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References

Corkum JP, Gillis JA, Tang DT. Visual estimation of Dupuytren's flexion contractures–a prospective comparative trial. Plast Surg (Oakv). 2018, 26: 165–8.

Gude W, Morelli V. Ganglion cysts of the wrist: pathophysiology, clinical picture, and management. Curr Rev Musculoskelet Med. 2008, 1: 205–11.

Royal College of Surgeons of England. Procedures of Limited Clinical Value document, 2011. https://www.rcseng.ac.uk/library-and-publications/rcs-publications/docs/rcs-briefing-procedures-of-limited-clinical-value/ (accessed 27th September 2019).

Schubert C, Hui-Chou HG, See AP, Deune EG. Corticosteroid injection therapy for trigger finger or thumb: a retrospective review of 577 digits. Hand. 2013, 8: 439–44.

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Patient-reported outcomes after digit replantation and revision amputation: when is maximum recovery attained?

Dear Editor,

Amputations of digits account for the majority of upper extremity devascularization injuries. Studies have assessed patient-reported outcomes (PROs) after management of traumatic digit amputation and found improvements over time (Haas et al., 2011; Tessler et al., 2017). Despite varying lengths of follow-up in these studies, the expected time to maximal recovery of PROs after replantation or revision amputation (terminalization) is unknown. Such information is important in establishing more realistic patient expectation for recovery. We aimed to determine the postoperative time when maximum recovery, assessed by PROs, is expected after replantation or revision amputation using data from an international multi-centre study.

PROs were assessed with validated upper extremity questionnaires, including the Michigan Hand Outcomes Questionnaire (MHQ), the Disabilities of the Arm, Shoulder, and Hand (DASH) and the PROs Measurement Information System (PROMIS) upper extremity module. We also assessed global PROs with the 36-Item Short Form (SF-36) Physical Component Summary (PCS) and Mental Component Summary (MCS), to detect any changes in overall patient well-being (Appendix S1, available online).

Data from the Finger Replantation and Amputation Challenges in Assessing Impairment, Satisfaction and Effectiveness (FRANCHISE) collaboration were used to conduct this analysis (Chung et al., 2019). FRANCHISE is an international multi-centre collaborative of 19 hospitals that retrospectively enrolled adults between 1 August 2016 and 12 April 2018 who had previously undergone either revision amputation or replantation in each institution. Revision amputation entailed primary closure of the injured digit and replantation comprised of microvascular re-attachment of the amputated digit. Of the 2684 patients initially contacted for recruitment, 1877 were not reachable and 469 refused participation in the study, leaving 338 patients who met all study inclusion criteria. Of these 338 patients, 329 (97%), 254 (74%), 336 (99%) and 336 (99%) completed the MHQ, PROMIS, DASH and SF-36, respectively. The current analysis only included patients who had less than 7 years follow-up and had completed the PRO questionnaires on one occasion.

We analysed the potential nonlinear changes in PROs over time with a locally estimated scatterplot smoothing (*loess*) method. The maximal PRO recovery time was defined as when the increase in the fitted loess curve declined to less than 0.75%. With this time chosen as a fixed point, a piece-wise log linear spline model was fitted controlling for potentially confounding variables. We evaluated the interaction effect between recovery time and number of injured digits to examine any potential PRO differences between single digit amputation and multi-digit amputation patients (Jones et al., 1982).

Among 338 FRANCHISE patients, 280 met inclusion criteria. Age, race, work-related injury, injury pattern (number of fingers and thumb involvement) and number of missing fingers after surgery were identified as confounding variables and were adjusted. On average, replantation patients were younger (45.0 vs. 50.3 years, $p = 0.01$) and had more work-related injuries (81% vs. 52%; $p < 0.001$; Table 1). The mean follow-up time was not significantly different between the two groups.

Table 1. Descriptive statistics of revision amputation and replantation patients.

