Early, Continuous, Passive Motion Following Flexor Tendon Repair in Zone-II: Using an Originally Invented Passive Motion Device

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Objective: *To evaluate the invented device for early continuous passive motion with the rehabilitation program of fingers following flexor tendon repair in zone-II and to determine whether early motion of the affected finger can occur without increasing the rates of subsequent tendon rupture.*

Material and Method: *A quazi experimental study was done between January 2011 and August 2011 by selecting 5 cases with both, flexor digitorum superficialis (FDS) and flexor digitorum profundus (FDP) injuried in zone II of a finger using standard exclusion criteria. The operation was performed by a single surgeon using a standard four-strand repair suture technique and postoperative care consisted of a rehabilitation program with early, continuous, passive motion using and original device. The program was started 1 week post operatively with duration of 4 months. The authors evaluated the total active motion (TAM) by means of the Strickland-Glogovac formula and calculated results by using the Strickland's original classification system. The ratio of efficiency (E1/E2) was analyzed.*

Results: *In evaluation of the TAM, there were 2 cases with excellent results and good results in 3 cases. The range of motion obtained was nearly full motion in all 5 of the cases without subsequent tendon rupture. The ratio of efficiency (E1/E2) was 85/100 (85 of Baktir/100 of the present study) and higher than standard (80/80). As the total number of cases and the selection of cases were different (76 cases of Baktir/5 cases of the present study).*

Conclusion: *Early continuous passive motion using this originally invented device provides excellent long-term outcomes in the management of injured flexor tendon in zone II. Further studies should be done to compare our results with other continuous passive motion protocols with the inclusion of long term follow-up and measurements of grip strength.*

Keywords: *Continuous passive motion (CPM), Early motion, Original device for CPM, Finger motion*

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Before1995, the resulting motion of flexor tendon repair was poor until, the combined treatments of the tendon injuries were applied. It composed of special suture techniques with active or passive motion rehabilitation programs that included passive movement, dynamic control movement and controlled active motion therapies[1-7]. Chow applied some parts of the protocols obtained from Kleinert, Duran and Houser to form the "Washington protocol"[8,9].

However problems from the outcomes continued particularly in active digit motion, prevention of stiffness in the joints and interphalangeal joint contractures following zone-II flexor tendon injuries. Trumble randomized a prospective trial of actively placing and holding therapy as compared with passive motion therapy. He found that active motion therapy provided greater active finger motion than passive motion therapy after zone II flexor tendon repair without increasing the risk of subsequent tendon rupture[10]. Although it was clear that early passive motion improved the clinical results as compared to prolonged immobilization following flexor tendon repair, no study analyzed early, continuous, passive motion with the use of any device.

To any available knowledge, this is the first study of randomized patients to address early, continuous, passive motion using a device for rehabilitation following a standard repair of the tendon laceration. A standard four-strand repair of the flexor digitorum profundus (FDP) used in combination with

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the repair of the flexor digitorum superficialis (FDS) in zone II. The purpose of the present study was the application of a continuous, passive motion device invented by Dr. Niyom Laoopugsin (Fig. 1), promoting a program for improving finger motion after surgical, flexor tendon repair in zone-II and to determine, whether early motion of the finger can occur without increasing the rate of subsequent tendon rupture.

Material and Method

Study design

The research was a quazi experimental study. It was granted approval by the ethics committee. Five patients with both tendon FDS and FDP injuries in only one finger were selected by random sampling between January 2011 and August 2011. The range of age was 30-48 years old. All of the cases selected were surgically treated by the same surgeon and early rehabilitation was started with an original, continuous, passive motion device of the finger after surgically repairing the tendon. The device, invented by Dr. Niyom Laoopugsin and registered a petty patent No. 4490, was designed for continuous passive motion of the injured finger with a variable speed control (Fig. 2). The angle of motion can be adjusted to ranges of full flexion at 90 degrees of the proximal interphalangeal joint (PIPJ), to full extension of the joint to every rotation. The authors started the rehabilitation program as early as 7 days after surgically repairing the tendons and after the stitches at the skin were removed (Table 1). The program of continuous, passive motion was performed initially, with the angle between 60 and 90 degrees of flexion PIPJ (Fig. 3) in a counter clock wise direction (Fig. 4) and the angle was continuously increased until the patient obtained 90 degrees of flexion to full extension of the PIPJ by the fifth week (Fig. 5). The motion was set at the slowest speed of rotation but ran continuously for 15 minutes, 4 times a day, alternating with use of a dorsal plaster slab for the time remaining. The total duration of the program was 5 weeks.

