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Flexor Tendon Reconstruction of The Hand by Modified Paneva-Holevich Technique and Tendon Transfer Technique: A Comparative Study

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Abstract

Background: The rule for management of flexor tendon injury is primary repair. Under unfavorable conditions, two stage reconstruction becomes an option. Several techniques had been practiced for flexor tendon reconstruction. The aim of this study was to make a comparative study of the outcome between the modified Paneva-Holevich technique and the flexor digitorum superficialis **(**FDS) tendon transfer in repair of neglected flexor tendon injuries.

Methods: 40 patients were operated for flexor tendon reconstruction. They were divided into two groups (each 20 patients): The modified Paneva-Holevich technique (group I) and the FDS tendon transfer (group II). The results were assessed according to Active Range of Motion (AROM), patient satisfaction and complications.

Results: Mean age was 32.3±10.51 years in group I and for group II was 34.40±9.99 years with no statistically significant difference. The majority of patients were male with right hand dominance of both groups. In group I: the most operated finger was the middle finger (50% of cases), while in group II was the ring finger (30% of cases). There were no statistically significant differences between both groups as regard AROM, patient satisfaction and complications.

Conclusion: The modified Paneva-Holevich technique and the FDS tendon transfer are versatile and efficient for repair of neglected flexor tendon injuries with no superiority of one technique over the other.

Keywords:
Flexor tendon, modified Paneva-Holevich technique, tendon transfer.

1.Introduction

Flexor tendon injuries are usually complicated by adhesion formation and/or by tendon retraction at the site of injury. They ended up with loss of active flexion and later developed contracture of the digit. These injuries are managed by one or two stage tendon reconstructive procedures.[1, 2]

If favorable conditions are not present for single stage reconstruction, then a staged reconstruction may be considered.[3]

As pioneered by Hunter and Salisbury, classic staged flexor reconstruction involves the use of an extrinsic free donor tendon graft placed at the second stage following a first-stage implantation of a flexible silicone gliding implant.[4]

The main application for tendon transfer in the upper extremity is peripheral nerve injuries, but there are other indications. Focusing on tendon injuries, tendon transfers are mostly associated with extensor tendon treatment, but several authors have published their work on flexor tendon reconstruction with the use of a tendon transfer.[5]

In 1970, Paneva-Holevich reported her initial experience with a two-stage tenoplasty, the first stage of which involved the creation of a loop between the proximal stumps of flexor digitorum profundus (FDP) and flexor digitorum superficialis (FDS) in the palm. Following a 1-month interval, using the profundus muscle used as a motor, the sublimis tendon is routed through the pulley system and is attached to the distal phalanx.[6,7]

Chong enhanced the results reported by Paneva-Holevich by implanting Hunter rods at the first stage, thereby inducing the formation of a smooth sheath (pseudo sheath) for tendon gliding. Later, Chong and Kessler separately found satisfactory results in small series of patients treated with this modification, which has subsequently become defined as the modified Paneva-Holevich technique.[8]

Due to the heterogeneity of flexor tendon injuries, and the deficiency of high-level clinical evidence that compare reconstruction techniques, there are currently no consensus for flexor tendon reconstruction.[9]

In this work, we tried to make a comparative study between the modified Paneva-Holevich (PH) Technique and the adjacent Flexor digitorum superficialis (FDS) tendon transfer in reconstruction of the flexor tendons of the hand. The assessment was done according to active range of motion (AROM), patients' satisfaction and clinical complications.

2.Methods

An interventional prospective randomized control study was done from June 2021 to June 2023.The study was approved by our institutional review board (IRB code: R/16.12.89).

The study was conducted on 40 patients 20 patients for each group admitted for FDP reconstruction. The included patients admitted with chronic, neglected unrepaired flexor tendon injuries with full passive movement, failed primary flexor tendon repair, and failed tendon reconstruction. Patients less than 20 years or more than 60 years of age were excluded from the study. Also, patients with poor compliance to physiotherapy and who were refusing long term therapy and follow up were omitted. In addition, patients with joint stiffness or deformity were excluded from the study (Fig. 1).

2.1. Preoperative assessment

All patients were assessed preoperatively according to history, type of trauma, resting hand cascade, hand grip, hand power, passive hand movement, abnormal hand movement

(quadregia), tendons examination for each finger, flexion deformities, tenderness, swelling and any scar or contracture.
Photographic documentation, plain X-ray and Superficial US have been done to detect the status of the tendon injury and the length of the tendon defect. Also, Laboratory investigations that included complete blood count, coagulation profile, blood glucose level, and liver and renal function tests have been done. Written informed consent was obtained from all participating patients or their legal guardians.