Covariates	Revision amputation (*N* = 114)	Replantation (*N* = 166)	*p*-value[a]	Adjusted
Age (years)	50.3 (17.7)	45.0 (15.2)	0.01[b]	Yes
Gender			0.63	No
Male	95 (83)	143 (86)		
Female	19 (17)	23 (14)		
Race			<0.001[b]	Yes
White	54 (47)	15 (9)		
Non-white	60 (53)	151 (91)		
Insurance			0.39	No
Yes	98 (86)	135 (81)		
No	16 (14)	31 (19)		
Injury pattern			0.67	Yes
Single finger, not thumb	64 (56)	83 (50)		
Thumb only	19 (17)	36 (22)		
Multiple fingers, not thumb	26 (23)	41 (25)		
Multiple digits (including thumb)	5 (4)	6 (4)		
Number of digits amputated from injury			0.054	Yes
One	83 (73)	96 (58)		
Two	18 (16)	30 (18)		
Three	6 (5)	21 (13)		
Four	6 (5)	14 (8)		
Five	0 (0)	3 (2)		
Missing	0 (0)	2 (1)		
Number of digits missing after surgery			<0.001[b]	Yes
Zero	0 (0)	129 (78)		
One	83 (73)	24 (14)		
Two	18 (16)	7 (4)		
Three	6 (5)	1 (1)		
Four	6 (5)	1 (1)		
Five	0 (0)	1 (1)		
Missing	1 (1)	0 (0)		
Work-related Injury			<0.001[b]	Yes
Yes	59 (52)	135 (81)		
No	55 (48)	31 (19)		
Follow-up time (months)	42 (19)	43 (21)	0.61	No

Data presented as number (%) or mean (SD).
[a]Differences in means for continuous variables were assessed using *t*-tests; association between chronic pain and categorical variables was assessed using chi-square tests or Fisher's exact test.
[b]Statistical significance.

The interaction term between number of injured digits and PRO recovery time was only significant for MHQ in the revision amputation cohort, while it was significant for MHQ and SF-36 MCS for the replantation cohort; therefore, both a combined analysis and stratified analysis by number of injured digits was presented for the replantation group only (Table S1).

For the revision amputation cohort, the MHQ and SF-36 PCS had statistically significant maximum recovery times. The MHQ score reached maximal recovery at 47.8 months and SF-36 PCS peaked at 30.3 months (Table S2; Figure 1). On average, patients achieved 23% of peak MHQ recovery by 1 year and 58% by 2 years postoperatively (Table S3). Even though not reaching statistical significance, the SF-36 MCS recovery plateaued at 30.3 months (Table S2).

For the replantation group, the MHQ, PROMIS and SF-36 PCS scores demonstrated statistically

