A systematic review of outcomes of toe-to-thumb transfers for isolated traumatic thumb amputation

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Abstract

Background Toe-to-thumb transfer is an established procedure for reconstruction of traumatic thumb amputations. The four types of toe-to-thumb transfers are the second toe, the great toe, the wrap-around great toe and the trimmed great toe transfers. The purpose of this study is to conduct a systematic review of the literature to compare outcomes amongst different methods of toe-to-thumb transfers.

Methods A literature search using ‘toe-to-thumb transfer’ combined with ‘thumb injury’ and ‘thumb reconstruction’ as keywords and limited to humans and the English language identified 633 studies. Studies were included in the review if they: (1) present primary data, (2) report three or more toe-to-thumb transfers for isolated complete traumatic thumb amputation between the metacarpophalangeal joint and the

interphalangeal joint (both excluded) and (3) present functional outcome data.

Results Twenty-five studies representing 450 toe-to-thumb transfers met the inclusion criteria. They included 101 second toe transfers, 196 great toe transfers, 122 wrap-around transfers and 31 trimmed toe transfers. The mean survival rate was 96.4%. No statistically significant differences could be detected between the four transfers with regards to survival, arc of motion, total active motion, grip and pinch strength and static two-point discrimination.

Conclusions All four types of toe transfer procedures have predictably high survival rates and good patient satisfaction scores. The current data are inadequate to make any comments with regards to donor site morbidity. Till such data are available, an evidence-based recommendation for the superiority of a specific type of toe-to-thumb transfer cannot be made.

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Introduction

A free toe transfer is the preferred treatment for a traumatic complete thumb amputation distal to the metacarpophalangeal joint. Four types of free toe transfers have been described in literature (Fig. 1) [7, 31, 52, 56]. High success rates ranging from 95% to 100% have been described for all four techniques [13, 53, 58]. The great toe transfer is believed to have a better appearance and functional outcomes, whereas the second toe transfer has less donor site morbidity [53]. The wrap-around and the trimmed variations of the great toe transfer were introduced in an

Fig. 1 Comparison of the four types of free toe-to-thumb transfers

attempt to reduce donor morbidity and improve the aesthetic appearance. Although the outcomes of each of these transfers have been described in literature, a rigorous comparative evaluation of the outcomes of these four techniques has not been performed [53]. At present, the decision to use a particular toe transfer technique is mostly based on the surgeon's preference and training [29]. A systematic review will allow us to use the best available evidence from the literature to compare outcomes of these four procedures.

The specific aim of this study is to select publications with sufficient data that could be analysed to determine differences in outcome amongst the four toe transfer techniques. We hypothesise that the trimmed great toe transfer provides the best functional and aesthetic reconstruction of a thumb amputated distal to the metacarpophalangeal joint and has the lowest donor site morbidity.

Materials and Methods

Literature Search A systematic search of MEDLINE, EMBASE and ISI (science citation index/social sciences

citation index) conducted in November 2010 to identify English language citations for original studies relating to toe-to-thumb transfers for traumatic thumb amputations in humans published between 1967 and 2010 yielded 633 citations. The key words used for the search included 'toe-to-thumb transfer' combined with 'thumb injury' and 'thumb reconstruction'. The abstracts from the 633 citations were screened for predetermined inclusion and exclusion criteria (Table 1). Citations in which content was unclear based on a review of the abstracts underwent formal article review. Study references were screened manually to identify potential citations not captured by the initial database search.

Data Extraction On formal article review, we collected data with regards to study characteristics, patient demographic data, duration of follow-up and outcomes (survival and functional outcomes). The functional outcomes data included one or more of the following parameters: (1) arc of motion (AOM), (2) total active motion (TAM), (3) grip strength, (4) key pinch strength and (5) static two-point discrimination (2-PD). Data with regards to donor site morbidity and patient satisfaction were extracted from studies when they were available.

Table 1 Predetermined inclusion and exclusion criteria

A. Inclusion criteria	
1.	Toe-to-thumb transfer for isolated complete traumatic thumb amputation between MCPJ and IPJ (both excluded)
2.	Extractable functional outcome data
B. Exclusion criteria	
1.	Review articles
2.	Case series with less than 3 patients
3.	Study discussing surgical technique without any functional outcomes
4.	Toe-to-thumb transfer for congenital anomalies
5.	Toe to digit transfer
6.	Multiple (preliminary flap followed by toe-to-thumb transfer) or combined reconstructive procedure (simultaneous flap and toe transfer, multiple toe transfer, etc.)
7.	Duplicated results by the same author using the same sample of patients

Statistical Analysis Summary statistics including weighted mean and 95% confidence intervals (CI) were calculated for outcomes of the four toe transfer techniques. The weighted mean was calculated by dividing the mean for each study by the number of patients. The 95% CIs were used to determine differences in outcomes. Statistical significance was determined using chi-square test for survival outcomes and one-

way ANOVA for functional outcomes. Statistical significance was set at $p < 0.05$, and the statistic analyses were performed using statistical software (SPSS, v. 18, Chicago, IL, USA).

