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Scientific/Clinical Article

Prognostic factors for digital range of motion after intrasynovial flexor tendon injury and repair: Long-term follow-up on 273 patients treated with active extension-passive flexion with rubber bands

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ABSTRACT

Study Design: Observational cohort study.
Introduction: Investigating prognostic factors using population-based data may be used to improve functional outcome after flexor tendon injury and repair.
Purpose of the Study: The aim of this study is to investigate the effect of concomitant nerve transection, combined flexor digitorum profundus (FDP) and flexor digitorum superficialis (FDS) tendon transection and the age of the patient, on digital range of motion (ROM) more than 1 year after FDP tendon transection and repair in zone I and II.
Methods: Two hundred seventy-three patients with a total of 311 fingers admitted for FDP injury in zone I and II were treated with active extension-passive flexion with rubber bands and followed for at least 1 year. We compared outcome by evaluating digital mobility using Strickland's evaluation system.
Results: At 12 months 72% of patients aged > 50 had fair or poor ROM compared to 17% of patients aged 0-25 years. At 24 months the results for patients aged > 50 had improved to 33% with fair or poor ROM, whereas no improvement had occurred for patients aged 0-25 (17% with fair or poor ROM). Concomitant nerve transection and FDS tendon transection had no negative effects on digital mobility.
Discussion: Age above 50 was significantly associated with impaired digital ROM during the first year after flexor tendon injury and repair but not at 2 years follow-up. Concomitant nerve transection and combined transection of FDP and FDS do not affect digital mobility.
Conclusions: Older patients are likely to have a slower healing process and impaired digital ROM during the first year after surgery.

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Introduction

Adhesion formation and repair rupture after intrasynovial flexor tendon injury and repair are still challenging complications despite improvements in suture techniques and postoperative rehabilitation regimens.[1,2] Early controlled tendon mobilization after tendon injury and repair prevents adhesion formations and improves tendon healing as well as digit range of motion,[3-6] but the rate of complications has not clearly changed before and after the year 2000.[7]

Previous studies showed increasing age to be associated with a higher frequency of reoperation[8] and impaired digit range of motion.[9,10] Smoking and associated injuries also seem to be predictors of poor outcome after flexor tendon injury and repair,[9] as well as late rehabilitation.[11] These studies indicate that patient-based factors and concomitant injuries affect the functional long-term outcome. To better understand the effects of increasing age and combined injuries on the outcome after intrasynovial flexor tendon repair, we analyzed digit range of motion in 273 patients (with a total of 311 treated fingers) during at least 1-year follow-up.

Conflict of interest: The authors have no conflicts of interest to declare.

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The aim of this study was to describe digital range of motion after flexor digitorum profundus (FDP) tendon injury and repair in zone I and II and to estimate the effect of a concomitant nerve transection, the combination of FDP and flexor digitorum superficialis (FDS) tendon transection, and increasing age, on the long-term outcome after FDP tendon transection and repair in zone I and II.

Methods

All patients admitted for acute flexor tendon transection in zone I and II (digits I-V) between 2000 and 2006 at the department of hand surgery were considered for inclusion in the study (404 patients with 443 fingers). Table 1 shows the patient characteristics. We excluded patients with partially injured tendon ($n = 24$) and patients unable to attend medical appointments due to death ($n = 1$). Patients treated with tendon insertion to distal phalangeal bone ($n = 42$) and patients with injured thumbs ($n = 72$) were also excluded by which we were left with 273 included patients with a total of 311 treated fingers. Figure 1 shows the inclusion and exclusion criteria.