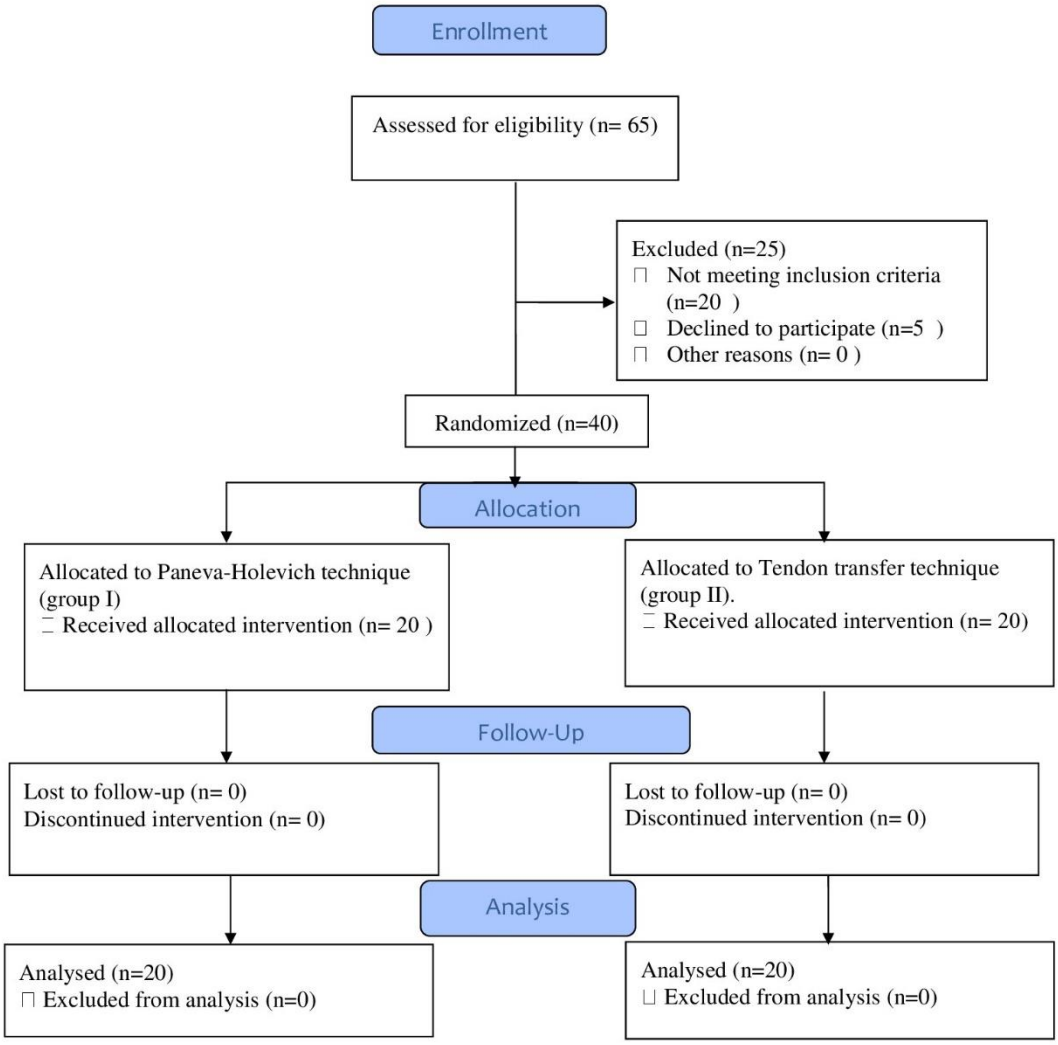

Figure (1): Flowchart of the study.

2.2. Surgical technique:
2.2.1.1st Stage: Under regional anesthesia and tourniquet control. The fibro-osseous digital flexor sheath was exposed via a volar Bruner incision **(Fig. 2)**, scarred portions of the flexor tendon and sheath were excised.
In The Modified Paneva-Holevich (PH) group: The proximal stumps of the superficialis and profundus tendons were sutured together at the level of the palmar crease making a

loop **(Fig. 3)**. In Adjacent FDS tendon transfer group: FDS tendon was left for the second stage.

A silicone catheter was selected, approximating in size the caliber of the superficialis tendon (2.67mm. to 4.67 mm.).[10]

In both groups, it was attached to the profundus stump distally. Proximally, it was sutured to the (FDP-FDS loop) in the modified PH technique group **(Fig. 3)**. In the tendon transfer group, the catheter was attached proximally to the proximal stump of FDP or extended as far as the palmar crease in the medial four fingers **(Fig. 4)**.

Then, attention was directed towards the flexor retinacular pulley system, reconstruction of A2 and A4 pulleys as mentioned above. Excising the fibrosed pully and sheath maintaining, whenever possible, at least 5 mm of the A2 and A4 pulleys to allow a shoulder for reconstruction of pulleys later. Pulley reconstruction was performed using a damaged tendon, a tendon graft, or an extensor retinaculum that was sutured to the remaining native pulley or fibro-osseous floor of the flexor sheath.[11]

Finally, the tourniquet was released, and hemostasis was done. The wound was closed in the standard fashion.

2.2.2. 2nd Stage: Under Wide Awake Local Anesthesia Initially Applied Tourniquet (WALAIAT).[12]

2.2.2.1 The Modified Paneva-Holevich (PH)Technique:

The palmar incision was opened, and the tendon anastomosis was located. Any excess bulk, sheath thickening or adhesions at the site around the palmar FDS-to-FDP anastomosis was debrided.

FDS was identified through a lazy S incision or multiple transverse incision in the forearm and divided at the musculo-tendinous junction. Traction at the site of the palmar FDS-FDP anastomosis delivers the FDS tendon into the palm, where it was sutured to the proximal end of the silicone catheter to be pulled to the distal FDP stump **(Fig. 5)**.

2.2.2.2. The adjacent FDS tendon transfer technique:

The access was via multiple transverse incisions at PIP, MCP, palmer crease and wrist in the donor digit, the tendon sheath was exposed; the FDS was approached and sectioned at the level of insertion. The FDS dissection has been continued as proximally to the wrist as needed to obtain a sufficient length and to change the arc of rotation of the FDS tendon to allow suitable transfer to the new recipient digit. **(Fig. 6)**.

In the recipient finger (both techniques), an angular incision was then made at the level of the distal phalanx. The distal attachment of the silicone catheter was identified and liberated. With traction on the rod, the FDS tendon was shuttled through the pulley system to its distal phalangeal insertion site.

The tension of the distal graft was evaluated by attaching the tendon into distal FDP stump then the movement of the finger was tested. Trans-fixation of the tendon to the bone, skin, and soft tissue of the distal phalanx was made. Intra operative movement has been assessed and adjusted accordingly **(Figs. 5,6)**.

2.3. Postoperative care

In both surgical stages, the wrist was splinted at 20–30-degree flexion and the MCP at 40-60 flexion. The IP joints were extended. Dorsal safety splint was applied for 3 weeks in first surgical stage and may extend up to 6 weeks in second surgical stage. The dorsal splint was removed hourly for passive range of movement exercises of operated finger with active movement exercises of non-involved fingers.