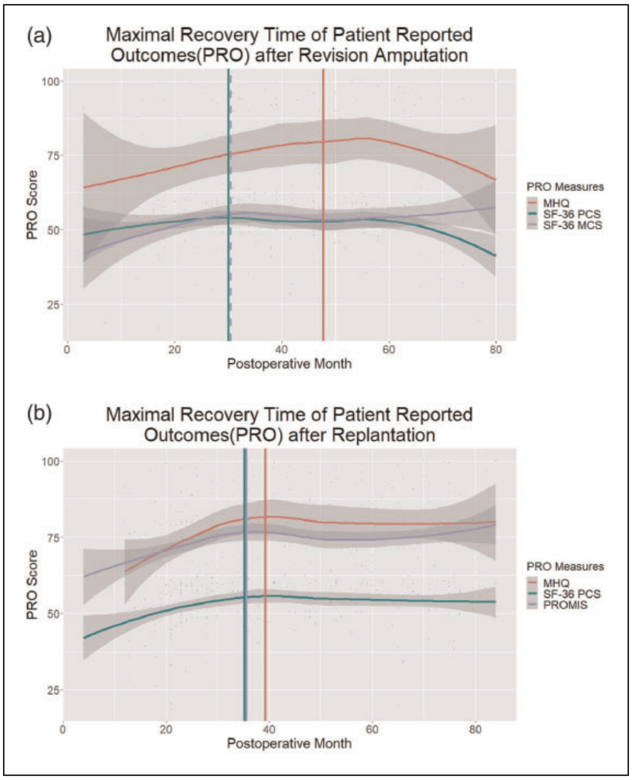

Figure 1. (a) Local polynomial regression (loess) curve for Michigan Hand Outcomes Questionnaire (MHQ), 36-Item Short Form Health Survey Physical Component Summary (SF-36 PCS), and 36-Item Short Form Health Survey Mental Component Summary (SF-36 MCS) after revision amputation. Maximal recovery occurred at 47.8 months postoperatively for MHQ and 30 months for SF-36 PCS and MCS. A solid line indicates a statistically significant recovery time and a dashed line indicates postoperative recovery time identified by the model but is not statistically significant. (b) Local polynomial regression (loess) curve for MHQ, Patient-Reported Outcomes Measurement Information System (PROMIS) upper extremity, SF-36 PCS after replantation. Maximal recovery occurred after 39.3 months for MHQ, 35.4 months for SF-36 PCS and 35.4 months for PROMIS.

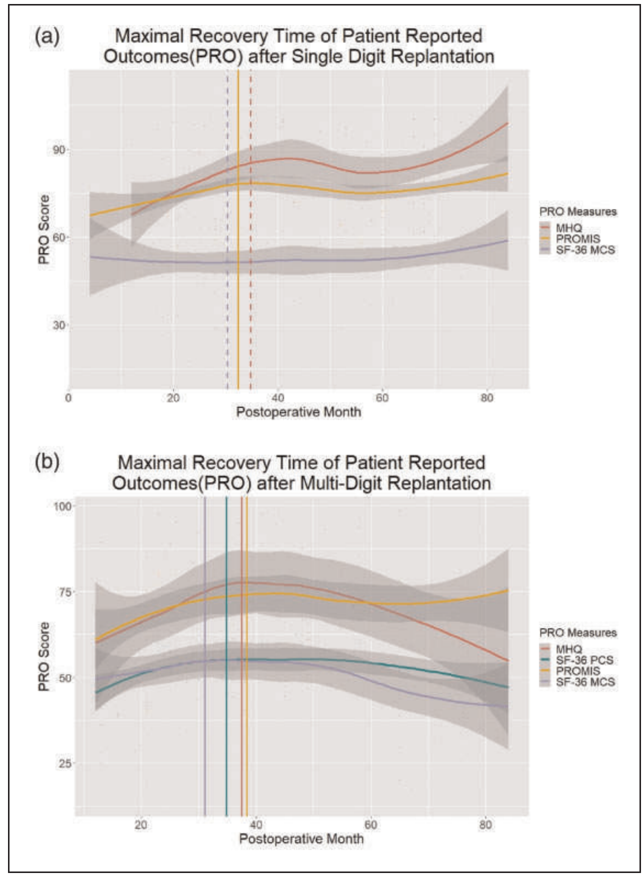

Figure 2. (a) Local polynomial regression (loess) curve for MHQ, PROMIS upper extremity and SF-36 MCS after single digit replantation. Maximal recovery occurred after 32.4 months for PROMIS. Other PRO measures did not have a statistically significant maximum time point. The SF-36 MCS score remained relatively constant perioperatively and throughout the entire recovery. (b) Local polynomial regression (loess) curve for MHQ, PROMIS upper extremity, SF-36 PCS and SF-36 MCS after multi-digit replantation. Maximal recovery was achieved after 37.5 months, 38.4 months, 31.1 months and 34.8 months for MHQ, PROMIS, SF-36 MCS and SF-36 PCS, respectively. The SF-36 MCS score remained relatively constant in the perioperative period and for most of recovery.

significant maximum recovery times. The MHQ, PROMIS and SF-36 PCS peaked at 39.3 months, 35.4 months and 35.4 months, respectively (Figure 1; Table S2). On average, patients achieved 34% of peak MHQ recovery by 1.5 years and 85% by 2.5 years postoperatively (Table S3). In single digit replantation patients, the PROMIS score culminated at 32.4 months postoperatively. In multi-digit replantation patients, MHQ, PROMIS, SF-36 MCS and SF-36 PCS had statistically significant maximal recovery times of 37.5, 38.4, 31.1 and 34.8 months postoperatively (Figure 2).