Results

Study Characteristics Twenty-five studies representing 450 toe-to-thumb transfers met the inclusion/exclusion criteria (Fig. 2) [3, 6, 9, 12, 15, 18, 22, 24, 26, 30, 31, 33, 35, 36, 38, 39, 43–46, 49, 51, 53–55]. These studies were published between 1980 and 2010, and all used retrospective data. They included 101 second toe transfers (22%), 196 great toe transfers (44%), 122 wrap-around transfers (27%) and 31 trimmed toe transfers (7%). The majority of the studies were from the USA ($n=7$) and accounted for 34% of all toe-to-thumb transfers ($n=155$; Table 2) [6, 22, 26, 36, 39, 45, 46].

Demographic Characteristics Data with regards to gender were available in 20 studies ($n=315$). There were 258 men (82%) and 57 women. Men accounted for 87% of second toe transfers, 90% of great toe transfers, 69% of wrap-around toe transfers and 61% of trimmed toe transfers. Data with regards to mean ages of patients were available in 20 studies ($n=312$), and the mean was 29 years. The mean

Fig. 2 Study attrition diagram

Table 2 Demographic, study, and patient characteristics

No.	Year	Authors	Place	No. of patients	Sex		Mean age (years)	Type of toe-to-thumb transfer				Success (%)	Follow-up (months)
					M	F		2 nd toe	Great toe	Wrap-around	Trimmed toe		
1	1980	Morrison et al.	Melbourne, Australia	5	3	2	25.6	0	0	5	0	100	18.2
2	1983	Poppen et al.	Sacramento, USA	5	4	1	23.8	0	5	0	0	100	–
3	1984	Minami et al.	Sapporo, Japan	3	–	–	–	0	3	0	0	100	–
4	1984	Morrison et al.	Melbourne, Australia	23	–	–	–	3	7	13	0	95.6	–
5	1985	Doi et al.	Ube, Japan	10	5	5	34.1	0	0	10	0	100	27.5
6	1986	Frykman et al.	Melbourne, Australia	11	7	4	32.9	3	8	0	0	100	54
7	1986	Tsai et al.	Louisville, USA	3	2	1	40.7	0	0	3	0	100	8.7
8	1987	Lipton et al.	Boston, USA	12	10	2	29.3	0	12	0	0	100	30.3
9	1987	Tsai et al.	Louisville, USA	3	3	0	15.3	3	0	0	0	100	60
10	1989	Vitkus et al.	Vilnius, Lithuania	3	3	0	27.3	3	0	0	0	100	42
11	1992	Reigstad et al.	Oslo, Norway	26	22	4	32	26	0	0	0	80.8	52
12	1994	Wei et al.	Taipei, Taiwan	45	38	7	26	10	0	15	20	98	30
13	1995	Barca et al.	Modena, Italy	27	22	5	21.5	10	4	13	0	100	77.4
14	1995	Songcharoen et al.	Bangkok, Thailand	15	13	2	–	0	0	15	0	86.7	27
15	1995	Wei et al.	Taipei, Taiwan	6	5	1	28.9	0	6	0	0	100	–
16	2000	Patradul et al.	Bangkok, Thailand	13	12	1	25	8	5	0	0	92.3	>12
17	2000	Lee et al.	Seoul, South Korea	37	23	14	26	0	0	37	0	100	25
18	2000	Chung et al.	Ann Arbor, USA	16	14	2	38.3	4	12	0	0	100	–
19	2003	Xu et al.	Shanghai, China	5	4	1	27	5	0	0	0	100	–
20	2004	Woo et al.	Taegu, South Korea	12	–	–	28.6	0	5	5	2	100	22
21	2004	Stupka et al.	Brno, Czechoslovakia	24	–	–	–	15	3	6	0	94.6	–
22	2006	Gulgonen et al.	Istanbul, Turkey	3	2	1	32.6	3	0	0	0	100	>240
23	2007	Lee et al.	San Francisco, USA	73	–	–	–	0	73	0	0	97.5	–
24	2008	Rosson et al.	San Francisco, USA	43	42	1	31	0	43	0	0	93	20.4
25	2010	Huang et al.	Guangzhou, China	27	24	3	29	8	10	0	9	100	18

ages for the second toe, great toe, wrap-around and the trimmed toe transfers were 23, 29, 28 and 30 years, respectively (Table 2).