All patients were postoperatively treated with active extension-passive flexion with rubber bands to maintain the involved fingers in flexion as described by Kleinert et al[12] and modified by Silfverskiold and May.[13] The hand was immobilized postoperatively with the wrist in neutral position, the metacarpophalangeal joints in 50°-70° flexion, and the proximal and distal interphalangeal joints

Table 1
Study data

Category	Explanation of categories	Number of fingers
Age	0-25 y	108
	26-50 y	140
	51 y and above	63
	Missing	0
Concomitant nerve transection	Yes (complete transection of the ulnar or radial digital nerve, with or without partial injury of the other, or complete transection of both the ulnar and radial digital nerves)	135
	No (partial or no concomitant nerve injury)	176
	Missing	0
Transection of FDP and FDS tendons	Yes (complete transection of both FDP and FDS tendons)	125
	No (complete transection of FDP with or without partial FDS injury, ie, transection of one of the distal segments or partial tendon laceration)	171
	Missing	15
Gender	Female	90
	Male	221
	Missing	0
Injury to the dominant hand	Yes	153
	No	158
	Missing	0
Single or multiple digit injury	Single	241
	Multiple	70
	Missing	0
Rupture of tendon repair	Yes	18
	No	293
	Missing	0
Number of core suture strands	2	227
	4	84
	Missing	0

FDP = flexor digitorum profundus; FDS = flexor digitorum superficialis.
The left column shows the patient characteristics, and the right columns show an explanation of each category and the number of patients in each group.

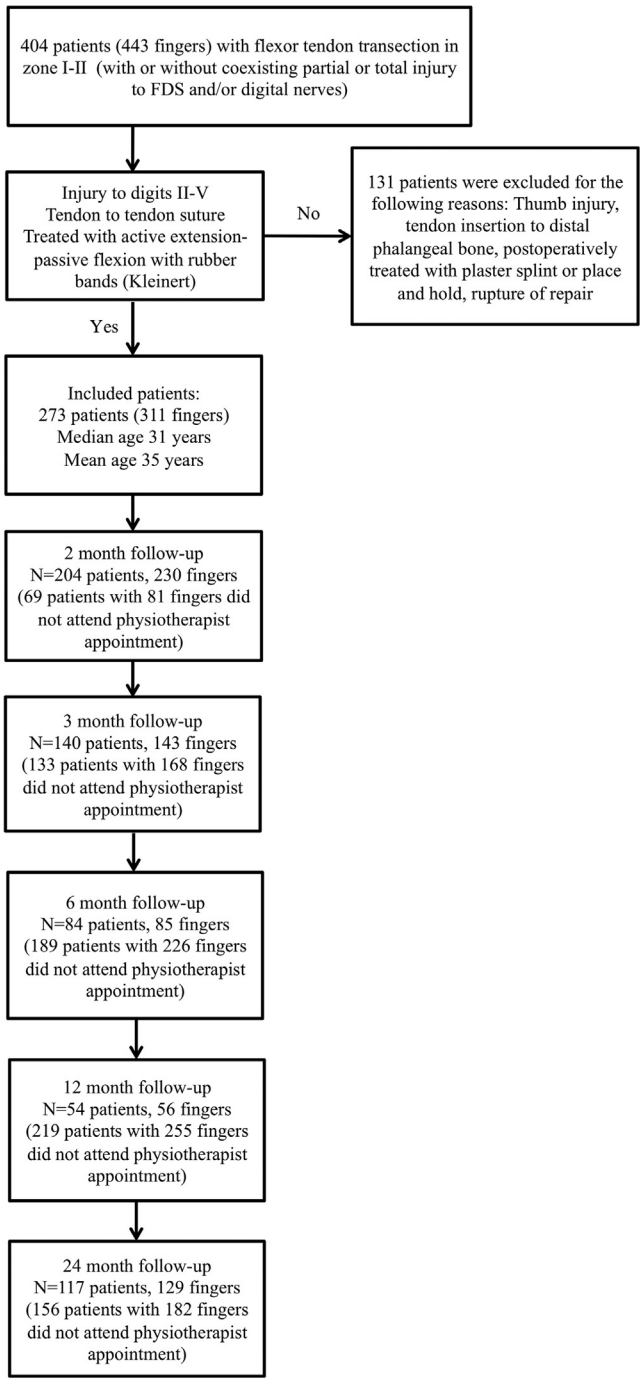

Fig. 1. Criteria for inclusion.

in full extension. Postoperative rehabilitation started on the first to fifth day after surgery. Rubber bands were attached to the fingertips and forearm and running under a pulley in the palm. Every hour, the patient performed 10 active interphalangeal joint extensions followed by passive flexion produced by the rubber bands. At the end of each passive flexion, the patient pressed in the fingertips with the uninjured hand to increase passive interphalangeal flexion. While passively flexing the fingers, the patient was allowed to contract the flexor muscles 2-3 seconds each time. The rubber bands were released at night, and the fingers immobilized in extension. This physical therapy program continued for 4 weeks after surgery, and after 4 weeks, the rubber bands were removed.

