Safari MR, Meier MR. Systematic review of effects of current transtibial prosthetic socket designs—Part 2: Quantitative outcomes. J Rehabil Res Dev. 2015;52(5):509–26.

Appendix 3. Summary of included studies examining effects of transtibial socket designs.

Study	Participants						Intervention		Outcome	Instrument	Main Conclusions
	N (M/F)	Age, yr (mean ± SD [range])	Inclusion Criteria	Residual Limb Characteristics	Cause of Amputation (*n*)	Other	Socket Type	Socket Use Before Test			
Hoskins et al., 2013 [26]	4 (3/1)	66.75 (58–73)	Wound present on residual limb; VAS user when wound was still open.	Not clear	Ulcer (2), Trauma (1), Infection (1).	BM: 91.88 kg (79–118); Height: 1.77 m (1.67–1.85); YSA: 4–23.	VAS	Not clear.	Wound size (surface area).	Photography camera.	Average of 161.50 d for wound size of 1.94 cm^2 to close; Users were able to ambulate despite presence of wound on residual limb.
Eshraghi et al., 2013 [27]	12 (9/3)	46.86 ± 12.3	No ulcer on residual limb; No residual limb volume change; Ability to ambulate without assistance; Residual limb length: ≥11 cm; Prosthesis user for last 6 mo.	L: 14.5 ± 1.2 cm	Diabetes (7), Trauma (5).	BM: 73.60 ± 11.5 kg; Height: 1.7 ± 0.05 m.	TSB + Dermo pin lock, Seal-In X5, and distal magnetic liners.	Not clear.	Interface pressure during swing.	TekScan (F-Socket transducer).	Pin lock liner showed higher interface pressure than distal magnetic liner at proximal region of both anterior and posterior aspects and distal region of anterior aspect of residual limb; Distal magnetic liner showed smallest mean peak pressure over these regions; Mean peak pressure for Seal-In X5 liner was highest of all 3 liners at all 4 sites measured.
Brunelli et al., 2013 [28]	10 (10/0)	44.9 (24–54)	Unilateral transtibial amputation; Age: 20–65 yr; BM: <116 kg; Carbon fiber foot users; Activity level: K3 or K4; Ability to ascend and descend ramps without aid; Absence of significant clinical disorders.	L: >11 cm	Trauma (8), Infection (1), PVD (1).	BM: 81 ± 15.8 kg; Height: 1.7 ± 0.7 m.	TSB + Seal-In X5 liner and silicone liner with sleeve suspension.	18 mo minimum for sleeve suspension; 7 wk minimum for Seal-In liner.	Pistoning; Energy cost of walking.	Photography camera; Metabolimeter.	Lower amount of pistoning was reported for Seal-In X5 liner; No significant difference between 2 systems in terms of energy cost and walking.
Eshraghi et	10	42 (30–	Unilateral transtibial	L: 14.5 ± 1.3 cm	Diabetes (5),	BM: 79.5 ±	TSB + Dermo pin lock,	1 mo for	Pistoning	7-camera Vicon	Seal-In X5 liner