Survival and Functional Outcome The overall survival rate was 96.4% (16 failures). No statistically significant differences could be detected amongst the four types of toe-to-thumb transfers with regards to survival or any of the functional outcome parameters (Tables 2 and 3).

Donor Site Morbidity Out of the 450 toe-to-thumb transfers analysed in this review, data with regards to donor foot complications were available for only 222 transfers (49%). These included 51 second toe transfers (50%), 102 great toe transfers (52%), 59 wrap-around transfers (48%) and none of the trimmed toe transfers. Plantar callus formation, delayed wound healing and weakness in push-off represent the three common complications seen at the donor site (Table 4).

Patient Satisfaction Patient satisfaction with the new thumb was assessed in 60 toe-to-thumb transfers (13%). These included 12 second toe (12%), 32 great toe (16%), 5 wrap-

around (4%) and 11 trimmed toe transfers (35%). Patient satisfaction with the donor site was assessed only in 33 transfers (7%). These include four second toe (4%), 22 great toe (11%), 5 wrap-around (4%) and 2 trimmed toe transfers (6%). In general, for the second toe option, hand satisfaction was lower because of the less aesthetically pleasing second toe, but the foot donor site satisfaction score was greater (Table 5).

Discussion

This systematic review of four different toe-to-thumb transfers showed an overall survival rate of 96.4%. This is similar to the 95–98% survival reported in literature for other free flaps [16, 17, 21]. One would expect a higher incidence of failure in toe-to-thumb transfers because the dissection is tedious, the vascular anatomy variable and the vessels prone to spasm. The distal to proximal dissection of the vascular pedicle after identification of the dominant vascular system (dorsal or plantar) at the ‘T’ junction in the first web space as described by Wei has simplified the

Table 3 Comparison of survival and functional outcomes between four types of toe-to-thumb transfers

No.	Outcome parameter	Type of transfer	No. of studies	No. of patients	Mean	95% CI	p value
1.	Survival (%) ^a	Second toe	13	101	93	n.a.	0.302
		Great toe	14	196	97	n.a.	
		Wrap-around	10	122	97	n.a.	
		Trimmed toe	3	31	99	n.a.	
2	Arc of motion at IPJ ^b (degrees)	Second toe ^c	4	24	32	20.8–43.2	0.686
		Great toe	7	147	33	26.4–38.8	
		Trimmed toe	2	22	27	22.7–31.3	
3.	Total active motion (degrees) (MCPJ + IPJ or PIPJ + DIPJ)	Second toe ^d	6	47	65	32.4–97.5	0.407
		Great toe ^e	8	146	58	29.2–87.1	
		Wrap-around ^f	3	16	46	22.6–69.4	
		Trimmed toe ^g	1	2	110	110–110	
4.	Grip strength (% of normal side)	Second toe	3	21	69	64.4–73.6	0.406
		Great toe	5	140	84	81.9–86	
		Wrap-around	2	40	86	81.2–90.8	
		Trimmed toe	2	29	78	71.9–84.1	
5.	Key pinch strength (% of normal side)	Second toe	3	16	50	34–66	0.227
		Great toe	5	67	81	77.5–84.4	
		Wrap-around	3	45	67	63.4–70.6	
		Trimmed toe	2	22	65	58.8–71.2	
6.	Static 2-PD (mm)	Second toe	9	58	10	7.5–12.1	0.874
		Great toe	10	169	11	8.1–13.4	
		Wrap-around	8	84	11	8.6–13.5	
		Trimmed toe	3	31	10	4.1–16.6	

^a CI for survival rates could not be calculated^b Does not include wrap-around transfer because the IPJ is fused^c Represents only motion at PIPJ of second toe transfers^d MCPJ + PIPJ + DIPJ^e MCPJ + IPJ^f MCPJ^g MCPJ + IPJ

elevation of toe-to-thumb transfers [50]. The largest series of 400 toe transfers was reported by Gu et al. in 1997 [14]. They noted spasm of the vessel in 65 cases. Approximately half of these cases were managed by conservative measures (adventitial stripping, local 2% lidocaine instillation and mechanical expansion) and the other half required resection and vein grafting. The authors suggested perfusing the divided toe with 50 mg heparin+5 ml 2% lidocaine solution to lower the incidence of vascular complications. We could find no difference in survival amongst the different toe-to-thumb transfer techniques (Table 3). This is not surprising because all four transfers share the same vascular pedicle.

