ORIGINAL ARTICLE

Contribution of Lumbrical Muscle Activity to the Paradoxical Extension Phenomenon Induced by Injuries to the Finger Flexor Tendons

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Abstract. The "Extensor habitus" phenomenon occurs in finger flexor tendon injuries and consists of a paradoxical extension of the interphalangeal joints after an attempt to flex the finger. The mechanism of extension is considered to be a contraction of the flexor digitorum profundus that is then transmitted *via* the lumbrical muscle structure to the extensor expansion. Using electromyography, we recorded the lumbrical muscle activity during the paradoxical extension phenomenon to determine whether the lumbrical muscle contributed to this event. Two patterns of electromyographical activity of the lumbrical muscle were observed. Group I (6 fingers) displayed electrical activities in the lumbrical muscle during flexion tasks, while group II (12 fingers) did not. In group I, the lesions were mainly located in zone V, and the response to range of motion exercises was satisfactory. In group II, nearly all of the lesion were located in zone II, and half of the cases required additional surgical interventions. Group II appeared to exhibit the "Extensor habitus" phenomenon, while group I exhibited an "Extensor habitus-like phenomenon." To distinguish between these two phenomena, an electromyographical examination of the lumbrical muscle must be performed. (Keio J Med 48 (4): 175-178, December 1999)

Key words: Extensor habitus phenomenon, Extensor habitus-like phenomenon, lumbrical muscle, flexor digitorum profundus

Introduction

For the rehabilitation of injuries to the finger flexor tendons, range of motion (ROM) exercises must be conducted at an early stage in the patient's recovery to ensure smooth tendon excursion.¹⁻³ The Kleinert method is frequently used postoperatively. This method enables early ROM exercises to be performed without imposing too much tension on the tendon. The Blocking exercise, in which the metacarpophalangeal (MP) joint is fixed and the interphalangeal (IP) joints are actively flexed, is also effective for the release of adhesive tendon. During this exercise, however, the flexion movements of the IP joints are sometimes hindered at a certain angle when the patient attempts to perform an active or an assisted active flexion of the finger. This event is followed by a paradoxical extension. Alternatively, if the IP joints are passively flexed by a therapist, a strong resistance is sometimes observed. In 1960

White named this phenomenon "Extensor habitus."⁴ He considered that when a transferred tendon was insufficiently tense, the force of the flexor digitorum profundus would be conducted through the lumbrical muscle structure to the extensor expansion, resulting in an extension of the IP joints (Fig. 1).

However, our clinical experience suggested that the contraction of the lumbrical muscle may in fact be involved in the paradoxical extension phenomenon in some cases.^{5,6} We therefore studied the contraction of the lumbrical muscle electromyographically. This report will discuss our findings and their relation to the mechanism of the paradoxical extension phenomenon that is sometimes detected after injuries to the finger flexor tendons.

Subjects

Sixteen patients (13 males and 3 females) whose fin-

gers exhibited the paradoxical extension phenomenon were included in the study. A total of 18 fingers were investigated. The average age of the patients was 29.5 years old (10–57 years old). All the patients were treated in our department, and their exercise programs were started 3–4 weeks after their initial orthopedic intervention. The fingers investigated in the study consisted of 4 right index fingers, 4 left index fingers, 1 right middle finger, 2 left middle fingers, 3 right ring fingers, 2 left ring fingers and 2 left little fingers. When the IP joints of these fingers were passively flexed while the

MP joint was maintained in an extended position, either a paradoxical extension of the IP joints or a resistive movement in the direction of flexion was detected.

The injured locations were classified according to the zones described by the Kleinert method.⁷ Consequently, 2 fingers were classified as zones I and II, 10 fingers as zone II, and 4 fingers as zone V. The following tendons were damaged: 2 flexor digitorum profundus in zones I and II, 6 flexor digitorum profundus in zone II, 4 flexor digitorum profundus and superficialis in zone II, 1 flexor digitorum profundus in zone V, and 3 flexor digitorum profundus and superficialis in zone V. In two cases, the MP joint had been dislocated because of a proximal phalanx fracture, and no obvious flexor tendon injuries were present. Adhesional lesions of the tendons in zone II were suspected based on the clinical features of the cases (Table 1).

Fig. 1 Mechanism of the Extensor habitus phenomenon.