2.4. Postoperative assessment

2.4.1. Active Range of Movement (AROM)

It was assessed at 6 months postoperatively according to primary outcome evaluation using modified Strickland system.[13, 14.]

2.4.2. Patient satisfaction

Patient satisfaction in terms of hand appearance and donor site morbidity was assessed on a five-point scale that was scaled from 1-5. Grade 1 was assigned as: not satisfied, grade 2: slightly satisfied, grade 3: moderately satisfied, grade 4: quite a bit satisfied, and grade 5: extremely satisfied.[15]

2.3.3. Statistical analysis

Data analysis was performed by SPSS software, version 25 (SPSS Inc., PASW statistics for windows version 25. Chicago: SPSS Inc.). Qualitative data were described using number and percent. Quantitative data were described using median (minimum and maximum) for non-normally distributed data and mean± Standard deviation for normally distributed data after testing normality using Shapiro Wilk test. P value was significant at (≤0.05).

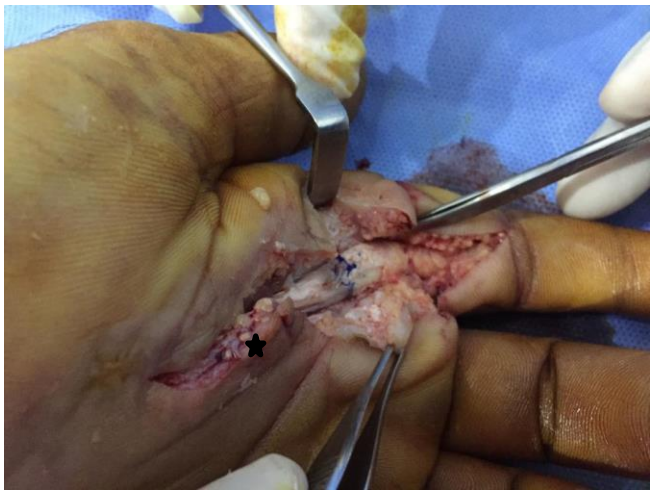

Figure (2): Volar Bruner incision, the fibro-osseous digital flexor sheath was exposed via a; scarred portions of the flexor tendon and sheath were excised.

★: old sutures line with extensive fibrous tenosynovitis and tendon adhesions

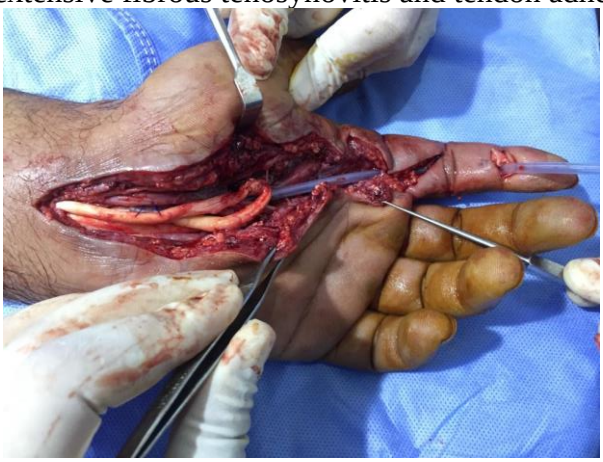

Figure (3): 1st stage of modified Paneva-Holevich technique: Appropriate silicon catheter was attached to the FDP stump distally and was sutured proximally to FDP-FDS loop of the left index finger.

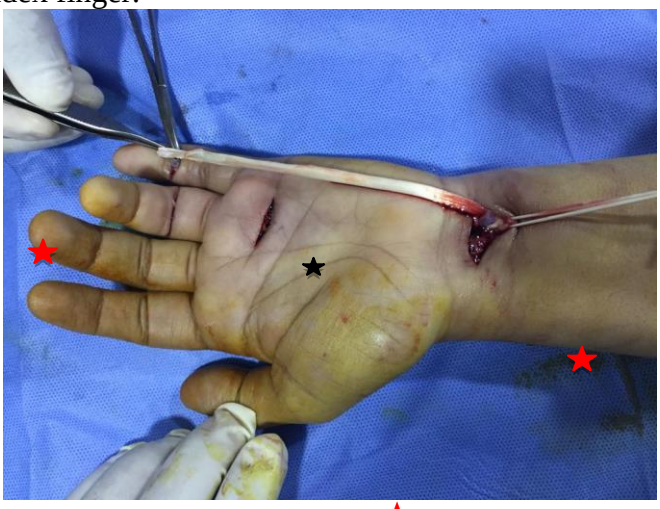

Figure (4): ***1st stage of tendon transfer technique:*** ★ Appropriate silicon catheter attached distally to the distal FDP stump and attached proximally to the proximal FDP stump of the left little finger.

★ : ***In the 2nd stage:*** FDS tendon of left ring finger is dissected and ready to be transferred to left little finger after removal of the catheter.