Our study was unable to find a difference in any of the functional parameters between the four transfer techniques (Table 3). The traditional teaching is that ‘A great toe

makes a great thumb’ because a great toe transfer results in better motion and superior strength compared to a second toe transfer [47]. In our review, the great toe transfer had only slightly better AOM at the interphalangeal joint (IPJ) compared to the second toe transfer (33° versus 32°). The IPJ AOM of the trimmed toe transfer was even less (27°) possibly because the trimmed toe transfer needs a longitudinal osteotomy through the IPJ [52]. However, these differences in IPJ AOM were not statistically significant. Similarly, although the TAM for trimmed toe transfer (110°) was greater than the second toe transfer (68°), great toe transfer (58°) and the wrap-around toe transfer (46°), these differences were not statistically significant. We feel that TAM is not an appropriate measure of function of a toe-to-thumb transfer in patients with preserved function of the metacarpophalangeal

Table 4 Donor foot complications

No.	Complications	Type of toe-to-thumb transfer			
		Second toe (%) (<i>n</i> =101)	Great toe (%) (<i>n</i> =196)	Wrap-around (%) (<i>n</i> =122)	Trimmed toe (%) (<i>n</i> =31)
1.	Do not mention complications	50 (50)	94 (48)	63 (52)	31 (100)
2.	No donor foot problems	12 (24)	7 (7)	8 (14)	–
3.	Callus (hyperkeratosis)	2/10 (20)	4/5 (80)	2/13 (15)	–
4.	Delayed wound healing	1/26 (4)	16/73 (22)	5/26 (19)	–
5.	Weakness in push-off	–	9/21 (43)	1/15 (7)	–
6.	Varus/valgus deformity	3/29 (10)	7/13 (54)	–	–
7.	Claw deformity	2/10 (20)	–	2/13 (15)	–
8.	Nail remnant	–	–	4/10 (40)	–
9.	Cold intolerance	–	24/85 (28)	–	–
10.	Pain	–	4/16 (25)	–	–

joint (MCPJ). There is a large variation in the normal arc of motion at the thumb MCPJ (50–90°) and this can influence TAM values significantly [20, 41, 42, 57]. This is highlighted by the 2 patients with trimmed toe transfers who achieved a TAM of 110° largely because the MCPJ AOM was 75° and the 16 patients with a wrap-around transfer who had a TAM of 46° despite a fused IPJ.

The grip and pinch strength of great toe transfer and its variants (wrap-around and trimmed toe) were noted to be higher when compared to the second toe transfer. However, these differences were not statistically significant. We believe that the contribution of the thumb to grip strength depends on the ability to open the first web and on the strength of the thenar muscles. Because this review included only thumb amputations distal to the MCPJ, the web space and the

insertions of the thenar muscles are preserved. Any mode of reconstruction that establishes a stable post with intact thenar musculature would likely result in return of near normal grip strength. The two major contributors to key pinch strength are the adductor pollicis and the flexor pollicis longus (FPL). We feel that a stable MCPJ may be more critical to key pinch than function of the FPL. Studies that have measured key pinch in wrap-around thumb reconstruction (IPJ fusion without FPL repair) or osteoplastic thumb reconstruction (no IPJ or FPL) have shown similar return of key pinch function [40]. On the contrary, the repair of FPL in a second toe transfer has not resulted in better key pinch strength. We feel that the current methods of measuring strength (grip or key pinch) are not sensitive enough to determine functional differences between the different modalities of toe-to-thumb transfers. The greater

Table 5 Assessment of patient satisfaction

No.	Type of toe-to-thumb transfer	Authors (method of assessment)	No. of toe-to-thumb transfers	Patient satisfaction scores		
				Donor site	Recipient site	
					Function	Aesthetics
1.	Second toe	Chung et al. (donor site: LFQ/recipient site: MHQ)	4	1.29	67.5	60.9
		Huang et al. [donor site: not assessed/recipient site: subjective score (1–100)]	8	–	74	83
2.	Great toe	Poppen et al. [recipient site: self-made subjective questionnaire (1–100)]	5	–	86	69
		Chung et al. (donor site: LFQ/recipient site: MHQ)	12	1.47	84.6	76.0
		Woo et al. ^a [subjective score (0–100) for both donor and recipient sites]	12	60	80	88
		Huang et al. (donor site: not assessed/recipient site: subjective score)	10	–	81	86
3.	Trimmed toe	Huang et al. (donor site: not assessed/recipient site: subjective score)	9	–	89	87

LFQ Lower Limb Functional Questionnaire, MHQ Michigan Hand Questionnaire

^a Includes great toe + wrap-around + trimmed toe transfers

plantar surface area of the great toe is probably better at replicating thumb function, but the current test measures do not assess this.