Our results suggest that the recovery time for PROs in replantation patients may be between 35 and 40 months. Therefore, patients who elect to undergo replantation must understand and agree to at least 3 years of dedicated recovery time. For revision amputation patients, such recovery time is more unclear as two PRO instruments showed dissimilar times of 30 months and 48 months. Revision amputation patients on average may take up to 4 years to recover from their psychosocial trauma as evidenced from the SF-36 MCS and MHQ. This delayed recovery in psychosocial well-being was not evident in the replantation group. It was surprising to find that PROs after revision amputation may take as long as 48 months for maximum recovery. This contrasts the common notion of rapid rehabilitation after revision amputation compared with after replantation. Whereas this statement may be true from a purely functional perspective, PROs indicate otherwise.

Our findings should be interpreted within the context of several limitations. This was not a longitudinal study, rather, it recruited patients with a range of follow-up periods cross-sectionally. Selection bias may have occurred, especially in patients with longer follow-up who may have returned for aberrantly negative outcomes. This may explain the observed downward trend in some PROs after attaining maximal recovery (Tables S4 and S5). Although significant confounders were adjusted, other unmeasured confounders may have introduced bias, such as the number of revision operations or complications that were not collected during the initial study; therefore, our results are indicative of averages for typical postoperative courses. Lastly, FRANCHISE recruited patients from the United States (US) and Asia who may have different preferences than patients in other geographical settings. However, because finger amputations are ubiquitous injuries and the US patients are from diverse backgrounds, we believe these results are generalizable to patients from other countries.

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References

Chung KC, Yoon AP, Malay S, Shauver MJ, Wang L, Kaur S. Patient-reported and functional outcomes after revision amputation and replantation of digit amputations: the FRANCHISE multicenter international retrospective cohort study. JAMA Surg. 2019, 154: 637–46.

Haas F, Hubmer M, Rappl T, Koch H, Parvizi I, Parvizi D. Long-term subjective and functional evaluation after thumb replantation with special attention to the quick DASH questionnaire and a specially designed trauma score called modified Mayo score. J Trauma. 2011, 71: 460–6.

Jones JM, Schenck RR, Chesney RB. Digital replantation and amputation—comparison of function. J Hand Surg Am. 1982, 7: 183–9.

Tessler O, Bartow MJ, Tremblay-Champagne MP et al. Long-term health-related quality of life outcomes in digital replantation versus revision amputation. J Reconstr Microsurg. 2017, 33: 446–51.

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Correction of scaphoid nonunion humpback deformity using three-dimensional printing technology

Dear Editor,

Following the diagnosis of a nonunion, anatomical reconstruction of the scaphoid is essential to achieve optimal wrist functionality and prevent associated arthritic changes, such as a scaphoid nonunion advanced collapse or SNAC wrist (Mathoulin and Arianni, 2018). In such cases, three-dimensional (3-D) preoperative planning with patient-specific guides can lead to a more anatomic reconstruction (Schweizer et al., 2016). In particular, the dimensions of a bone graft, when used, are essential in restoring normal scaphoid anatomy and carpal alignment (Mathoulin and Arianni, 2018). We report our experience with the use of 3-D printing technology to aid in the anatomical reconstruction of scaphoid nonunion humpback deformities.

High resolution bilateral computed tomography (CT) scans of both wrists in a patient were obtained and processed according to a specific protocol: slice thickness 0.4 mm, slice increment 0.2 mm, pixel size 0.29 mm, 120 kVp (Michielsen et al., 2019). Following this, 3-D computer models of the scaphoids were created with medical images processing software (Mimics Medical, Leuven, Belgium), and a mirrored version of the normal contralateral scaphoid was then superimposed over the nonunited scaphoid.