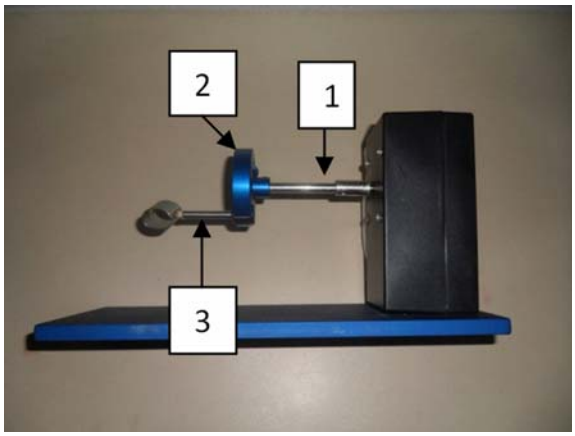

Fig. 1 An originally invented continuous, passive motion device composed of a fixed axis (1) between the adaptor and blue metal piece (2) which rotates together with the removable axis (3)

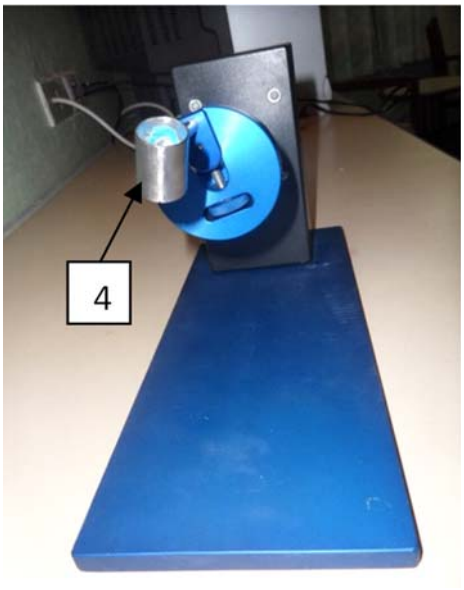

Fig. 2 The metal ring (4) adheres at the distal part of the removable axis by a locking screw which allows motion of the ring while catching the distal part of the finger

Definition and selection of cases

The cases with appointments scheduled on odd days in the hospital were selected for the present study. Both, the FDS and FDP tendons were ruptured completely each case, two cases to the index fingers, two cases to the middle fingers and one case to the little finger. All tendons were repaired in the standard fashion with use of the Strickland's technique composed with two core sutures (four strand) using 3-0 polyester and a continuous circumferential or an epitendinuous, repetitive suture using 6-0 monofilament nylon (Fig. 6). The original, continuous, passive motion device was applied with a 9 volt, electrical generator adapted from 220 volts.

Exclusion criteria

Patients with multiple injuries were excluded as they would be more difficult to evaluate. Patients

Table 1. Rehabilitation program

	Rehabilitation program
Day 0	Flexor tendon repaired, dorsal plaster slab application (Position: wrist 30 degree dorsiflexion, MCP joint 90 degree palmar flexion, PIP and DIP joints in slight flexion
Day 2-7	Dressing change, dorsal plaster slab application in the same position. All stitches removed on Day7
Day 8-14	Dorsal plaster slab application in the same position. Rehabilitation with the continuous, passive motion device started. Rotation: allowing 60 to 90 degrees of flexion of PIPJ. 15 x 4 (four times a day for 15 minutes each). Assessment of range of active flexion achieved, flexion/extension lag, total active motion.
Day 15-21	Dorsal plaster slab application in the same position. Continuous, passive motion device applied. Rotation: allowing 30 to 90 degrees of flexion of PIPJ. 15 x 4 (four times a day for 15 minutes each).
Day 22-28	Dorsal plaster slab application in the same position. Continuous, passive motion device applied. Rotation: allowing 10 to 90 degrees of flexion of PIPJ. 15 x 4 (four times a day for 15 minutes each). Assessment of range of active flexion achieved, flexion/extension lag, total active motion.
Day 29-35	Off dorsal plaster slab Day 29. Continuous, passive motion device applied. Rotation: allowing 90 degree flexion to full extension of PIPJ. 15 x 4 (four times a day for 15 minutes each).
Day 36-42	Active flexion extension against resistance. Assessment of range of active flexion achieved, flexion/extension lag, total active motion every 2 weeks till 4 months.
4 months	Assessment of range of active flexion achieved, flexion/extension lag, total active motion.