al., 2012 [29]	(10/0)	72)	amputation; Activity level: K2 and K3; Residual limb free of wounds and pain; No upper limb disability; Experience with silicone liner; No volume fluctuation of residual limb; Ability to ambulate freely; Residual limb length: ≥13 cm.		Trauma (5).	12.2 kg; Height: 1.7 ± 0.05 m.	Seal-In X5, and distal magnetic liners.	each suspension type.	(static condition).	612 motion analysis system.	showed least pistoning among 3 systems; Pin lock and magnetic systems had comparable pistoning; Users reported least problem with Seal-In liner and were most satisfied with cosmesis, suspension, and fit of Seal-In X5 liner.
Ali et al., 2012 [30]	9 (7/2)	49.33 ± 15.05	None.	NR	Trauma (3), PVD (2), Diabetes (4).	BM: 72.44 ± 16.30 kg; Height: 1.7 ± 0.08 m; Activity level: K2–K3 (8), K3–K4 (1).	TSB + Dermo and Seal-In X5 liners.	>4 wk	Interface pressure.	TekScan (F-socket transducer).	Mean peak pressure at anterior, posterior, and medial aspect of residual limb was higher for Seal-In X5 liner than Dermo liner; Suspension was scored higher for Seal-In X5 liner.
Gholizadeh et al., 2012 [31]	1 (0/1)	51	None.	Bony residual limb with adventitious bursa; No soft tissue at distal end of tibia.	PVD	Pain at distal end of residual limb, particularly during swing phase.	TSB + Dermo and Seal-In X5 liners.	2 wk	Pistoning (static condition).	Photography camera.	Seal-In X5 liner decreased amount of pistoning, skin traction, and pain at distal end of residual limb.
Gholizadeh et al., 2012 [32]	10 (NR)	45.8 (22–71)	Unilateral amputation; No pain or ulcer on residual limb; No volume fluctuation of residual limb; No dependence on assistive devices for ambulation; Good upper-limb strength.	L: 14.45 ± 1.30 cm	Diabetes (5), Trauma (5).	BM: 73.8 ± 14.19 kg; Height: 1.7 ± 0.06 m; Activity level: K2 (4), K3 (6).	TSB + Dermo and Seal-In X5 liners.	4 wk for each liner	Pistoning (gait).	7-camera Vicon 612 motion analysis system (MXF20 camera).	Maximum displacement was 5.4 ± 0.6 and 2.5 ± 04 mm for Dermo and Seal-In X5 liners, respectively.
Boutwell et al., 2012 [33]	12 (4/7)	55.9 (43–67)	Age: 18–70 yr; Amputation without serious complications; Experience with definitive prosthesis: ≥60 mo; Ability to walk ≥10 m over level ground without use of walking aids; No medication that could interfere with balance or gait.	Bony (5); Padded (5); Average (1).	Trauma (6), PVD (1), Other (4).	BM: 88.2 ± 18.2 kg; Height: 1.7 ± 0.09 m.	TSB + Alpha liner with 3 and 9 mm uniform thickness.	≥2 wk for each socket type.	Interface pressure; Gait characteristics; Comfort and function.	Novel pliance system; 8-camera Eagle Digital RealTime system; Six force platform.	Thicker gel liner reduced pressure over bony prominences of residual limb in users with either padded or bony residual limb with little effect on gait characteristics; Thicker gel liner seems to increase vertical GRF during