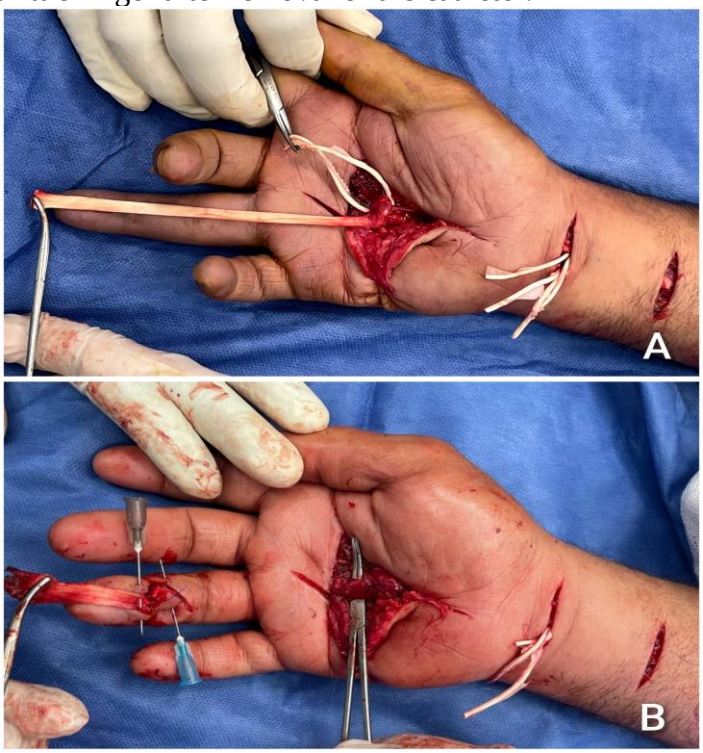

Figure (5): 2nd stage of modified Paneva-Holevich technique a- tendon anastomosis was located through palmar incision and the FDS was identified through multiple transverse incision in the forearm and divided at the musculo-tendinous junction, FDS tendon was then delivered into the palm. b- FDS tendon was delivered to the distal FDP stump.

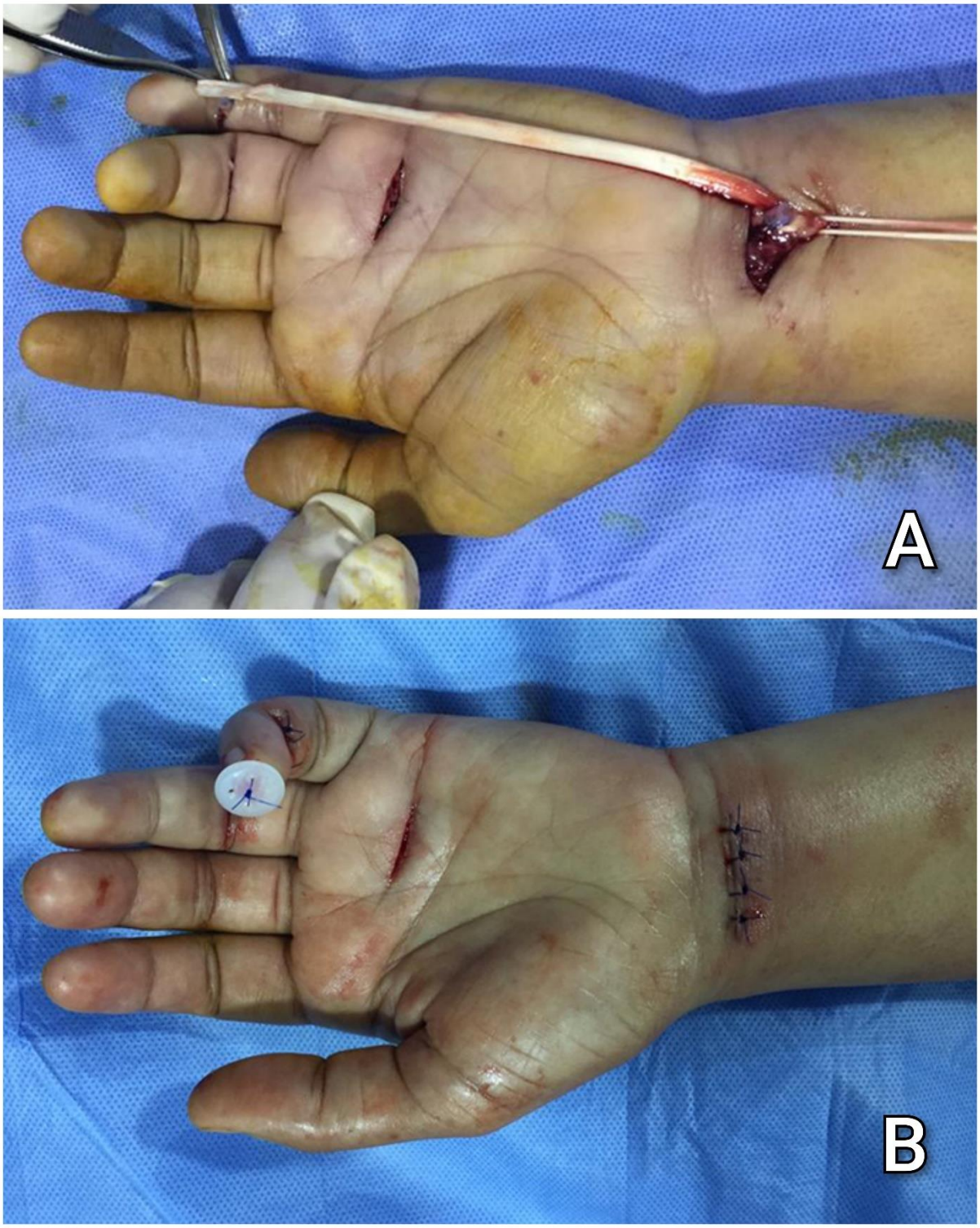

Figure (6): 2nd stage of tendon transfer technique a- Access to the 4th FDS tendon was done via multiple transverse incisions at PIP, MCP, palmer crease and wrist in the donor digit, FDS tendon was approached and sectioned at the level of insertion. b- 4th FDS

tendon was delivered to the distal phalangeal insertion site of the little finger and transfixed after intraoperative movement adjustment.

