

# The Effect of Smoking on Post-operative Finger Range of Motion in Patients with Tendon Grafts

IVAN JUSTAN<sup>1,2</sup>, PETRA OVESNÁ<sup>3</sup>, TOMÁŠ KUBEK<sup>1</sup>, PETR HÝŽA<sup>1</sup>, IGOR STUPKA<sup>1</sup> and ZDENĚK DVOŘÁK<sup>1</sup>

<sup>1</sup>Department of Plastic and Aesthetic Surgery, Masaryk University, Faculty of Medicine, St. Anne's University Hospital, Brno, Czech Republic;

<sup>2</sup>SurGal Clinic, Brno, Czech Republic;

<sup>3</sup>Institute of Biostatistics and Analyses, Masaryk University, Faculty of Medicine and Faculty of Science, Brno, Czech Republic

**Abstract.** *Background: The finger range of motion (ROM) was evaluated in patients with hand flexor tendon replacement using a tendon graft and the effect of smoking was investigated. The first hypothesis was: a tendon graft increases the post-operative ROM. The second hypothesis was: smoking has a negative effect on the final finger ROM. Patients and Methods: Fifty seven autologous tendon grafts in 48 patients were included. The patients were grouped as non-smokers or smokers ("light" or "heavy"). The modified Strickland system and Total Active Motion (TAM) system, were chosen for the evaluation. Results: The first hypothesis was proved by all the measurements. The post-operative status assessed by the Strickland method was different between the non-smokers and smokers with a better score in the smokers. Conclusion: A significant ROM improvement occurs after reconstruction and is even slightly better in smokers than in non-smokers.*

Since the introduction of the two-stage tendon grafting technique by Hunter in 1965 (1), this method has become popular with hand surgeons (2, 3). Nowadays it has been fully established and it is not subject to substantial variation or variable outcome. This technique is considered as the gold standard for severely injured digits in our department. We have tried to minimise the main post-operative complications such as rupture, adhesion and contracture, by using our extensive knowledge of tendon graft biomechanical properties, changes during the healing process and postoperative rehabilitation requirements.

*Correspondence to:* Ivan Justan, Tyršova 48, Brno 61200, Czech Republic. Tel: +420 777 136 908, Fax: +420 541 211 644, e-mail: justan@operativa.cz

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However not all factors have been clearly investigated and the influence of age, surgery timing, steroid abuse and patients' polymorbidity as well as cicatrix from injury or infection, stiffened joints, trophic changes and damage to more than one digit have been discussed (4). Above all smoking has been mentioned as a factor with a negative influence on tissue healing generally. From this point of view the impact of smoking includes tendon healing as well. Nicotine is responsible for delayed tendon-to-bone healing in experimental animal models (5-7). Every surgeon encourages their patient to stop smoking due to the well-known complications.

Two hypotheses were therefore investigated, firstly that a tendon graft increases the postoperative range of motion (ROM) of a finger and secondly that smoking has a negative effect on the final finger ROM after tendon grafting.

## Patients and Methods

Between January 2000 and December 2005 operations were conducted on 48 patients with tendon injury of triphalangeal fingers demanding two-stage tendon grafting. In total, 58 autologous tendon grafts harvested either from the m.palmaris longus or m.flexor digitorum superficialis were used. All the patients were operated on at our department by different surgeons, using a standardized procedure including total removal of the ruptured tendon from its insertion into the distal phalanx from the distal forearm and consecutive replacement with a harvested tendon graft. A standard reinsertion using a monofilamentous non-absorbable suture USP 3/0 through the nail plate was carried out in all the cases. Different types of proximal suture were performed, but all the cases had at least 2 cm overlap of their stumps (8, 9). The patients underwent the same static rehabilitation protocol and their ROMs were recorded before and after surgery by the same physiotherapists.

The patients were divided into two groups: non-smokers and smokers. The smokers group had two subgroups of "light" smokers and "heavy" smokers (Table I), divided due to statistical reasoning and not according to WHO guidelines. The "light" group smoked up to 15 cigarettes a day, the "heavy" smokers more than 15 cigarettes a day.

Table I. Numbers of patients in each group. The last column indicates the number of patients with more than 1 tendon graft.