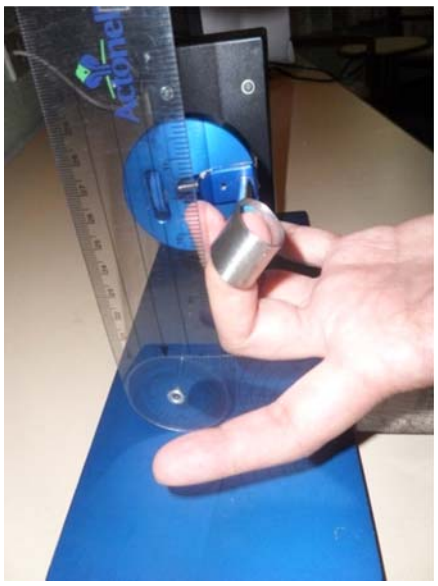

Fig. 3 The passive motion of the PIP joint occurs with nearly 90 degrees of flexion

less than fifteen years old were excluded because they have been found to have a considerably increased risk of subsequent tendon rupture[11]. Patients more than seventy-five years old were also excluded because of normal deterioration in hand function scores and unavailable, normative data for these patients[12].

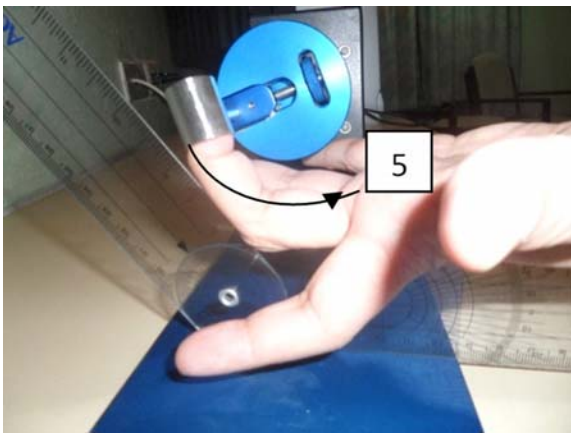

Fig. 4 The angle was changed along the counter clock wise rotation (5) of the blue metal piece

Assessment

At their final follow-up, with a minimum of 4 months of therapy, active flexion and extension of the PIPJ and DIPJ of the injured fingers were measured with use of a goniometer. All of the surgical repairs were assessed, fortnightly, by the same physician. The results of the total active motion (TAM) were evaluated by means of the Strickland-Glogovac formula[13]. This is:

$$\frac{(\text{active PIPJ + DIPJ flexion}) - \text{extension lag}}{175} \times 100 = \%$$

of normal PIPJ and DIPJ motion and the results were calculated with the use of the Strickland's original classification system as shown in Table 2.

Statistical analysis

Statistical testing of the differences in the TAM were carried out by using comparative analyses of the ratio of efficiency; E1/E2 value. It was applied in the present study as per the use of an originally invented, continuous, passive motion device in the rehabilitation program as a new method in the pilot project with a small number of patients. A value of 80/80 or more was considered to indicate a significant difference.

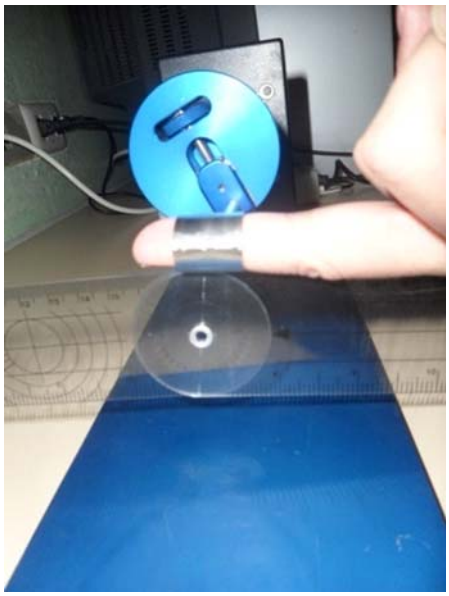

Fig. 5 Full passive extension of the finger

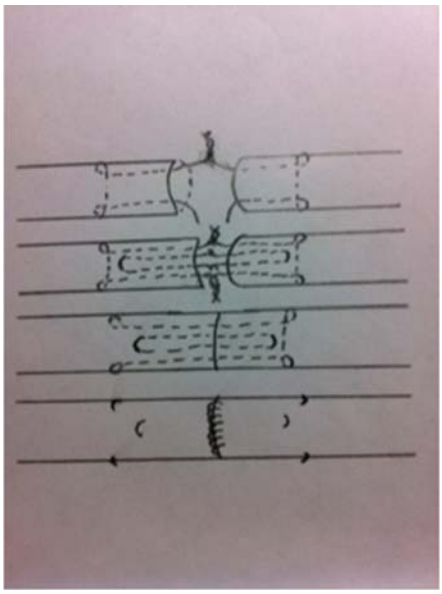

Fig. 6 Strickland 4-strand technique uses two core 3/0 polyester sutures and a running 6/0 nylon for epitendinuous suture