Case no.1

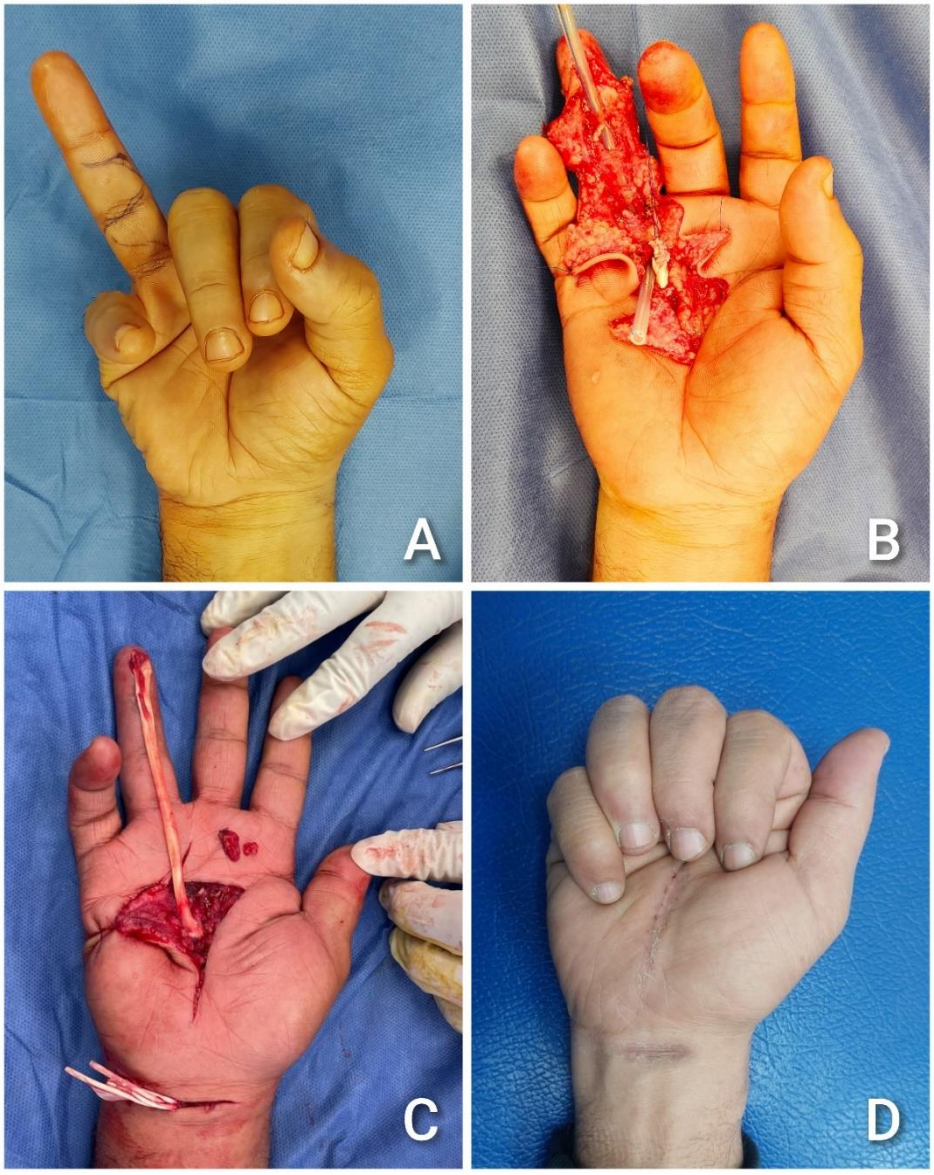

Figure (7): (Case no.1): "Modified PH technique" in male 38 years old. **A**: preoperative picture of right ring finger old FDP & FDS cut. **B**:1st stage reconstruction: scarred tissue excision, placement of adequate silicon catheter and loop formation between FDP & FDS of the same finger. **C**: 2nd stage: Identification, debulking excision of extra fibrous tissue around the loop and reflection of FDP-FDS loop after separation of FDS at the musculotendinous junction. **D:** post operative AROM with satisfied results.

