-Leg 4 + Trias mounted on a bone anchored prosthesis after OI versus socket suspended at Baseline (BL) – left side					Sig. ^a
Level walking – Gait analysis	Gait speed (m/s) Ref. ^b : 1.39 ± 0.12	BL	6m	12m	18m	24m	n.a.
		0.48 ± 0.01	0.45 ± 0.01	0.43 ± 0.03	0.50 ± 0.02	0.44 ± 0.01	

Category	Outcomes	Results for C-Leg 4 + Trias mounted on a bone anchored prosthesis after OI versus socket suspended at Baseline (BL) – left side					Sig. ^a
• Spatio-temporal parameters		Gait speed decreased at 6 and 12 months post-OI. At 18 months, it increased to 4.2% above the BL value, whereas at 24 months it decreased to 8.3% below BL.					
	Cadence (steps/min) Ref.: 121.00 ± 7.24	BL	6m	12m	18m	24m	n.a.
		59.10 ± 3.16	62.30 ± 1.36	57.30 ± 5.77	62.60 ± 2.76	59.20 ± 3.57	
		Cadence increased at 6 months post-OI, decreased at 12 months, peaked at 18 months, and nearly returned to BL at 24 months.					
Stride length (m) Ref.: 1.39 ± 0.09	BL	6m	12m	18m	24m	n.a.	
	0.98 ± 0.02	0.87 ± 0.03	0.89 ± 0.03	0.95 ± 0.04	0.89 ± 0.02		
	Stride length remained below BL at all postoperative time points. It increased by 9.2% from 6 to 18 months post-OI and decreased by 6.3% from 18 to 24 months.						
Step width (m) Ref.: 0.11 ± 0.03	BL	6m	12m	18m	24m	n.a.	
	0.14 ± 0.02	0.16 ± 0.01	0.19 ± 0.02	0.16 ± 0.02	0.17 ± 0.00		
	Step width was higher than BL at all post OI timepoints. The lowest post OI value was documented at 6 and 18 months, the highest at 12 months.						
Toe off (% GC) Ref. l: 60.34 ± 1.39 Ref. r: 60.53 ± 1.34		BL	6m	12m	18m	24m	n.a.
	l	67.20 ± 0.84	69.70 ± 1.52	66.40 ± 5.67	70.40 ± 0.56	70.20 ± 2.21	
	r	70.70 ± 1.65	71.00 ± 3.77	73.30 ± 2.46	67.00 ± 2.23	71.50 ± 2.13	
	At BL, toe-off was delayed compared with the reference data on both sides (right: 10.2%; left: 6.7% of the gait cycle). The delay increased at 6 months post-OI and decreased to 6.06% at 12 months. At 24 months, the delay exceeded BL values on both sides, while left-right symmetry improved (left: 9.86%; right: 10.97%).						
Double support (% GC) Ref. l: 21.19 ± 2.39 Ref. r: 21.19 ± 2.39		BL	6m	12m	18m	24m	n.a.
	l	38.00 ± 1.38	42.40 ± 2.98	37.70 ± 4.93	37.40 ± 3.02	40.70 ± 5.19	
	r	37.70 ± 1.38	41.80 ± 2.98	38.40 ± 4.93	36.50 ± 3.02	39.70 ± 5.19	
	Left and right double support times were lowest at 18 months post-OI and highest at 6 months post-OI. Left-right symmetry was highest at BL and lowest at 24 months.						

Category	Outcomes	Results for C-Leg 4 + Trias mounted on a bone anchored prosthesis after OI versus socket suspended at Baseline (BL) – left side						Sig. ^a
Level walking – Gait analysis	Sagittal: Trunk Lean total Range of Motion (ROM) WRT Pelvis (Degree) Ref. l: 3.58 ± 1.49 Ref. r: 3.58 ± 1.45		BL	6m	12m	18m	24m	n.a.
		l	5.56 ± 0.90	4.11 ± 0.25	3.81 ± 0.71	3.38 ± 0.95	3.63 ± 0.33	
Joint kinematics • Trunk		r	5.32 ± 0.09	4.94 ± 0.64	3.65 ± 0.53	2.99 ± 0.23	4.74 ± 1.05	Total trunk lean ROM decreased from BL to 12 months post-OI (left: –1.75°; right: –1.67°), approaching the reference ROM. Left ROM remained close to the reference values at 18 and 24 months.
	Transverse: Trunk Rotation WRT Pelvis at the Left Side (Degree) Ref. l: 15.63 ± 4.90 Ref. r: 15.37 ± 4.99		BL	6m	12m	18m	24m	n.a.
		l	8.14 ± 0.79	6.70 ± 0.47	6.04 ± 0.76	6.22 ± 0.58	4.83 ± 1.30	
		r	8.25 ± 0.50	8.56 ± 2.74	5.63 ± 0.65	7.85 ± 2.62	7.05 ± 2.48	Trunk rotation was lower than the reference value at BL and further decreased at all postoperative timepoints. Left, the lowest postoperative ROM was observed at 24 months (–13.31° vs. BL), whereas the highest postoperative ROM was observed at 6 months (–11.44° vs. BL).
• Pelvis	Pelvic Tilt total ROM (Degree) Ref. l: 3.26 ± 0.93 Ref. r: 3.32 ± 0.95		BL	6m	12m	18m	24m	n.a.
		l	7.27 ± 1.13	8.37 ± 1.22	12.01 ± 1.70	10.69 ± 1.27	9.57 ± 0.99	
		r	6.62 ± 0.64	8.29 ± 0.52	10.01 ± 0.46	9.32 ± 0.72	9.00 ± 1.96	Pelvic tilt ROM was higher than the reference values at BL and further increased postoperatively. Peak ROM was observed at 12 months on both sides (left: +4.74°; right: +3.39° vs. BL), while the lowest postoperative ROM occurred at 6 months (left: +1.10°; right: +1.67° vs. BL).
	Pelvic Obliquity total ROM (Degree) Ref. l: 10.41 ± 3.07 Ref. r: 10.38 ± 2.97		BL	6m	12m	18m	24m	n.a.
		l	5.67 ± 0.83	7.21 ± 0.62	6.50 ± 0.59	6.27 ± 0.69	7.32 ± 0.18	
		r	6.05 ± 1.18	7.34 ± 0.18	7.53 ± 0.36	6.37 ± 0.50	7.54 ± 0.27	Pelvic obliquity ROM was lower than the reference values at all time points on both sides. The lowest values occurred at BL, whereas the highest postoperative values were observed at 24 months (left: +1.65°; right: +1.40° vs. BL). The authors also described hip hiking (offset) on the left side at all time points, with the greatest magnitude at 24 months.
	Pelvic Rotation total ROM (Degree) Ref. l: 11.76 ± 3.11		BL	6m	12m	18m	24m	n.a.
		l	20.08 ± 4.86	10.24 ± 1.53	12.01 ± 3.50	14.09 ± 3.66	13.26 ± 0.57	