Follow-up time was at least 1 year. Finger mobility was controlled 2, 3, 6, 12, and 24 months postoperatively by a physiotherapist trained in hand physiotherapy (Fig. 1). All patients were treated at the same clinic, and to ensure reliability with measurements, the same therapist treated the patient during the follow-up sessions.

Digital range of motion of patients with coexisting nerve transection (complete transection of the ulnar or radial digital nerve, with or without partial injury of the other, or complete transection of both the ulnar and radial digital nerves) were compared to digital range of motion of patients with intact or partially injured nerves. Patients with transection of both the FDP and FDS tendons were identified and their digital range of motion were compared to patients without FDS tendon injury. Age was categorized into the groups 0-25 years, 26-50 years, and more than 50 years old.

We compared outcome by evaluating digital mobility using Strickland's evaluation system.[3,14] Finger mobility was measured using a finger goniometer placed on the dorsal side of the finger with the forearm and wrist in neutral position. Digital mobility was computed by the sum of proximal interphalangeal and distal interphalangeal joint flexion in attempted fist position minus the extensor lag at these joints. Proximal interphalangeal and distal interphalangeal joint motion was graded using Strickland's criteria into 4 functional categories: excellent (≥150°), good (125-149°), fair (90-124°), and poor (<90°). Hyperextension was equal to 0°. Patients with rupture of tendon repair (30 fingers) were excluded from the analysis.

Statistical analysis

Chi-square tests were used to test for associations between Strickland functional categories and age, coexisting nerve transection, and patients with transection of both the FDP and the FDS tendons, assuming that there were no patterns in which patients who chose to attend the follow-up appointments (a missing completely at random [MCAR] assumption). Logistic regression was used to assess the plausibility of the MCAR assumption by testing for patterns in the attendance rates of physiotherapist appointments. Specifically, we tested whether age and Strickland score at previous appointment were associated with attending a given physiotherapy appointment, and whether concomitant nerve injury and transection of both FDP and FDS were associated with physiotherapy appointment attendance. All tests were 2 sided with an alpha of 0.05.

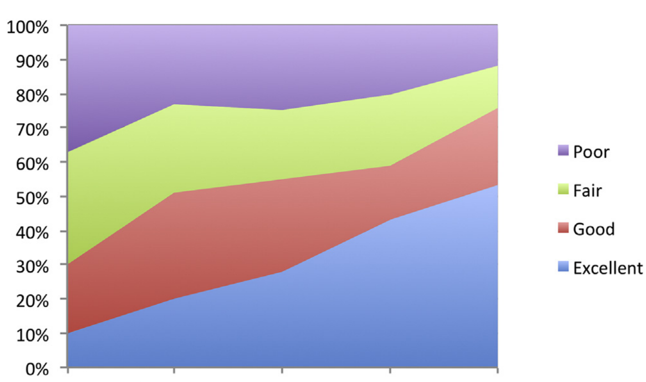

Fig. 2. Improved digital mobility over time. The percentage of all patients with poor (purple), fair (green), good (red), and excellent (blue) digital mobility using Strickland's evaluation system at 2, 3, 6, 12, and 24 mo of follow-up.

