DOI 10.18019/1028-4427-2019-25-3-290-296

Technology of temporary isolation of the deep digital flexor tendon and management of patients in zone II delayed repair

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Introduction Healing of the digital flexor tendon following zone II delayed repair is associated with tenogenic contractures. **Objective** Develop and test a new technology of tendon repair in scarry fibro-osseous canals in clinic. **Material and methods** Medical reports and clinical findings of 11 patients with flexor tendon injures to 13 fingers occurred 4 to 6 weeks were reviewed. Two-stage tendon plasty was secured for the patients. With the possibility of suturing in scarry obliterated canal treatment was produced according to the technique developed. Split sterile bioinert polymeric tubes were used for temporary tendon isolation. **Results** An experience of delayed repair of 13 deep digital flexor tendons and temporary isolation with a split polymeric tube in zone II is reported. Motor rehabilitation of patients could be initiated after 3 postoperative days with the repaired tendon being unloaded with the tube. There was no tube reaction, tendon repair failures or other complications observed with the use of new technology. Discussion Polymeric tube can prevent adhesion in the tunnel, protect the repaired site during early motion stress. **Conclusion** The new technology can be an alternative to a two-stage flexor tendon reconstruction facilitating good function recovery and ability to return to work after 2.5–3.5 months.
Keywords: tendon repair, early motion stress, tendon temporary isolation, fibro-osseous canal

INTRODUCTION

Adhesion formation after repair of an injury to the digital flexor is a major problem in hand surgery and fundamental basic science studies of tendon biology and experience with tendon repair techniques are unlikely to offer a solution at the turn of the century [1]. Atraumatic suture technique and precision equipment allow improvements in outcomes of tendon repair. In addition to this, requirements to tendon suture formulated by Yu.Yu. Dzhenelidze in 1936 [2] are essential thus far. Sutures must be easily placed in the tendon, secure suture knots for minimal tendon bundles, secure smooth gliding tendon surface, secure juncture at tendon ends, secure minimal interference with tendon vascularity and repair of synovial sheath over the tendon if possible. Six characteristics of an ideal primary flexor tendon repair listed by J.W. Strickland in 1990es identified the above requirements additionally including "early motion stress to the tendon" [3]. The latter can be applied with sufficient strength throughout healing. Favorable remodeling of the scar around a tendon is accomplished by applying stress to the tendon, which in turn transmits the stress to adjacent scar [4].

Postoperative restorative treatment involves biological aspects of connective tissue regeneration. Tendon healing can be activated by extrinsic fibroblasts in the epitenon and in the tendon itself, and intrinsic repair of intrasynovial flexor tendon include three stages [5]: inflammatory phase (0 to 14 days), reparative (2 to 6 weeks) and remodeling phase (6 weeks to 3.5 months). Collagen production is primarily from the fibroblasts of the epitenon during the first two stages with the formation of peritendinous adhesions being limited. Adhesions are likely to decrease with epitendinous suture applied over intrastem suture and following restoration of the canal wall due to motion stress [6]. However, 10 % to 50 % loss of baseline suture strength occurs during the first 5–21 postoperative days [3], and uncontrollable motion stress can result in suture defect and rupture of the flexor tendon repair. Inevitable biologically substantiated peritendinous adhesion is a major reason of poor outcomes of flexor tendon repair. Greater difficulties are observed with delayed flexor tendon suture in the scarry fibro-osseous canal [7, 8].

The purpose of the study was to develop and clinically test a new technology for treatment of an old injury to the digital flexor tendon to allow zone II delayed tendon repair, formation of the smooth wall of the fibro-osseous canal and safe application of early motion stress with absent external immobilization.