Methods

To clarify the mechanism of the paradoxical extension phenomenon, an electromyographical study was conducted on the lumbrical muscle to determine its involvement in the extension of the IP joints. The electromyographical measurements were performed using an MS20 (Medelec Ltd, Surrey GU22 9JV, UK) according to a method described in a textbook.⁸ A concentric needle electrode was inserted in the distal

Table 1 Subjects

Case No.	Initials	Age (years)	Sex	Affected Fingers	Damaged Tendons	Zone	Cause of Injury	Surgical Intervention	Additional Surgical Intervention
1		54	male	Rt. index	FDS, FDP	V	glass cut	tendon suture	
2		57	female	Lt. little	FDS, FDP	V	subcutaneous rupture	tendon transfer	
3		10	male	Lt. index	FDP	V	knife cut	tendon suture	
4		41	female	Rt. index	FDS, FDP	V	crash	tendon suture	
5		22	male	Rt. index	(PP fracture)		motorcycle accident	pinning, tenolysis	
6		13	female	Lt. index	FDP	II	knife cut	PIP joint release	
7		26	male	Rt. ring	FDP	II	crash	tendon transfer	shortening pulley reconstruction
8		40	male	Lt. ring	FDS, FDP	II	crash	no intervention	
9		32	male	Rt. ring	FDS	II	crash	tendon transfer	tenolysis
10		41	male	Rt. ring	FDS, FDP	II	crash	no intervention	tenolysis
11		20	male	Rt. index	FDP	II	saw cut	joint transplantation	tenolysis
12		17	male	Lt. middle	(MPJ fracture)		motorcycle accident	ligament reconstruction	
13		20	male	Rt. middle	FDS, FDP	II	knife cut	tendon suture	
14		17	male	Lt. index	FDP	I, II	crash	tendon transfer	
				Lt. middle	FDP	I, II		tendon transfer	
15		43	male	Lt. ring	FDP	II	knife cut	tendon suture	
				Lt. little	FDP	II		tendon transfer	
16		20	male	Lt. index	FDS, FDP	II	crash injury	tendon suture	

FDS: flexor digitorum superficialis, FDP: flexor digitorum profundus, PP: proximal phalanx, MPJ: metacarpophalangeal joint, PIP: proximal interphalangeal.

portion of the lumbrical muscle belly to detect the electromyographical signals. The frequency band varied from 10 to 10,000 Hz, and the electrical signals were amplified by a bioamplifier. Motor unit action potentials were observed for each of the following four limb positions described by Long and Brown (1964)⁹: 1) MP joint flexion with extension of the IP joints, 2) extension of the IP joints with extension of the MP joint, 3) flexion of all finger joints, and 4) flexion of the IP joints with extension of the MP joint. In positions 1 and 2, the lumbrical muscle acts as prime mover and the flexor digitorum profundus is not involved. In positions 3 and 4, the flexor digitorum profundus acts as the prime mover and the lumbrical muscle is not involved.

Results

All 18 fingers were capable of performing the four finger flexion tasks required by the electromyographical examination as long as the complete motion was not required.

Based on the pattern of electromyographical activity in the lumbrical muscle, the fingers were classified into two groups. Group I showed electrical activity in the lumbrical muscle in positions 3 and/or 4, while group II showed no signs of electrical activity (Fig. 2). Though other patterns of activity were theoretically possible, these two patterns were the only ones observed in this study. Six fingers were classified as group I and 12 fingers as group II.

Among the group I cases, four of the fingers had been injured in zone V and one in zone II. In the remaining finger, where a proximal phalanx fracture had occurred, an adhesional tendon lesion was suspected in zone II. Paradoxical extension occurred in four fingers, and resistance was felt in two. The total active motion (TAM) values at the time of the paradoxical extension phenomenon's first appearance were severely limited, but the final TAM values measured 10 to 12 weeks after the initial surgical intervention had improved greatly as a result of the Blocking exercise in all group I cases except one (case #5). The paradoxical extension phenomenon disappeared in group I as the ROM exercises progressed. In the one exception, the flexor tendon was in an advanced state of adhesion after a proximal phalanx fracture. In this case, the TAM value did not improve, and the paradoxical phenomenon persisted (Table 2).

Twelve fingers were classified as group II. Among them, 9 fingers were injured in zone II and 2 fingers were injured in zones I and II. In the remaining finger, where an MP joint dislocation fracture had occurred, an adhesional tendon lesion was suspected in zone II. The paradoxical extension phenomenon occurred in 10 fingers, and resistance was felt in two. In one of

Fig. 2 EMG activities of lumbricalis during four movements: (1) IPs extension with MP flexion, {the lumbricalis is the prime mover}, (2) MP extension with IPs extension, {the lumbricalis is the prime mover}, (3) Flexion all joints, {the flexor digitorum profundus is the prime mover}, and (4) MP extension with IP flexion, {the flexor digitorum profundus is the prime mover}.