Table 2
Digital mobility at 2, 3, 6, 12, and 24 months of follow-up

Category	Strickland's evaluation system																								
	2-mo follow-up					3-mo follow-up					6-mo follow-up					12-mo follow-up					24-mo follow-up				
	Excellent	Good	Fair	Poor	*P*-value	Excellent	Good	Fair	Poor	*P*-value	Excellent	Good	Fair	Poor	*P*-value	Excellent	Good	Fair	Poor	*P*-value	Excellent	Good	Fair	Poor	*P*-value
All patients	24 (10)	46 (20)	75 (33)	85 (37)		28 (20)	45 (31)	37 (26)	33 (23)		24 (28)	23 (27)	17 (20)	21 (25)		24 (43)	9 (16)	12 (21)	11 (20)		69 (53)	30 (23)	15 (12)	15 (12)	
Age																									
0-25 y	14 (18)	18 (23)	23 (29)	24 (30)	.05*	17 (33)	18 (35)	7 (14)	9 (18)	.004*	11 (42)	11 (42)	1 (4)	3 (12)	.005*	13 (72)	2 (11)	1 (6)	2 (11)	.02*	28 (65)	8 (18)	5 (12)	2 (5)	.20
26-50 y	10 (10)	19 (19)	35 (34)	38 (37)		11 (17)	17 (27)	18 (28)	18 (28)		12 (28)	10 (23)	10 (23)	11 (26)		8 (30)	7 (26)	7 (26)	5 (18)		28 (45)	19 (31)	7 (11)	8 (13)	
>51 y	0 (0)	9 (18)	17 (35)	23 (47)		0 (0)	10 (36)	12 (43)	6 (21)		1 (6)	2 (12)	6 (38)	7 (44)		3 (28)	0 (0)	4 (36)	4 (36)		13 (54)	3 (13)	3 (13)	5 (20)	
Concomitant complete nerve transection																									
Yes	11 (12)	11 (12)	34 (35)	39 (41)	.07	13 (25)	16 (30)	10 (19)	14 (26)	.38	17 (32)	13 (24)	12 (23)	11 (21)	.48	10 (44)	4 (17)	4 (17)	5 (22)	.93	26 (48)	15 (28)	7 (13)	6 (11)	.69
No	13 (10)	35 (26)	41 (30)	46 (34)		15 (17)	29 (32)	27 (30)	19 (21)		7 (22)	10 (31)	5 (16)	10 (31)		14 (43)	5 (15)	8 (24)	6 (18)		43 (59)	15 (21)	9 (12)	6 (8)	
Transection of FDP and FDS tendons																									
Yes	10 (11)	18 (21)	22 (25)	37 (43)	.41	13 (22)	20 (35)	15 (26)	10 (17)	.74	7 (30)	5 (21)	3 (12)	9 (37)	.33	11 (52)	2 (10)	3 (14)	5 (24)	.39	22 (46)	11 (23)	6 (12)	9 (19)	.29
No	14 (10)	27 (20)	48 (36)	46 (34)		16 (18)	29 (32)	26 (28)	20 (22)		15 (26)	18 (31)	13 (22)	12 (21)		11 (34)	7 (22)	8 (25)	6 (19)		44 (59)	16 (21)	9 (12)	6 (8)	

FDP = flexor digitorum profundus; FDS = flexor digitorum superficialis.
Number of patients and percentage of patients in parentheses for each category: excellent, good, fair, or poor digital range of motion using Strickland's evaluation system.
The following significance symbol is used: *$P < 0.05$.

Ethics statement

The Central Ethical Review Board approved the study. This study evaluates standard care retrospectively (ie, no intervention was performed). All analyses were conducted on anonymized and deidentified data in order to preserve personal integrity.

Results

Using Strickland's evaluation system, patients demonstrated improved digital mobility over time. Thirty percent of the fingers had good or excellent digital range of motion at 2-month follow-up. At 3-month follow-up, 51% had good or excellent outcome, at 6 months 55%, at 12 months 59%, and at 24 months 76% (Fig. 2). A concomitant digital nerve transection or a combined FDP and FDS tendon transection did not affect the digital mobility during the study period (Table 2). Increasing age was significantly associated with impaired outcome during the first year after surgical repair, but this difference could not be detected 24 months after surgery (Figs. 3A-3C) (Table 2).

Age and Strickland score at previous follow-up time were not associated with the probability of attending a given physiotherapy appointment (all P values $> .5$). Concomitant nerve injury and transection of both FDP and FDS were not significantly associated with physiotherapy appointment attendance (P values $> .5$).