	Patients	Grafts	More grafts
Total	48	58	9
Non-smokers	28	33	4
Smokers	20	25	5
“Light“ smokers	11	13	2
“Heavy“ smokers	9	12	3

Table II. Evaluation scheme of the Total Active Motion system.

Excellent	No side difference
Good	TAM >75% of the contralateral side
Fair	TAM >50% of the contralateral side
Poor	TAM <50% of the contralateral side

Table III. Evaluation scheme of the adjusted Strickland system.

	%	Degrees
Excellent	75-100%	132<
Good	50-74%	88-131
Fair	25-49%	45-87
Poor	0-24%	<44

Assessment of finger motion was performed by two methods. The total Active Motion System (TAM) (10) evaluates distal interphalangeal joints (DIP), proximal interphalangeal joints (PIP) and metacarpophalangeal joints (MP) and is recorded as flexion (MP+PIP+DIP) – extension deficit (MP+PIP+DIP)=TAM in degrees (Table II). The adjusted Strickland system (11) involves only PIP and DIP joints and is recorded as (flexion (PIP+DIP) – extension deficit (PIP+DIP)):175 degrees ×100% of normal ROM in PIP and DIP joints (Table III). Mean follow up was 26 months (18-41 months). Standard non-parametric statistical methods were used for hypotheses testing. The Mann-Whitney test was applied to assess the difference between two independent groups and the Wilcoxon matched pairs test was used to assess the difference between two dependent groups.

## Results

The effect of the tendon graft on the finger ROM was tested by comparing the groups before and after surgery (Table IV and V and Figure 1). Improvement in the finger ROM in comparison with the status before surgery was recorded both in the non-smokers and smokers (both “light” and “heavy”). This difference was documented by both methods (TAM and

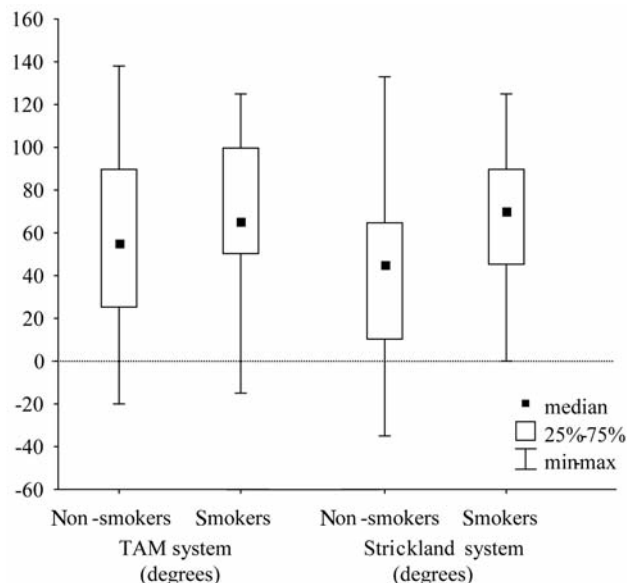


Figure 1. Distribution of results after surgery for both evaluation systems in smokers and non-smokers.

Strickland systems). According to the TAM system, the average improvement was 53.8 degrees for non-smokers and 68.4 degrees for smokers. In the modified Strickland system, the average improvement was 41.7 degrees for non-smokers and 62.8 degrees for smokers.

The finger ROM before the tendon graft implantation was not significantly different between the non-smokers and smokers (Table VI) and no difference was also demonstrated between the “light” and “heavy” smokers (Table VII). The post-operative finger motion ability assessed by the adjusted Strickland method showed a difference between the non-smokers and smokers with a better score in the smokers. The differences were not significant when assessed by the TAM system (Table VI).

Comparison of the difference in finger ROM preoperatively and postoperatively (post-op ROM minus pre-op ROM) is shown in Tables VIII and IX. The motion ability improved more in the smokers than in the non-smokers; however, a significant difference was recorded only by the adjusted Strickland method and not by the TAM system.

No negative effects of smoking on the motion ability of patients with tendon graft were demonstrated. The improvement in motion ability did not differ between the “light” and “heavy” smokers and, thus, did not depend on number of cigarettes per day.

Evaluations for each individual group according to the TAM system scheme and the adjusted Strickland system scheme are shown in Table X.

Table IV. Comparison of finger ROM before and after surgery, in non-smokers and smokers.