Case no.2

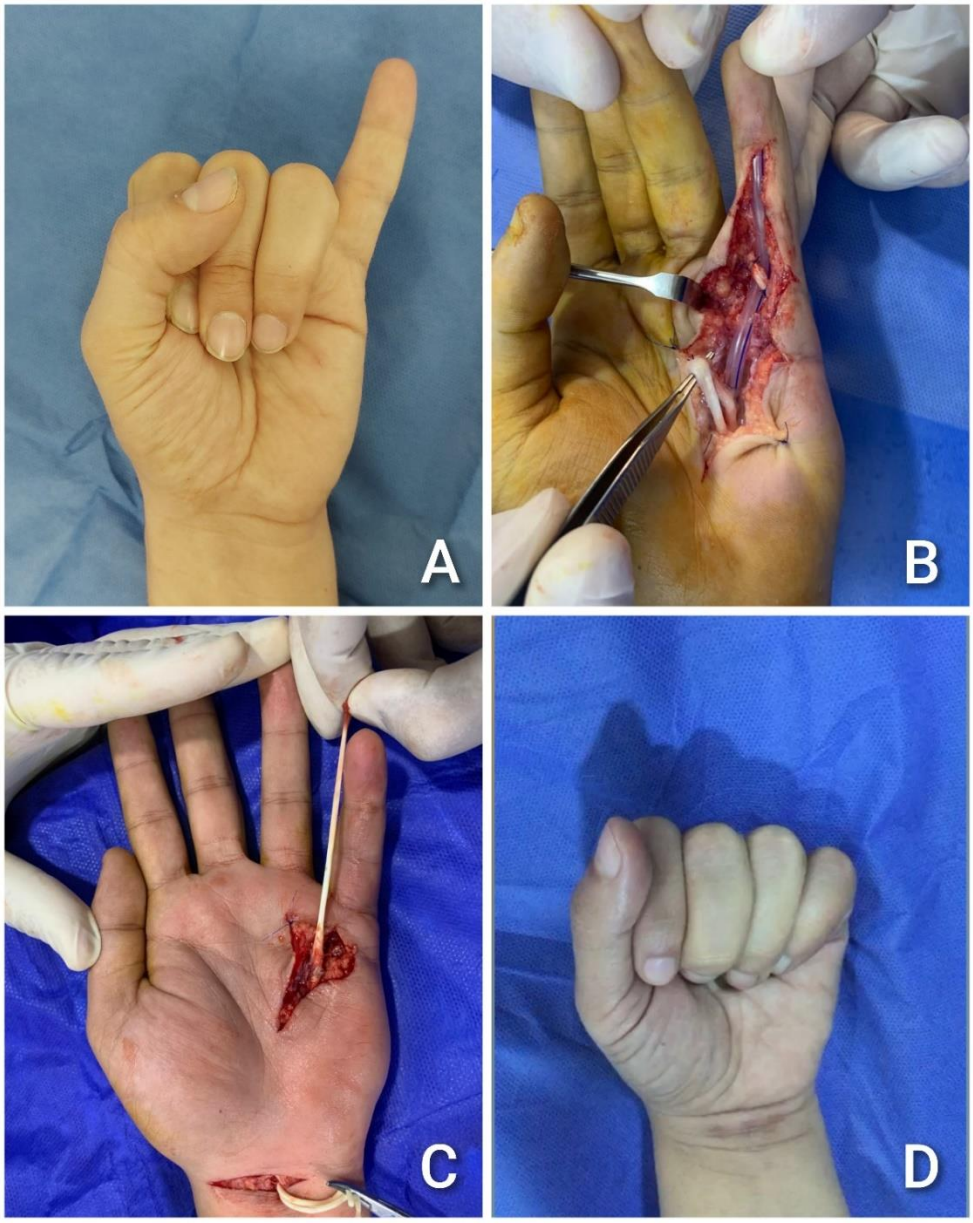

Figure (8): (Case no.2): "Modified PH technique" in male 30 years old. **A**: preoperative picture of left little finger old FDP & FDS cut. **B**:1st stage reconstruction: scarred tissue excision, placement of adequate silicon catheter, pully reconstruction and loop formation between FDP & FDS of the same finger. **C**: 2nd stage: reflection of FDP-FDS loop after separation of FDS at the musculotendinous junction with attachment of FDS to distal phalanx. **D:** post operative AROM with satisfied results.

Case no.3

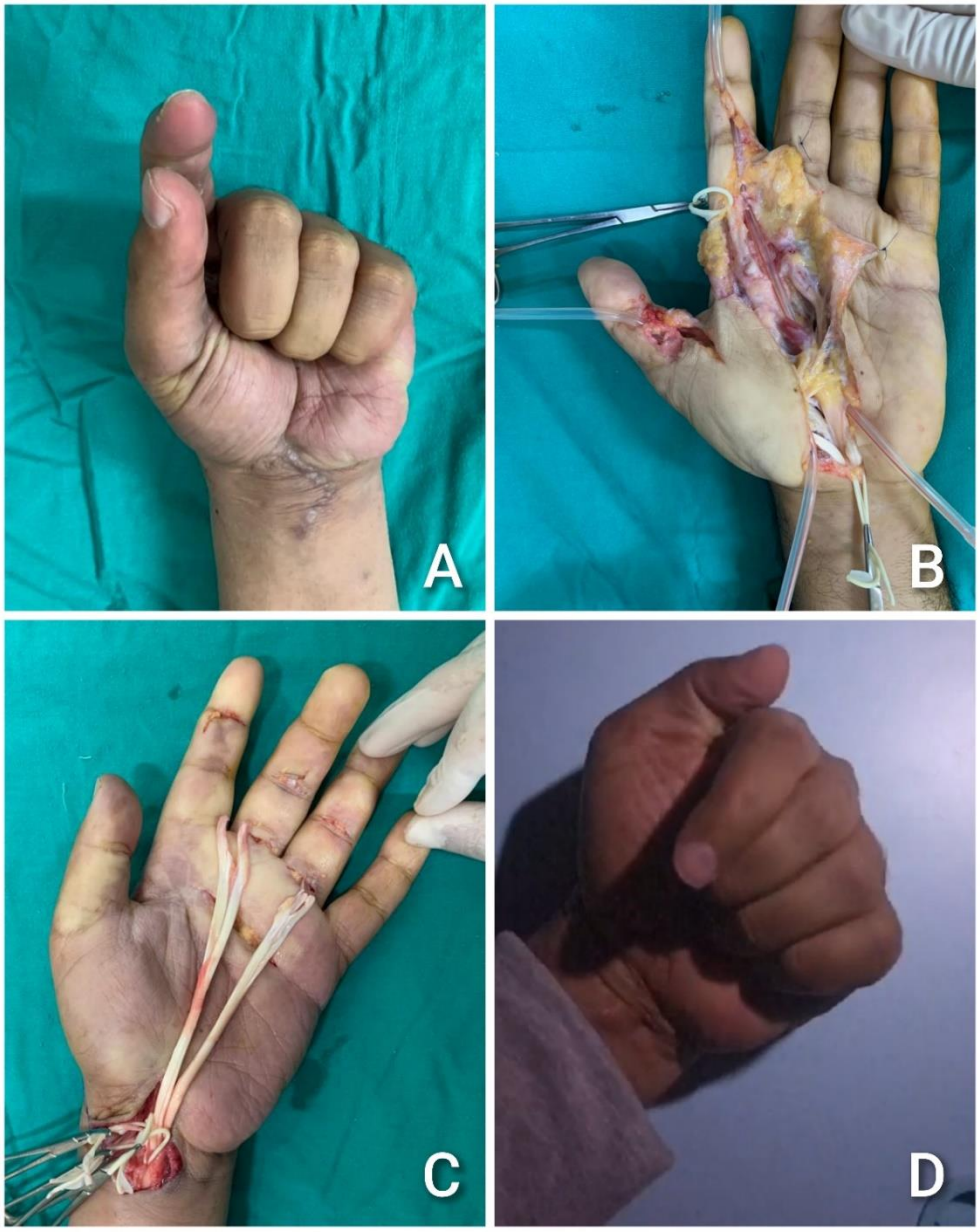

Figure (9): (Case no. 3): "Tendon transfer technique" in male 35 years old. **A**: preoperative picture of left index & thumb fingers old flexors cut. **B**:1st stage reconstruction: scarred tissue excision, placement of adequate silicon catheters underneath intact pully system. **C**: 2nd stage: transfer of FDS of left middle and ring to thumb & index respectively with tension adjustment and fixation to the distal phalanxes of thumb and index fingers. **D:** post operative AROM with satisfied results.