Discussion

We found age to be significantly associated with impaired digital range of motion during the first year after FDP tendon injury and repair. This effect could, however, not be detected at 2-year follow-up. Concomitant nerve transection and FDS tendon transection did not affect digital mobility during the study period.

Our results showing negative correlation between age and digital range of motion are supported by Moriya et al[10] and Rigo and Rokkum[9] who reported age to be a predictor of poor outcome after flexor tendon injury and repair. We detected a negative effect of increasing age on digital range of motion the first year after surgery, but this effect was no longer seen 2 years postoperatively. This indicates that follow-up studies of digital mobility after finger trauma benefit from continuing over a 2-year time span.

We found no evidence for impaired digital range of motion following combined transection of FDP and digital nerves. Earlier studies of the effect of combined nerve and flexor tendon injuries on digit range of motion after flexor tendon repair have shown conflicting results. Trumble et al[15] demonstrated poorer outcomes within this patient group, but Rosberg et al[16] found no significant effect on digit range of motion after flexor tendon repair in patients with a concomitant digital nerve injury. However, a previous study has shown a protective effect of a nerve injury on the risk of repair rupture.[8] Nerve injury may thus have a protective effect on the repaired tendon by decreasing the risk of repair rupture after FDP tendon transection and repair[8] without negatively affecting digital range of motion.

In our study, combined transection of FDP and FDS does not seem to affect digital mobility. These results match those of Strickland and Glogovac[3] and of Baktir et al[17] who studied digital mobility and reported similar results following repair of both the FDS and FDP tendon. Rigo and Rokkum[9] on the other hand, reported decreased range of motion following repair of FDP in combination with repaired and unrepaired FDS tendon transection. This effect was, however, detected only at 8-week follow-up, at 3 months it was no longer significant. We find those results convincing and interesting but also surprising since 2 repairs are likely to give greater contact surface between the suture and the sheath leading to more adhesion formations.[18]

Thirty percent of the fingers treated with active extension-passive flexion with rubber bands[12] after flexor tendon injury and