Results

The results of the TAM, as provided under the rehabilitation program, were measured fortnightly for detection of the progression and the authors selected the end results at the final follow-up appointment. All of the five cases had shown resulting limitations at the DIPJ in full flexion of the injured finger (Fig. 7, 8). In case No. 4, as shown in Fig. 9 and 10, limitations were evident in the DIPJ in full flexion of not only the injured little finger but also in the unaffected fingers. According to Strickland's original

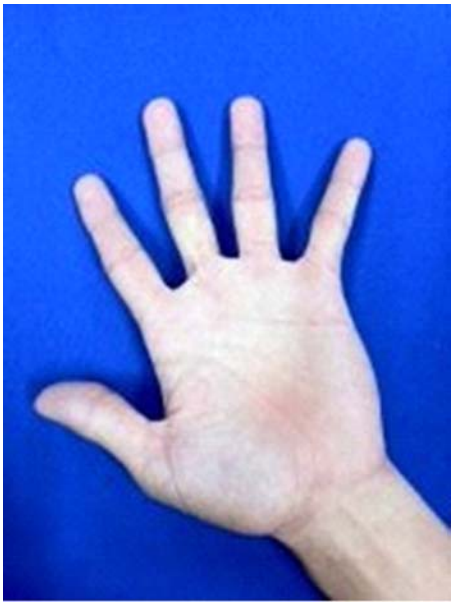

Fig. 7 Case No. 1 showed full extension DIPJ & PIPJ of all fingers (injured middle finger)

Table 2. Strickland's original classification system

Grade	Percentage range
Excellent	85-100%
Good	70-84%
Fair	50-69%
Poor	0-49%

classification system there were 2 cases with excellent results and good results in 3 cases without subsequent ruptured tendons (Table 3). The range of motion was nearly complete motion to all of the patients. They were all able to return to their work without restrictions.

Fig. 8 Case No. 1 showed limited full flexion DIPJ in only the injured finger

Discussion

Although recent studies have shown that active motion groups regain significantly more motion and have less severe flexion contractures than the patients in the passive motion groups, the authors have postulated that better tendon gliding is evident in therapy with early, continuous, passive motion using the authors' new device. The patients have shown fewer adhesions and improved tendon excursion, resulting in improved digital motion without further rupturing of the repaired tendons.

According to Elliot and Harris, at 6 to 12 months following flexor tendon repair, the range of motion remained unchanged but the patients felt better because the speed of motion had increased. This phenomenon may be related to the decrease in the friction of the repaired tendon against surrounding tissues, such as the sheath[14]. The speed of motion was not a concentrated factor in the present study at 4

Fig. 9 Case No. 4 showed full extension DIPJ & PIPJ of all fingers (injured little finger)

Fig. 10 Case No. 4 showed some limitation of full flexion DIPJ of all fingers (injured little finger)

Table 3. Patient related information

No.	Month	Age (yrs)	Injured tendon	Hand/finger	Zone	TAM (percent)	Tendon ruptured	Strickland's grade
1	Jan	32	FDS & FDP	Rt/middle	II	75	No	Good
2	Feb	30	FDS & FDP	Rt/index	II	87	No	Excellent
3	Feb	48	FDS & FDP	Rt/index	II	85	No	Excellent
4	Apr	45	FDS & FDP	Rt/little	II	78	No	Good
5	Aug	35	FDS & FDP	Lt/middle	II	74	No	Good

Table 4. Results of zone II flexor tendon injuries treated by continuous active motion regimens

	Number of fingers	Number of tendons	Follow-up period (months)	Good and excellent
Small et al (1989)	117	205	34	77%
Cullen et al (1989)	31	56	24	77.5%
Elliot et al (1994)	63	99	12	79.4%
Baktir et al (1996)	47	76	12	85%
Riaz et al (1999)	39	65	127	75%

months after flexor tendon repair because the short period of recovery time. In the experience of Baktir, patients with a high range of good and excellent results developed scores in the 85 percentile range (Table 4). The present study shows 100% of the patients with score in the ranges of the good and excellent result groups. The E1/E2 ratio of efficiency was higher than 80/80 (85/100 = 85 of Baktir/100 of the present study) as the numbers and selection of cases were significantly different (Baktir = 76 cases/the present study = 5 cases). The grip strength testing following flexor tendon injuries may be used as a measurement of the outcomes in further studies[15]. The weak points of the present research were; first, that the comparison study should be done among the groups of cases visiting in the same hospital; second, the comparative group had a continuous active regimen which differentiates from the rehabilitation program in the present study and finally, the duration of the follow-up may not be long enough to accurately measure the grip strength.