Non-smokers		Finger motion ability					p-value (Wilcoxon test)
		N	Mean	Median	Min	Max	
TAM (degrees)	Pre-op	33	68.7	75.0	10	110	<0.001
	Post-op	33	122.5	115.0	40	223	
	Difference	–	53.8	55.0	–20	138	
Strickland (degrees)	Pre-op	33	3.1	0.0	0	40	<0.001
	Post-op	33	44.8	45.0	0	133	
	Difference	–	41.7	45.0	–35	133	

Smokers		Fingers motion ability					p-value (Wilcoxon test)
		N	Mean	Median	Min	Max	
TAM (degrees)	Pre-op	25	66.2	70.0	20	105	<0.001
	Post-op	25	134.6	155.0	25	215	
	Difference	–	68.4	65.0	–15	125	
Strickland (degrees)	Pre-op	25	4.2	0.0	0	35	<0.001
	Post-op	25	67.0	75.0	0	125	
	Difference	–	62.8	70.0	0	125	

ROM: Range of motion; TAM: Total active motion system.

Table V. Comparison of finger ROM before and after surgery. In groups of “light” and “heavy” smokers.

Smokers 0-14 cigarettes per day		Finger motion ability					p-value (Wilcoxon test)
		N	Mean	Median	Min	Max	
TAM (degrees)	Pre-op	13	74.2	70.0	30	105	0.002
	Post-op	13	143.8	155.0	50	215	
	Difference	–	69.6	65.0	–15	125	
Strickland (degrees)	Pre-op	13	6.5	0.0	0	35	0.002
	Post-op	13	71.9	70.0	0	125	
	Difference	–	65.4	60.0	0	125	

Smokers 15 or more cigarettes per day		Finger motion ability					p-value (Wilcoxon test)
		N	Mean	Median	Min	Max	
TAM (degrees)	Pre-op	12	57.6	57.5	20	95	0.002
	Post-op	12	124.6	150.0	25	175	
	Difference	–	67.0	82.0	5	110	
Strickland (degrees)	Pre-op	12	1.8	0.0	0	10	0.002
	Post-op	12	61.7	75.0	5	110	
	Difference	–	59.9	75.0	5	105	

ROM: Range of motion; TAM: Total active motion system.

## Discussion

The first hypothesis regarding improvement after two stage tendon grafting was not expected to fail, since in agreement with Schneider (12) in our department fusion or amputation is still indicated in fingers with massive injury, and

statistically significant improvement was found in all the groups regardless of the scoring system.

The second hypothesis was also expected to be easily proved as no article concerning any positive effect of smoking on wound healing has been found. Indeed tobacco smoking reduces blood flow in different tissue types which

Table VI. Comparison of ROM status before and after the surgery, in non-smokers and smokers.

Pre-operative status		Finger motion evaluation					p-value (M-W test)
		N	Mean	Median	Min	Max	
TAM pre-op (degrees)	Non-smokers	33	68.7	75.0	10	110	0.603
	Smokers	25	66.2	70.0	20	105	
Strickland pre-op (degrees)	Non-smokers	33	3.1	0.0	0	40	0.432
	Smokers	25	4.2	0.0	0	35	
Post-operative status (M-W test)		Finger motion evaluation					p-value
		N	Mean	Median	Min	Max	
TAM post-op (degrees)	Non-smokers	33	122.5	115.0	40	223	0.195
	Smokers	25	134.6	155.0	25	215	
Strickland post-op (degrees)	Non-smokers	33	44.8	45.0	0	133	0.022
	Smokers	25	67.0	75.0	0	125	

ROM: Range of motion; TAM: Total active motion system; M-W: Mann-Whitney.

Table VII. Comparison of ROM status before and after surgery in groups of “light” smokers and “heavy” smokers.

Pre-operative status	Cigarettes per day	Finger motion evaluation					p-value (M-W test)
		N	Mean	Median	Min	Max	
TAM pre-op (degrees)	0-14	13	74.2	70.0	30	105	0.108
	15 or more	12	57.6	57.5	20	95	
Strickland pre-op (degrees)	0-14	13	6.5	0.0	0	35	0.793
	15 or more	12	1.8	0.0	0	10	
Post-operative status	Cigarettes per day	Finger motion evaluation					p-value (M-W test)
		N	Mean	Median	Min	Max	
TAM post-op (degrees)	0-14	13	143.8	155.0	50	215	0.643
	15 or more	12	124.6	150.0	25	175	
Strickland post-op (degrees)	0-14	13	71.9	70.0	0	125	0.703
	15 or more	12	61.7	75.0	5	110	

ROM: Range of motion; TAM: Total active motion system; M-W: Mann-Whitney.