											weight acceptance.
Sanders and Fatone, 2011 [5]	7 (6/1)	47 (25–67)	None.	L: 14–23 cm	Trauma (6); Diabetes (1).	BM: 58–102 kg; Height: 1.6–1.88 m; Activity level: K2 (1), K3 (2), K4 (4).	VAS	3 wk–1 yr	Residual limb in-socket volume.	Bioimpedence.	VAS socket maintained or increased volume in 6 subjects; Residual limb volume was less affected by VAS socket in users with diabetes or PVD; Results further indicated that subjects showed increased in limb volume with more elevated vacuum.
Klute et al., 2011 [21]	5 (NR)	56 ± 9	Age: 18–70 yr; Ability to walk on treadmill for 30 min; Prosthesis use: >1 yr (diabetic or dysvascular), >4 mo (all others); No disorder, pain, or injury interfering with gait.	—	Trauma (4), Diabetes (1).	BM: 84 ± 11 kg; Height: 1.78 ± 0.1 m; YSA: 13 ± 15	TSB + pin lock Alpha liner; VAS.	3 wk	Residual limb volume; Limb pistoning.	Optical scanning; 12-camera motion analysis system.	No significant difference in volume reported; VAS socket showed less pistoning.
Gholizadeh et al., 2012 [34]	6 (NR)	43 (22–49)	Unilateral amputation; Residual limb length: ≥13 cm; Stable limb volume; Intact upper limb; No pain or wound on residual limb; Mobility without assistive devices.	L: 14.41 ± 1.42 cm	Diabetes (3), Trauma (3).	BM: 77.16 ± 14.95 kg; Activity level: K2–K3.	TSB + Dermo and Seal-In X5 liners.	4 wk	Pistoning (static condition).	7-camera Vicon motion analysis system.	Maximum pistoning occurred after adding 90 N distal traction load; Movement of pin lock liner was larger (5 ± 1.5 mm) than with Seal-In X5 liner (2 ± 1 mm); Users expressed less skin stretch and more secure feeling with Seal-In X5 liner.
Gerschutz et al., 2010 [35]	1 (NR)	NR	None.	NR	NR	Residual limb volume fluctuation; New to VAS socket; Diabetes; Activity level: K2.	VAS with 2 different vacuum settings; TSB suction socket.	15.5 wk	Residual limb volume fluctuation.	OMEGA Tracer (over liner).	VAS resulted in 0.8% volume change compared with 4.9% in TSB socket; 2 different pressure settings (–33.86 and –50.79 kPa) showed similar results; Wound healing was observed; Improvement in volume retentions observed with VAS socket use during 3.5 mo period.

Dumbleton et al., 2009 [36]	EG: 24 (20/4); CG: 24 (20/4)	EG: 50.04 (25–69); CG: 60.54 (29–89)	≥1 yr postamputation; Use of prosthesis for ADLs for ≥6 mo.	L: 14.1 cm (10.5–17.5) (EG); 12.3 cm (7–18) (CG)	EG: PVD (4), Trauma (20); CG: PVD (8), Trauma (18).	NR	HS (ICECAST) + silicone liner; PTB (suspension NR).	>6 mo	Interface pressure.	6 channel F-scan system and shoe sensors.	Uniform pressure distribution of HS socket was not confirmed; Pressure distribution showed consistent pattern between 2 sockets; Interface pressure was higher for HS socket and had narrower SD; PTB socket showed steeper pressure gradients.
Lenka et al., 2008 [37]	14 (NR)	EG: 71 ± 5; CG: 24 ± 3.8	No orthopedic or neurological disorders.	NR	NR	BM: 22.17 ± 3.02 kg (EG), 19.35 ± 3.09 kg (CG); Height: 1.64 ± 0.05 m (EG), 1.7 ± 0.03 m (CG).	PTB	EG: >3 yr; CG: >2 yr	Gait parameters; Dynamic weight-bearing distribution.	Computer dynography; Foot sensors.	Younger users walked faster, had higher cadence, and better step length symmetry than older users; GRF at early stance in younger users was small than for older users; Load at posterior heel was larger in younger users.
Rogers et al., 2008 [38]	1 (1/0)	41	None.	NR	NR	BM: 85 kg; Height: 1.8 m; Activity level: K4.	VAS with 3 different compliant socket walls.	Subject wore conventional socket for 1 yr	Interface pressure; Gait parameters.	TekScan F-scan mobile system; 6-camera Vicon 370 3D motion analysis system.	Interface pressure over tibular head and distal tibia were higher in conventional VAS socket than for those of compliance sockets; GRF was not different in sockets, but walking was faster with compliant sockets.
Dou et al., 2006 [39]	1 (1/0)	25	None.	NR	NR	Ability to walk ≥500 m without any dyskinesia.	TSB + silicone liner.	NR	Interface pressure.	Novel pliance measurement system.	In natural gait conditions, maximum mean pressure occurred at patella tendon and popliteal area; Pressure at medial and anterior distal tibia was also high.
Selles et al., 2005 [24]	EG: 12 (NR); CG: 14	EG: 67.6 ± 13.5; CG:	Unilateral transtibial amputation; Age: ≥18 yr; Prosthesis use: ≥1 yr;	NR	EG: Trauma (5), Diabetes (7); CG:	Phantom pain: 6 (EG), 10 (CG).	EG: HS (ICEX + pin lock); CG: TSB + comfort/two color liner	3 mo	Gait analysis; Cost and time of socket	3-camera ProReflex infrared system.	ICEX and TSB sockets function similarly to