Conclusion

This was a pilot project and had started with a small number of cases. It may not be sufficient to draw any final conclusions but it appears that early, continuous, passive motion provides an excellent long-term outcome for the management of flexor tendon injuries in zone II. Also, the authors results highlight the rehabilitation program with the invented continuous passive motion device.

Potential conflicts of interest

None.

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การเริ่มที่เร็วและต่อเนื่องในการเคลื่อนที่ ชนิด passive หลังผ่าตัดเย็บต่อเส้นเอ็น Flexor บริเวณ zone-II โดยอาศัยสิ่งประดิษฐ์เครื่องช่วยในการงอเหยียดนิ้ว

นิยม ละออปักษิณ, อรุณวงศ์ เทพชาตรี, ปวริศร สุขวนิช

วัตถุประสงค์: *เพื่อเป็นการวิเคราะห์ผลการประยุกต์ใช้สิ่งประดิษฐ์เครื่องช่วยในการงอเหยียดนิ้วร่วมกับโปรแกรมกายภาพบำบัด โดยให้มีการเริ่มต้นที่เร็วและต่อเนื่องหลังจากเย็บต่อเส้นเอ็น flexor บริเวณ zone II และเพื่อศึกษาผลการเคลื่อนไหวของข้อนิ้วหลังจากเย็บต่อเส้นเอ็นที่เริ่มต้นเร็วจะไม่ทำให้เกิดการหลุดของรอยต่อเส้นเอ็นตามมา*

วัสดุและวิธีการ: *เป็นการศึกษากึ่งทดลองตั้งแต่ มกราคม พ.ศ. 2554 ถึง สิงหาคม พ.ศ. 2554 จำนวน 5 ราย โดยที่ทุกรายได้รับบาดเจ็บทั้ง flexor digitorum superficialis (FDS) และ flexor digitorum profundus (FDP) บริเวณ zone II ใน 1 นิ้ว พร้อมกับข้อบ่งชี้มาตรฐานในการคัดเลือกผู้ป่วยออก รักษาโดยแพทย์ท่านเดียวกัน โดยใช้เทคนิคการเย็บซ่อมแบบ standard four-strand หลังผ่าตัดจะใช้โปรแกรมกายภาพบำบัดแบบเริ่มต้นที่เร็วและให้ต่อเนื่อง โดยใช้สิ่งประดิษฐ์ช่วยในการงอและเหยียดนิ้ว โปรแกรมจะเริ่มเร็วตั้งแต่ 1 อาทิตย์หลังผ่าตัดและสิ้นสุดเมื่อครบ 4 เดือน ผู้วิจัยได้ประเมินโดยดูผลรวมระยะการเคลื่อนไหวของข้อของนิ้ว (TAM) โดยใช้สูตรของ Strickland-Glogovac และคำนวณโดยใช้ระบบ Strickland's original classification หลังจากนั้นทำการวิเคราะห์อัตราส่วนประสิทธิภาพ (E1/E2)*

ผลการศึกษา: *เมื่อพิจารณาในเรื่อง TAM มี 2 ราย ที่ผลการรักษาอยู่ในกลุ่มยอดเยี่ยม และ 3 ราย ที่ผลการรักษาอยู่ในกลุ่มดี โดยระยะการเคลื่อนไหวของข้อนิ้วเกือบเต็มที่เหมือนปกติทั้ง 5 รายและไม่มีการหลุดของรอยต่อเส้นเอ็น อัตราส่วน E1/E2 มีค่าสูงกว่า 80/80 (85/100 = ของ Baktir/ของการศึกษาครั้งนี้) ซึ่งอาจเป็นเพราะจำนวนและการเลือก case ต่างกัน (76 รายของ Baktir/5 รายของการศึกษาครั้งนี้)*

สรุป: *การเริ่มต้นที่เร็วและต่อเนื่อง โดยใช้สิ่งประดิษฐ์ช่วยในการงอและเหยียดนิ้ว ได้ให้ผลการรักษาระยะยาวที่ดีในการรักษาการบาดเจ็บของเส้นเอ็น flexor ในบริเวณ zone II การศึกษาต่อไปควรมีการเปรียบเทียบกับโปรแกรมการทำกายภาพบำบัดในแบบอื่นๆ รวมทั้งติดตามการวัดกำลังการกำของมือในระยะยาว*