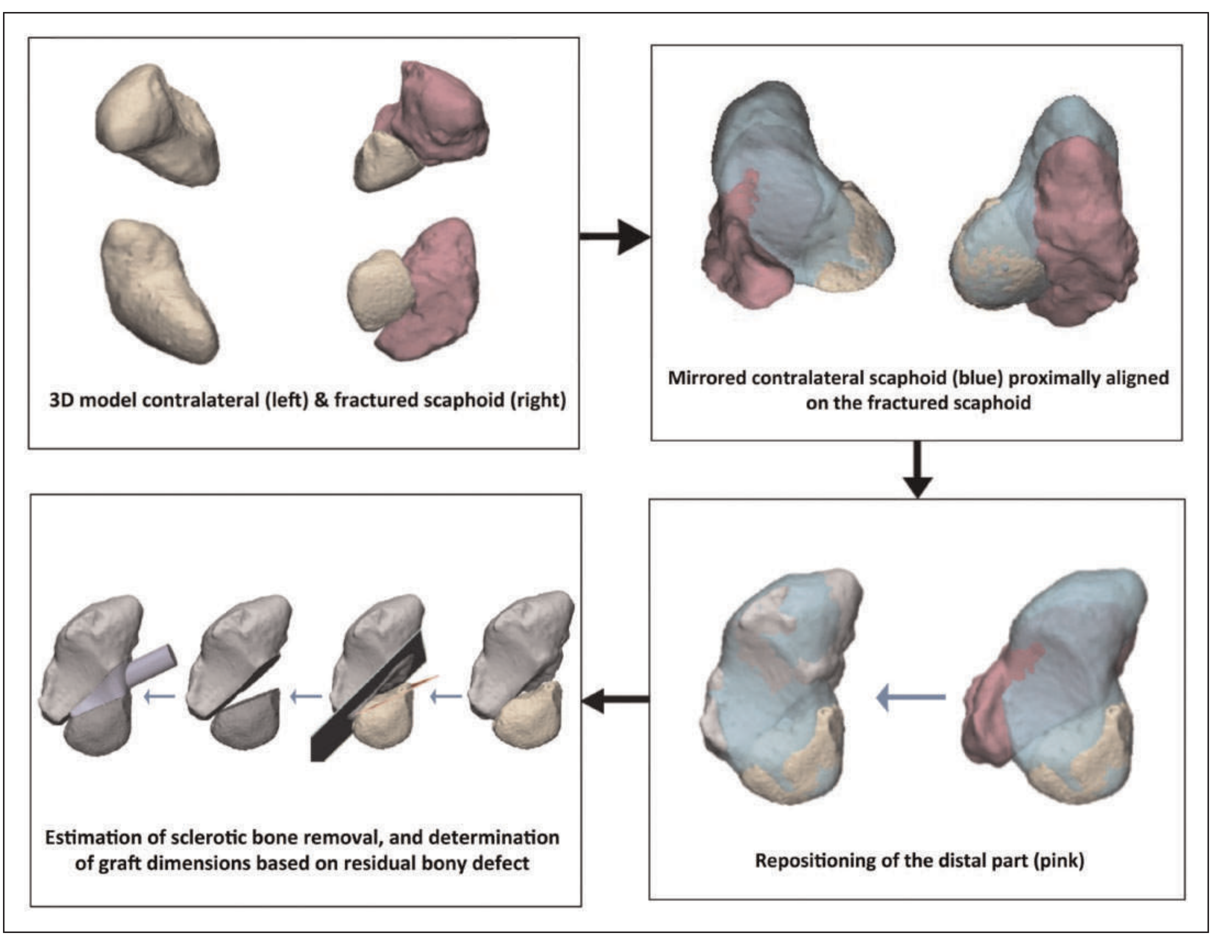

Figure 1. Preoperative three-dimensional planning showing the virtual pathways involved in estimating the dimensions of a bone graft, which would be used for subsequent 3-D printing of the model.
3-D: three dimensional.