There was also no difference in recovery of sensation as determined by measurement of static two-point discrimination between the four types of toe-to-thumb transfers. In all transfers, sensation is regained by suture of the plantar digital nerves to the digital nerves of the thumb. Therefore, any difference in sensory recovery between great toe transfer (including wrap-around and trimmed toe) and the second toe transfer would have indicated differences in native sensitivity between the great and second toes. Previous studies have determined that there are no differences in static 2-PD (6–10 mm) or Semmes–Weinstein monofilament measurements (3.44–3.67) between the great and second toes of young normal volunteers [4, 19].

We found that donor site morbidity has not been mentioned in 51% of the studies (Table 4). No data with regards to complications are available for trimmed toe transfers. The common problems seen at the donor site include callus formation on the plantar aspect of the foot, delayed wound healing and weakness in the push-off phase of gait. It is difficult to make comments about the prevalence of specific complications from the available data because in most cases they represent the complications seen in a single study. For example, callus formation was seen in 80% of cases with a great toe transfer, and delayed wound healing was noted in 22% of great toe transfers. However, this represents data from a single study [12, 22]. On a similar note, data with regards to patient satisfaction with the new thumb and the donor site were available only in four studies and represent 13% and 7%, respectively of the all toe-to-thumb transfers included in this study (Table 5) [6, 18, 36, 54]. In addition, each of these four studies uses a different method of assessing patient satisfaction. Although the patient satisfaction scores for the second toe transfers appear lower compared to the great toe and trimmed toe transfers, these differences were not statistically significant.

This systematic review has several limitations. There were a number of studies published in languages other than English. A number of studies were not included because they had only survival data and no data with regards to functional outcomes [8, 10, 11, 14, 27, 28, 32, 34, 37, 48, 58]. Other studies were rejected because they did not mention the level of the amputated thumb [2]. Five studies were rejected because of duplication of data from prior publications [1, 5, 23, 25, 52]. There were variations in the quality and quantity of data presented in the 25 studies that were included in this review. All studies included in this review were retrospective case series with a non-randomised design. This level of evidence contains inherent biases that make reliable statistical analysis difficult. None of the studies had truly sufficient data about the functional

outcomes, and there were variations in the reporting of outcomes. A uniform method of presenting range of motion, strength and sensibility would be useful to compare studies. Donor site foot morbidity has been underestimated in most studies, and subjective patient satisfaction was assessed in only four studies [6, 18, 36, 54]. Objective assessment of the functional capacity of the new thumb was assessed in two studies, and the functional loss at the foot was assessed in only one study. Lastly, the fact that this systematic review showed a high success rate for a technically difficult procedure may mean that there is a publication bias, and these studies represent the best results and not what may be achieved in routine clinical practice.

Despite these limitations, we were able to present the best available evidence in the literature to provide a valid, consistent review of the reported outcome results with standardised measurements of the four currently performed toe-to-thumb transfer procedures. We included only patients with traumatic thumb amputation through the proximal phalanx in order to control for the possible differences in functional outcome that may have occurred, if we were to include amputations at levels distal to the IPJ or proximal to MCPJ. This systemic review study found no statistically significant differences in the factors of survival, AOM, TAM, grip and key pinch strength and static 2-PD among the four toe-to-thumb transfer procedures. Our review also determined that the current data are inadequate to make any comments with regards to donor site morbidity and patient satisfaction scores. Till such data are available, an evidence-based recommendation for a specific type of toe-to-thumb transfer cannot be made. The selection of the appropriate toe transfer technique currently solely relies on the preference of the surgeon who shares his/her recommendation to the patient.

Further research should focus on prospective comparative outcomes study and should incorporate relevant objective questionnaires such as the Michigan Hand Outcome Questionnaire and Lower Limb Functional Questionnaire to evaluate the transferred toe function, aesthetics, donor site morbidity and patient satisfaction. Future efforts in this field will evaluate the psychosocial factors influencing the selection of the toe transfer procedures and their outcomes in a more sophisticated outcomes-based evaluation. Additionally, utility analysis of patient and surgeon preferences for these procedures can help in understanding the decision-making process when faced with the uncertainty of treatment selection in this complex reconstructive procedures.

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