Table 2 Outcome of the Paradoxical Extension Phenomenon

Group	Case No.	initial	Initial TAM (degree)	Final TAM (degree)	PEP outcome
I	1		48	158	disappeared
	2		67	214	disappeared
	3		96	214	disappeared
	4		72	171	disappeared
	5		42	84	persisted
	6		58	216	disappeared
II	7		103	149	disappeared
	8		73	82	persisted
	9		94	194	disappeared
	10		31	186	disappeared
	11		78	78	disappeared
	12		29	61	persisted
	13		54	86	unknown
	14		81	192	disappeared
	15		36	163	disappeared
	16		41	189	disappeared
			37	143	disappeared
			78	251	disappeared

PEP: paradoxical extension phenomenon, TAM: total active motion, TAM is the sum of the flexion angles of the DIP, PIP and MP joints.

the two cases where transferred tendon loosening was suspected, an additional surgical procedure to shorten the tendon was performed. The TAM value was improved, and the paradoxical extension phenomenon disappeared (case #7). In the cases that did not receive intervention, the paradoxical extension phenomenon persisted (case #8). Tenolytic procedures were performed in two cases of severe adhesion for severe adhesive condition (case #9, #10), and the tendon in one

finger was surgically reconstructed (case #11). In these three fingers, the additional reconstructive surgical interventions improved the final TAM values, and the paradoxical extension phenomena disappeared in each case. In the other seven fingers, conservative release procedures to tendon adhesion were performed, mainly through the use of Blocking exercises. With the exception of two cases in which the ROM exercises were interrupted for non-medical reasons (case #12, #13), excellent tendon excursions were achieved, and the paradoxical extension phenomena disappeared (Table 2).

Discussion

The paradoxical extension phenomenon was named "Extensor habitus" by White in 1960.⁴ White suggested that this phenomenon occurred when a transferred tendon was loosened in zone II after the surgical reconstruction of a ruptured flexor digitorum profundus or when a rupture of the flexor digitorum profundus persisted at a point distal to the origin of the lumbrical muscle. In 1970, Parkes reported on the "lumbrical plus phenomenon," which was considered to result from the degeneration or contracture of the lumbrical muscle because of excessive strain caused by a shortened flexor tendon.¹⁰ In either case, active contraction of the lumbrical muscle itself was not detected. Instead, the contractive force of the flexor digitorum profundus was transmitted *via* the lumbrical muscle structure to the extensor expansion, extending the IP joint (Fig. 1). Since ROM exercises were not considered to be very effective, surgical reconstruction of the ruptured tendon of the flexor digitorum profundus or the resection of the lumbrical muscle were the most common treatments.¹¹

Since the origin of the lumbrical muscle has a specific structure that is associated with the flexor digitorum profundus, we suspected that in some cases of the so-called paradoxical extension phenomenon, the actual contraction of the lumbrical muscle was contributing to the movement. We divided our cases into two groups according to the presence or absence of electrical activity in the lumbrical muscle during specific movements.

Among the six fingers in group I in which the activity of the lumbrical muscle was detected by electromyography, four fingers had zone V lesions. Since zone V is proximal to the origin of the lumbrical muscle, the possibility of what White had called "Extensor habitus" was ruled out in these fingers. We propose that this phenomenon should be called an "Extensor habitus-like phenomenon" that occurs as a result of the actual contraction of the lumbrical muscle.⁶ The mechanism for this type of paradoxical extension phenomenon can be explained by either of the followings: 1) the suppression of flexion movements because of pain during postoperative ROM exercises, or 2) the facilitation of

lumbrical muscle activity by contracture of the IP joints and/or adhesion of the flexor tendon as a result of excessive MP joint flexion during ROM exercises. These explanations were supported by our finding that conservative ROM exercises were sufficient to eliminate this phenomenon in some cases.¹²

In two cases, the responsible lesion appeared to be in zone II instead of zone V. We believe that in these cases, the Extensor habitus phenomenon and the Extensor habitus-like phenomenon may co-exist. In other words, the contraction of the lumbrical muscle is facilitated by the vigorous fixation of the MP joint during the Blocking exercise.

In group II, where the contraction of the lumbrical muscle was not detected, the injured regions were located in zone II, which is more distal to the origin of the lumbrical muscle. No cases of zone V lesions were included in group II. Consequently, White's Extensor habitus phenomenon appears to be occurring in this group. In half of the group II cases, the TAM value was improved and the paradoxical extension phenomenon was eliminated only after additional surgical intervention.

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