	(NR)	57.9 ± 15.6	Active walkers with/without walking aid; No recent residual limb problems; Capable of residual limb distal weight-bearing; No known problems using silicone liners.		Trauma (6), Diabetes (3), PVD (4), Other (1).		and pin lock.		manufacturing.		conventional socket in terms of gait characteristics; ICEX socket manufacturing was less time consuming, but cost of materials was higher than for TSB socket; Number of postdelivery visits was higher for ICEX socket.
Aström and Stenström, 2004 [40]	29 (24/5)	39.77 (7–78)	Good fit of conventional suspension with or without silicone liners; Ability to walk indoors; Prosthesis use: ≥1 yr; Capable of answering questionnaire.	Long (6); Ordinary (20); Short (3)	Trauma (15), Tumor (1), Infection (2), Diabetes (3), PVD (8).	No problems (5); Stump problems (20), with pain as limiting factor (18); Foot or knee problems (3); Arm amputation (1).	TSB + polyurethane liner; TSB (ICEROSS/EVA/suction socket).	>2 mo	Gait symmetry (8).	Vicon 370 3D motion analysis system.	No gait parameters showed better symmetry with any type of socket.
Beil and Street, 2004 [41]	8 (NR)	46 (33–65)	NR	NR	No PVD.	YSA: 18 (6–32).	TSB + urethane liner (pin lock or sleeve suspension).	Not clear.	Average positive and negative pressure during gait; Pressure impulse during swing.	Force sensing pressure sensors; Air pressure sensor.	Stance phase average pressure was not significantly different between 2 sockets; Overall positive pressure, impulse value, average positive pressure, and distal negative pressure during swing were significantly higher in TSB and pin lock sockets.
Datta et al., 2004 [22]	EG: 11 (11/0); CG: 10 (8/2)	EG: 47.8 ± 16.9; CG: 52.2 ± 16.2	Attending routine medical or prosthetic review or repairs; Endolite PTB socket with Pelite liner, cuff suspension, and Multiflex ankle/foot mechanism; Ability to walk without aids (e.g., sticks or crutches); Health contralateral limb; No gait problems as result of socket	—	EG: PVD (3), Trauma (7), Other (1); CG: PVD (4), Trauma (3), Other (3).	BM: 85.4 ± 11.5 kg (EG), 82.4 ± 15.9 (CG); Height: 1.73 ± 0.04 m (EG), 1.71 ± 0.06 m (CG); YSA: 11.6 ± 11.8 (EG), 8.6 ± 15.9 (CG).	HS (ICEX); PTB.	>6 wk	Gait parameters; Symmetry index.	Vicon 370 3D motion analysis system.	No significant differences between EG and CG demonstrated for any measured variables.