Case no.4

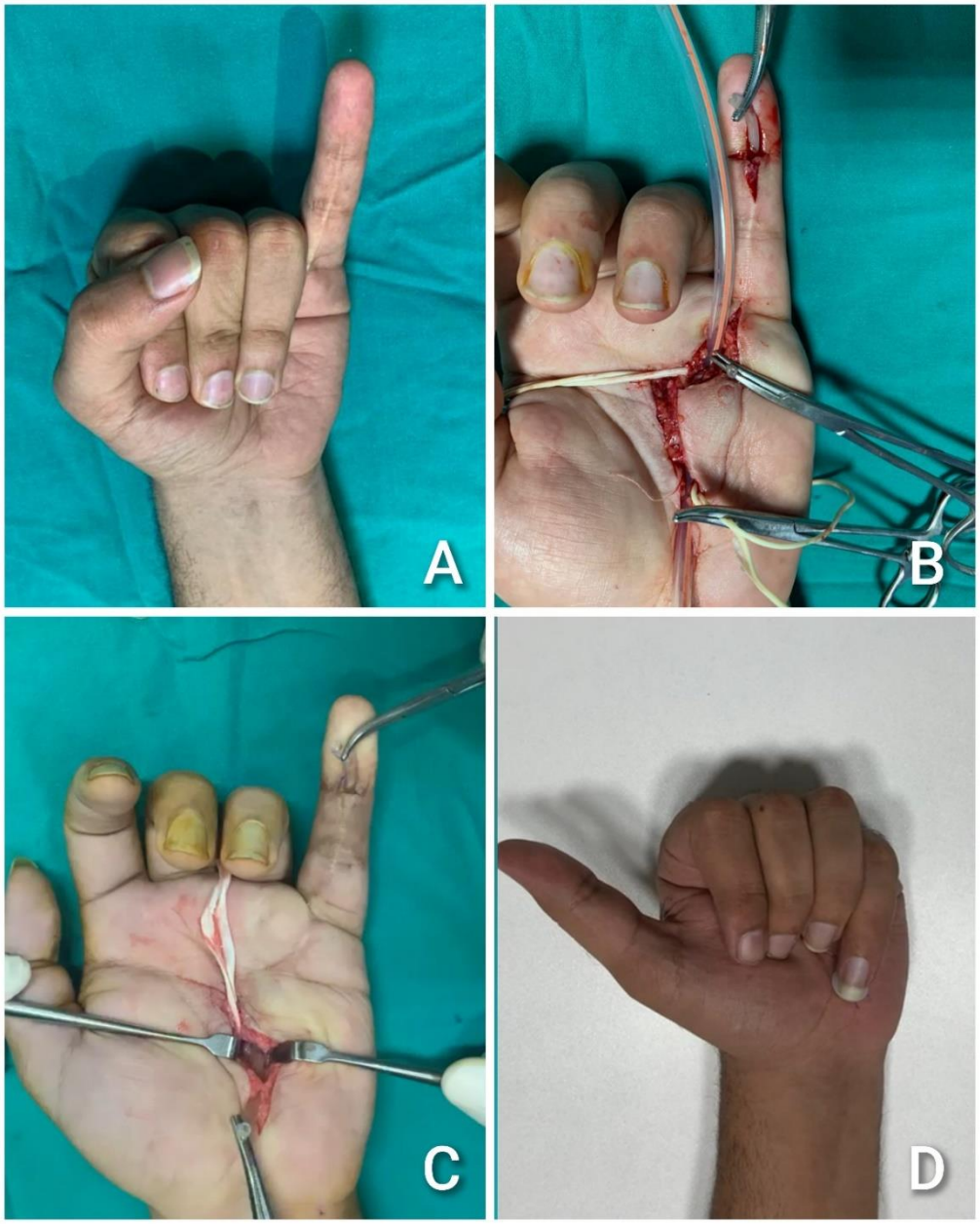

Figure (10): (Case no.4): "Tendon transfer technique" in male 28 years old. **A**: preoperative picture of left little finger old flexors cut. **B**:1st stage reconstruction: scarred tissue excision, placement of adequate silicon catheters underneath intact pully system. **C**: 2nd stage: transfer of FDS of left ring to left little with tension adjustment and fixation to the distal phalanx and pullout sutures. **D:** post operative AROM with satisfied results.

3.Results

3.1. Demographic data

no statistically significant difference between studied groups as regard their age & sex. Mean age of group I was 32.3±10.51 (21-48 years) versus 34.40±9.99(22-55 years) for group II. Group I include 80% males versus 90% of group II were males. no statistically significant difference between studied groups as regard dominant hand with 65% of

group I have right hand dominance versus 45% of group II. There was no statistically significant difference between both groups as regard the injured finger. In group I: 50% had middle finger injury, 20% little finger injury and 15% ring & index injuries. In group II: the involved fingers were ring finger (30%), middle finger (25%), little finger (25%) and index finger (20%) (Table 1).

3.2. Time since injury, Follow up and AROM.

There was no statistically significant difference between studied groups as regard time since injury, time between first and second stage, follow up duration and active range of motion. Median time since injury was 4 months for group I versus 6 months for group II. Median time between 1st and 2nd stage was 3 for group I versus 3 months for group II .Median active range of motion is 255 for group I versus 253 for group II (Table 2).

3.3. Patient satisfaction

In group I, eleven patients (55% of cases) had score 5 (the best satisfaction score). In group II, ten patients (50% of cases) had score 5 No statistically significant difference detected between both groups (Table 3).