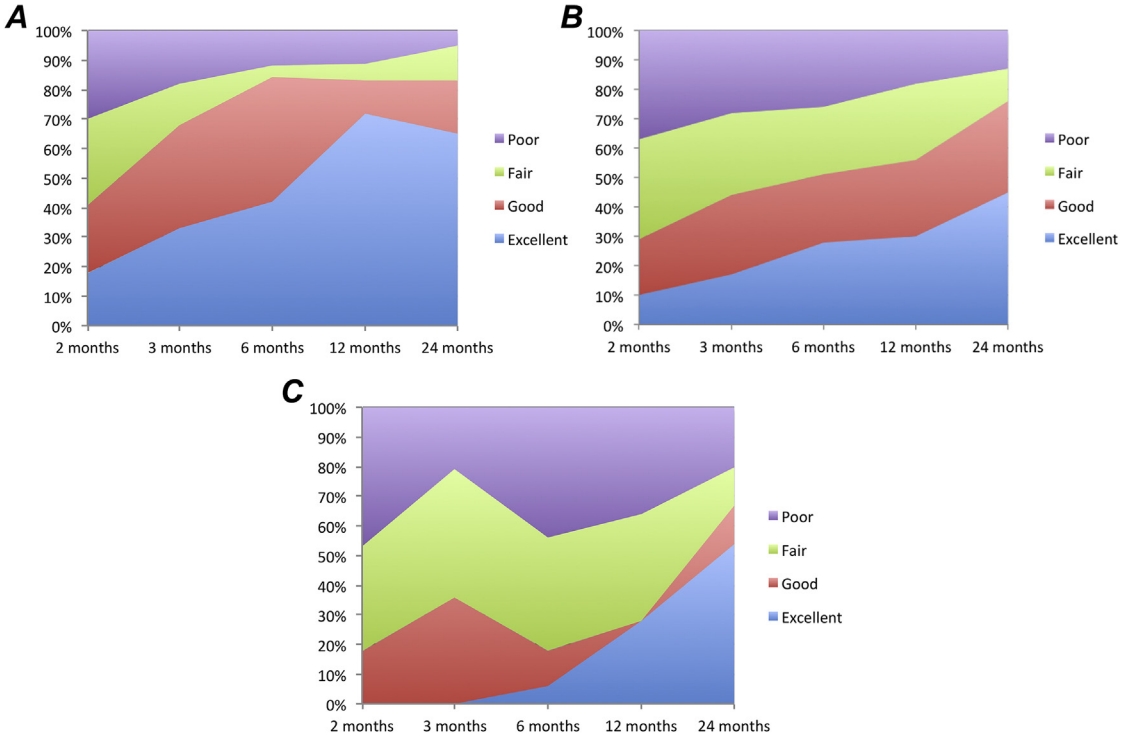

Fig. 3. Increasing age was associated with impaired outcome during the first year after surgical repair. The percentage of patients divided in 3 age categories with poor (purple), fair (green), good (red), and excellent (blue) digital mobility using Strickland's evaluation system at 2, 3, 6, 12, and 24 mo follow-up. (**A**) 0-25 y. (**B**) 26-50 y. (**C**) >51 y.

repair in zone I and II demonstrated good or excellent digital range of motion 3 months after surgery. The percentage of fingers with good or excellent mobility increased during the 2-year study period to 76% at the last follow-up of 24 months after surgery. Our results are comparable to those of Baktir et al[17] who reviewed 33 patients (41 fingers) treated with passive flexion and extension with rubber band after flexor tendon transection and found excellent or good results in 78% of digits 1 year after surgery. Su et al[19] describe similar results following FDP tendon injury and repair in 38 patients (51 fingers), with or without FDS tendon injury. After postoperative rehabilitation with the modified Kleinert method, approximately 70% of the fingers showed good or excellent digital range of motion 6 months after surgery. These studies suggest that the outcome after flexor tendon repairs in zone I and II, treated with passive motion therapy is acceptable. However, passive mobilization protocols may have a higher risk of tendon adhesion and loss of digit range of motion compared to active motion protocols, whereas active protocols may have a higher risk of repair rupture.[20] No complete consensus exists concerning the best type of motion or the ideal hand posture during rehabilitation.

The strength of this study is the relatively large cohort. The study consists of all consecutive patients during the 6-year study period. The fluctuating number of patients attending the physiotherapist appointments is a limitation. However, the fact that no patterns in the patients that attended the physiotherapy appointments could be observed indicates that a missing completely at random assumption seems plausible, which strengthens the results (although unmeasured confounding still can cause untestable deviations from the MCAR assumption, as in all observational studies). The age of the patient seems not to affect attendance, and we found no evidence suggesting that patients with excellent mobility ignore their appointments at the physiotherapist because they already are satisfied with their digital mobility.

Conclusion

Age seems to be an important prognostic factor affecting the initial outcome after intrasynovial FDP tendon transection and repair, whereas coexisting digital nerve transection or FDS tendon transection do not affect digital mobility. The digital mobility after flexor tendon repair continues to increase between 1 and 2 years after surgery.

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1. The study design is
   a. RCTs
   b. qualitative
   c. prospective
   d. retrospective

2. Following tendon repair the patients were managed by
   a. early active flexion as described by Evans
   b. the Duran method of passive flexion and extension
   c. a system of active extension and passive flexion via rubber band traction as described by Kleinert
   d. a system of active flexion and passive extension via rubber band traction as described by Kleinman

3. The extensive literature review revealed
   a. there is yet no consensus on the ideal post op management approach
   b. early active motion results in fewer ruptures
   c. the Kleinert method id superior to all others
   d. serious flaws in the Strickland method of evaluation

4. Age effected (or not) digital mobility in the following way
   a. no effect on outcomes
   b. older patients lagged behind in regaining ROM, but caught up in the second post op year
   c. older patients lost motion in the second post op year
   d. younger patients lagged behind in regaining ROM, but caught up in the second post op year

5. Concomitant nerve transection adversely affected digital mobility
   a. true
   b. false

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