			discomfort.							
Goswami et al., 2003 [42]	7 (NR)	45 (27–66)	Cause of limb loss: trauma or birth defect.	L: 10.3 cm (4.5–17.5)	Trauma and congenital.	BM: 83 kg (59–107).	VAS + urethane liner (undersized, natural, and oversized sockets).	Not clear	Residual limb volume.	Alginate casting and water casting.	Subjects lost average of 2% residual limb volume in 15% undersized socket; In natural-sized sockets, users gained 5%; In oversized sockets, users gained 11%; No pain, discomfort, or reddening of skin were reported as result of residual limb volume gain.
Beil et al., 2002 [14]	9 (NR)	46 (33–65)	None.	L: 13 cm (8–20)	NR	YSA: 8 (6–32); No vascular complications.	VAS + urethane liner with and without vacuum.	Not clear	Average peak positive and negative pressure; Pressure impulse for stance and swing; Overall average pressure.	Force sensing pressure sensors; Air pressure sensor.	During stance, pressure impulse variation and average peak pressure were significantly lower with VAS socket; During swing phase, impulse value and average and peak negative pressure were significantly greater in VAS socket.
Yiğiter et al., 2002 [43]	20 (13/7)	27.8 (15–37)	Attending first prosthetic fitting; Residual limb muscle strength: ≥4; No joint limitation, muscle shortening, residual limb edema, pain, or problems with residual limb shape; Ability to stand within parallel bars and walk with Canadian crutches.	L: 12.5–17.5 cm	Trauma	BM: 62.5 ± 8.9 kg; Height: 1.69 ± 0.09 m.	PTB; TSB (type of liners not indicated).	Not clear	Weight-bearing capabilities of residual limb and balance; Time-distance parameter of gait, including walking speed; Pistoning; Prosthesis mass, socket, and volume.	Juxtaposed scales; Footprints; Gruendel method.	Improved balance and time distance parameters reported with TSB socket; Pistoning was smaller and ascending and descending stairs and inclines were faster with TSB socket; No correlation found between suspension and other ambulatory activities.
Tanner and Berke, 2001 [44]	1 (1/0)	37	NR	Short, conical residual limb with moderate soft tissue distal to tibia.	Trauma	None.	TSB + 3S with pin lock.	Several months	Vertical tibia/soft tissue movement.	X-ray.	Vertical tibia and soft tissue movement between full weight-bearing and non-weight-bearing was 31 and 2 mm, respectively.
Board et al., 2001 [13]	11 (NR)	45 (32–64)	Amputation caused by trauma; Ability to walk	Not clear	Trauma	BM: 83 kg (56.2–95.3);	VAS + urethane liner with and without	Not clear	Pistoning; Gait symmetry;	X-ray; 2 60 Hz cameras;	Vacuum results in less pistoning,

			30 min on treadmill.			Height: 1.67 m (1.40–1.83); YSA: 15.2 (6–41).	vacuum.		Residual limb volume change.	Casting and water displacement.	increased gait symmetry (step length and stance durance), and residual limb volume gain after 30 min of treadmill walking.
Isakov et al., 2000 [45]	14 (14/0)	45.07 (32–57)	None.	Not clear.	Trauma	—	PTB	Not clear	Time-distance parameters of gait; Knee kinematic; EMG.	Electronic walkway (GaitRight); High-speed video camera; MEGA portable EMG logger.	Stance time and single support time were shorted in amputated limb, whereas swing time, step time, and step length were shorter in intact limb; Prosthetic limb had more flexed knee and higher ratio of biceps femoris/vastus lateralis activity at heel strike.
Zhang et al., 1998 [46]	5 (NR)	65 (43–75)	Regular use of PTB prosthesis.	Bony residual limbs (2); More soft tissue over residual limb (1); Not stated (1)	Not clear	—	PTB + cuff/SC suspension.	Not clear	Interface pressure; Shear stress.	Transducer based on strain-gauge diaphragm technique.	Maximum interface pressure was 320 kPA during walking and occurred at popliteal area; Popliteal area, medial and lateral tibia, and anterior distal tibia were all high pressure areas; Maximum shear stress was 61 kPa measured at medial tibial area.

3D = three-dimensional, 3S = silicone suction socket, ADL = activity of daily living, BM = body mass, CG = control group, EG = experiment group, EMG = electromyography, EVA = ethylene vinyl acetate, F = female, GRF = ground reaction force, HS = hydrostatic, L = length, M = male, NR = not reported, PTB = patellar tendon bearing, PVD = peripheral vascular disease, SC = supracondylar, SD = standard deviation, TSB = total surface bearing, VAS = vacuum-assisted suction, YSA = years since amputation.