3.4. Complications

There was no statistically significant difference between studied groups as regard incidence of complications. In group I: 10% had tendon adhesion, 10% had contracture scar, 5% had catheter infection and 5% had bowstringing. In group II: 5% had Partial stiffness, 5% had catheter infection, 10% had bowstringing and 15% had contracture scar (Table 4).

1-Table (1): Demographic data

	Group I N=20(%)	**Group II N=20**(%)	**Test of significance**
Age / years			t=0.910
Mean ±SD	32.3±10.51	34.40±9.99	p=0.369
Gender			
Male	16(80.0)	18(90.0)	χ^2=0.784
Female	4(20.0)	2(10.0)	p=0.376
Injured hand			
Right	13(65.0)	9(45.0)	χ^2=1.62
Left	7(35.0)	11(55.0)	p=0.204
Injured finger			
Ring	3(15.0)	6(30.0)	MC=2.92
Middle	10(50.0)	5(25.0)	P=0.404
Little	4(20.0)	5(25.0)	
Index	3(15.0)	4(20.0)	

t: Student t test, 2=Chi-Square test

χ^2=Chi-Square test

MC: Monte Carlo test

2-Table (2): Time since injury, Time between 1st and 2nd stage, Follow up in months and Active Range Of Motion(AROM)

	Group I N=20	**Group II N=20**	**Test of significance**
Time since injury (months)	4(2-24)	6(2-36)	Z=0.488 P=0.626
Time between 1st and 2nd stage	3(2-5)	3(3-7)	Z=0.735 P=0.462
Follow up months	6(4-8)	6(3-8)	Z=0.193 P=0.847
Active ROM	255(220-270)	253(230-270)	Z=0.274 P=0.784

Z:Mann Whitney U test

3-Table (3): Patient satisfaction

	Group I N=20(%)	**Group II N=20(%)**	**Test of significance**
Patient satisfaction **2** **3** **4** **5**	 1(5.0) 5(25.0) 3(15.0) 11(55.0)	 1(5.0) 2(10.0) 7(35.0) 10(50.0)	 MC=2.96 P=0.402
Median score (min-max)	5(2-5)	5(2-5)	Z=0.148 P=0.882

MC: Monte Carlo test, Z: Mann Whitney U test

4-Table (4): Complications

	Group I N=20(%)	**Group II N=20(%)**	**Test of significance**
Complications **Tendon adhesion** **Partial stiffness** **Contracture scar** **Catheter infection** **bowstringing**	 2(10) 0 2(10) 1(5) 1(5)	 0 1(5) 3(15) 1(5) 2(10)	 MC=3.48 P=0.481

MC: Monte Carlo test

4.Discussion

Boyes outlined the prerequisites for flexor tendon reconstruction in a single stage. It needs the presence of a healed wound, supple joints with full passive mobility, absence of

significant scarring in the tendon bed, and an intact flexor retinacular pulley system. if these favorable conditions are not present, a staged reconstruction is considered.[16]

In this research, the modified Paneva-Holevich technique (group I) and the FDS tendon transfer (group II) were investigated as a comparative study in a staged reconstruction of neglected flexor tendon injuries. Each group was conducted on 20 patients. Age of patients ranged from 21 to 55 years of age and most of them were male. This could be due to the main working force are male in our society. The most operated finger in group I was the middle finger (n. 10) while in group II was the ring finger (n. 6). The least operated fingers in group I were the index and ring (n.3 each) while in group II was the index finger (n. 4). Four little fingers were operated in group I while five middle fingers and five little fingers were included in group II. The mean follow up period was 6 months.

The outcome of both techniques as a comparative study showed that the median AROM was insignificant between both groups. In The Modified PH technique AROM was 255° ranging from (220° to 270°) versus 253 ranging from (230° to 270°) in FDS transfer. No statistically significant difference between studied groups as regard patient satisfaction score. In the modified PH, 55% have a satisfaction score of 5 versus 50% of FDS transfer.

Using the modified PH, two patients (10%) developed tendon adhesions, one patient (5%) developed bowstring, one patient (5%) developed catheter infection and two cases (10%) developed contracture scar. The FDS technique showed one case (5%) had Partial stiffness, one case (5%) had catheter infection, two cases (10%) had bowstringing. Also, three cases developed contracture when FDS of index finger was transferred to reconstruct FDP of middle (long) finger. This might be due to relative shortening of index FDS. It was relieved with aggressive physiotherapy and lengthening exercises, except for one patient. So, lengthening of index FDS is recommend when it is transferred to middle finger intra-operatively. There was no statistically significant difference between studied groups as regard incidence of complications (P=0.481).

Advantages of this study were that, in both techniques, the intra-synovial donor tendon (FDS) was used with less morbidity and complication. When it was hard to find out the loop or the loop was being fibrosed in modified PH technique, we could convert to tendon transfer technique by excluding the loop or excising it and transfer of the adjacent FDS tendon to reconstruct the FDP tendon of choice and that indicated the versatility of this study. To the best of our knowledge, no previous studies have compared the two techniques.

A limitation of this study that we used the AROM for the whole finger, while others used the AROM for each joint. Other limitations were the small sample size and the short follow up period. Further studies with large number of patients, expanding the follow up period and sharing experiences with other higher centers is recommended.

5. Conclusion

The modified PH technique and FDS transfer technique were beneficial in treating cases of FDP reconstruction after missed or old injuries. There were no statistically significant differences between the two techniques as regard AROM, patient satisfaction and complications.

Ethics approval and consent to participate.

The study was approved by our institutional review board (IRB code: R/16.12.89). The study conformed with the ethical standards set forth in the 1964 Declaration of Helsinki and its later amendments. All participants or their legal guardians provided written informed consent prior to study enrollment.

Informed consent

Informed consent was obtained from the patients or their legal guardians for publication of data in this study.

Competing interest

The author declares that they have no competing interests.

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