Category	Outcomes	Results for C-Leg 4 + Trias mounted on a bone anchored prosthesis after OI versus socket suspended at Baseline (BL) – left side						Sig. ^a
	Ref. r: 11.84 ± 3.24	r	20.40 ± 1.48	7.92 ± 2.15	10.56 ± 3.74	12.62 ± 1.37	13.69 ± 4.51	
		Pelvic rotation ROM was higher than the reference values at BL and decreased at all postoperative time points at both sides. The lowest postoperative ROM occurred at 6 months (left: -9.84°; right: -12.48°). The highest postoperative ROM for the left side was recorded at 18 months (-5.99° compared to BL).						
• Hip	Hip Flex/Extension total ROM (Degree) Ref. l: 42.54 ± 3.07 Ref. r: 42.83 ± 2.43		BL	6m	12m	18m	24m	n.a.
		l	36.73 ± 2.27	29.62 ± 1.20	29.47 ± 3.27	30.36 ± 0.96	31.60 ± 1.90	
		r	49.63 ± 0.50	45.61 ± 0.99	49.49 ± 1.24	44.50 ± 1.11	47.19 ± 1.91	
		Left hip ROM was below the reference values and right hip ROM above the reference values at all time points. For the left side, ROM was highest at BL, lowest at 6 months (-7.11° vs. BL), and reached its highest postoperative value at 24 months (-5.13° vs. BL).						
	Hip Abd/Adduction total ROM (Degree) Ref. l: 12.84 ± 3.31 Ref. r: 12.80 ± 3.47		BL	6m	12m	18m	24m	n.a.
		l	8.78 ± 1.79	6.51 ± 0.66	8.51 ± 1.00	8.26 ± 1.14	9.83 ± 1.27	
		r	7.39 ± 1.02	5.17 ± 0.24	5.80 ± 0.49	5.24 ± 0.64	5.71 ± 0.52	
		Hip frontal plane ROM was lower than the reference values on both sides at BL. On the left side, ROM decreased initially to 6 months (-2.27° vs. BL) and then increased, exceeding the BL value by 1.05° at 24 months. On the right side, all postoperative ROM values remained below BL.						
	Hip Rotation total ROM (Degree) Ref. l: 20.52 ± 3.54 Ref. r: 18.93 ± 3.32		BL	6m	12m	18m	24m	n.a.
		l	23.40 ± 2.04	17.29 ± 8.50	9.71 ± 3.30	9.45 ± 1.32	13.32 ± 1.81	
		r	24.06 ± 3.14	10.35 ± 0.81	12.23 ± 2.42	17.08 ± 1.79	13.17 ± 3.69	
		Hip rotation ROM decreased on both sides at all time points after OI compared with BL. The lowest ROM was observed at 18 months on the left side and at 6 months on the right side. In contrast, the highest postoperative ROM was observed at 6 months on the left side and at 18 months on the right side.						
Activity, Mobility, ADLs	AMP/47 K1: 15–26 K2: 27–36		BL	6m	12m	18m	24m	n.a.
			26.0	29.0	28.0	27.0	32.0	
		AMP improved from K1 at BL to K2 at 6 months post-OI and maintained this level until 24 months. The highest score was observed at 24 months post-OI.						

Category	Outcomes	Results for C-Leg 4 + Trias mounted on a bone anchored prosthesis after OI versus socket suspended at Baseline (BL) – left side					Sig. ^a
	TUG Test (time s)	BL	6m	12m	18m	24m	n.a.
		39.9	40.9	36.2	28.9	32.0	
		TUG improved at all time points post-OI except at 6 months. The greatest improvement was observed at 18 months (11 s; 27.6% lower than BL).					
	L-Test (time s)	BL	6m	12m	18m	24m	n.a.
		71.8	73.0	63.0	53.3	61.7	
		L-test time was improved at all time points after OI compared to BL besides 6 months. The highest improvement was at 18 months (15s, 25.77%)					
Preference, Satisfaction, QoL	Q-TFA	No actual scores were reported. Based on the graphical data, the authors reported improvements in the global score and all subscores at all postoperative time points compared with BL, except for a slight decrease in prosthetic use at 12 months.					n.a.

^a no difference (0), positive trend (+), negative trend (–), significant (++/--), not applicable (n.a.)
^b spatio-temporal and kinematic data from 16 healthy adults (aged 21–59) served as reference

Author’s Conclusion “Although self-reported measures improved 6 months after surgery, functional mobility, spatio-temporal, and kinematic changes took longer to improve, indicating the need for extended recovery.” (Ravari et al., 2026)

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