Table VIII. Comparison of ROM changes in preoperative and postoperative status in non-smokers and smokers.

		ROM change (post-op – pre-op)					p-value (M-W test)
		N	Mean	Median	Min	Max	
TAM (degrees)	Non-smokers	33	53.8	55.0	-20	138	0.169
	Smokers	25	68.4	65.0	-15	125	
Strickland (degrees)	Non-smokers	33	41.7	45.0	-35	133	0.028
	Smokers	25	62.8	70.0	0	125	

ROM: Range of motion; TAM: Total active motion system; M-W: Mann-Whitney.

Table IX. Comparison of ROM changes in preoperative and postoperative status in “light” smokers and “heavy” smokers.

	Cigarettes per day	Motion ability change (post-op – pre-op)					p-value (M-W test)
		N	Mean	Median	Min	Max	
TAM (degrees)	0-14	13	69.6	65.0	-15	125	0.723
	15 or more	12	67.0	82.0	5	110	
Strickland (degrees)	0-14	13	65.4	60.0	0	125	0.935
	15 or more	12	59.9	75.0	5	105	

ROM: Range of motion; TAM: Total active motion system; M-W: Mann-Whitney.

impairs the healing process. Also a negative influence of nicotine on the synthesis of collagen has been discovered (13). Due to microvascular changes, inhibition of revascularization and the strong vasoconstrictive effect of nicotine, smokers have 1.8 times less mature collagen in their surgical wounds than non-smokers (14). Moreover, free radical gas, such as nitric oxide which is synthesized from L-arginine by nitric oxide synthase (NOS) could play a certain role in this process. Lin *et al.* (15) demonstrated that NOS is induced during tendon healing and inhibition of NOS resulted in a significant reduction in the cross-sectional area and failure load of healing in the Achilles tendon.

The present results showed no negative effect of tobacco smoking on the ROM after tendon graft reconstruction and surprisingly, the adjusted Strickland scoring scheme, showed a significantly better score in the smokers. In our opinion the Strickland system is more precise than TAM scoring for evaluating tendon graft reconstruction because it involves motion only in the PIP and DIP joints. Overly keen patients are able to overload MP joints during rehabilitation and thus the joints become more relaxed. From this point of view this phenomenon discredits the TAM system slightly with regard to an evaluation of exclusively extrinsic flexor function. In line with Peacock’s “one wound concept” (16) focusing only on the tendon smoking might indeed inhibit tendon healing, so that the final tendon strength is achieved later on, but the same inhibition would also apply for the creation of adhesions. Gelberman *et al.*’s study showed that the strength at the site of repair does not increase substantially until three weeks post surgery, by which time revascularization was observed at the site (17). Enveloping of the grafts by vascular adhesions after two weeks and complete integration by six weeks was also described (18). Active rehabilitation is usually started after four postoperative weeks in our protocol. If healing and adhesion formation was retarded in smokers, the adhesions could be weak and prone to easier remodeling. Non-smokers could be handicapped due to their standard healing and also their adhesions could be more mature and steady by the fourth postoperative week. In our opinion smokers could achieve the better postoperative ROM thanks

Table X. Means of the TAM and the adjusted Strickland system in non-smokers, smokers, “light” smokers and “heavy” smokers. Values show graft numbers.

	Excellent	Good	Fair	Poor
Non-smokers				
TAM	0	9	12	12
Strickland	1	5	11	16
Smokers				
TAM	1	13	5	7
Strickland	0	8	11	6
“Light” smokers				
TAM	0	7	3	3
Strickland	0	5	6	2
“Heavy” smokers				
TAM	0	6	2	4
Strickland	0	3	5	4

TAM: Total active motion system.

to a lower quality of healing process which enables disturbance of adhesions.

**Conclusion**

Significant ROM improvement occurs after reconstruction in both non-smokers and smokers (mild and heavy) even slightly better in smokers. No negative effects of smoking on the ROM change after the graft implantation are demonstrated.

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