Zenchenko A.V., Cherniakova Iu.M. Technology of temporary isolation of the deep digital flexor tendon and management of patients in zone II delayed repair. *Genij Ortopedii*, 2019, T. 25, No 3, pp. 290-296. DOI 10.18019/1028-4427-2019-25-3-290-296. (In Russian)

MATERIAL AND METHODS

The review included findings of 11 patients with delayed injury to 13 flexor digitorum profundus tendons at the fibrous-osseous canal repaired with the new technique. All patients (9 males aged from 19 to 47 years and 2 females aged from 34 to 42 years) received treatment for old injury to the superficial and deep digital flexor tendons in zone II at the Gomel Regional Clinical Hospital between January 2014 and November 2018. The injuries resulted from cut wounds of the hand palmar surface and were seen to occur 4 to 6 weeks ago with no injuries to bones, joints and vascular and nerve trunks. Primary tendon repair was not produced for the patients due to late presentation and clinical symptoms under-evaluated by the surgeon. Patients were referred to our hospital for two-stage reconstruction of the deep digital flexor tendon depending on how long ago injury occurred.

No active flexion in the interphalangeal joint of injured fingers and arthrogenic contractures were observed on admission with active flexion of 20° persisting in metacarpophalangeal joint due to contraction of the vermiform and interosseous muscles. Options of surgical repair and rehabilitation were preoperatively discussed with patients provided the final decision on suture or stage grafting to be made intraoperatively and based on condition of ligaments and canal wall, suture level, possibility of minimal gapping at the repair site, etc.

In compliance with ethical standards of the Helsinki declaration [9] patients were provided with information on the deep flexor tendon repair technique [10]. New technology consisted of two procedures including delayed suture of the deep flexor tendon, its temporary isolation and blockage with longitudinally split tube to be followed by removal of the tube after 4 weeks. Patients provided an informed consent on treatment using the technique offered in case of scarry obliteration of the fibro-osseous canal and the possibility of tendon repair in zone II [10]. Sterile elastic transparent radiotranslucent tube made of phthalate free polyvinyl chloride, bioinert synthetic polymer, obtained from postoperative wound drainage set (Angiplast Private Limited, India) was used for isolation of the repaired tendon. The outer diameter of the tube was 4 mm, the inner diameter of the tube was 3 mm, wall thickness was 0.5 mm, tensile strength was 200 N and modulus of elasticity was 14.34 MPa. The tube length was determined intraoperatively measuring the distance from the distal palmar crease to the base of the ungual phalanx at the digital extension.

RESULTS

The technique [10] was tested in clinical setting during repair of 13 flexor digitorum profundus tendons. The first procedure was performed under conduction anesthesia using tourniquet and pneumatic cuff applied to the middle third of the humerus. Zigzag approach to the canal started with scar excision that extended to the proximal third of index phalanx and the mid of the ungula phalanx. Annular pulleys A2 and A4 were dissected, U-incised and retained if possible. Scarry tissue was excised at the approach, canal and tendon pedicle. The distal end of the deep flexor tendon of at least 1.5 cm was acceptable for suture. The proximal tendon end was exposed using an additional incision at the distal palmar crease and pulled under the pulley A1 to the digital wound using guide-bouige. Intrastem Cuneo repair was produced with nonabsorbable Daklon braided suture size 2/0–3/0 and the junction was adapted with epitendinous Kleinert slow absorbing suture size 5/0. Suture quality was identified with passive digital extension: the suture did not stretch and tear at full digital extension. Implantation tube was longitudinally split all along and the proximal portion of the inner concave surface was placed over the tendon in the surgical digital wound and moved proximally up to the distal palmar crease over the tendon surface so that the tube inner concavity embraced the palmar and lateral tendon by 2/3 of the diameter. Loop suture was used for the proximal tube and the tendon with the distal tube sutured to the ungual phalanx. Annular pulleys A2 and A4 were repaired with lengthening and half of the pulleys' width maintained in 5 cases. Scarry obliteration of the canal and tissue excision prevented pulleys' repair in 8 cases without A2 and A4 pulley reconstruction. Loop sutures were applied for all surgical wounds and a tight aseptic boxing glove shaped dressing used. Photographs (Fig. 1), diagram and a radiograph (Fig. 2) demonstrate stages of the first surgical procedure.

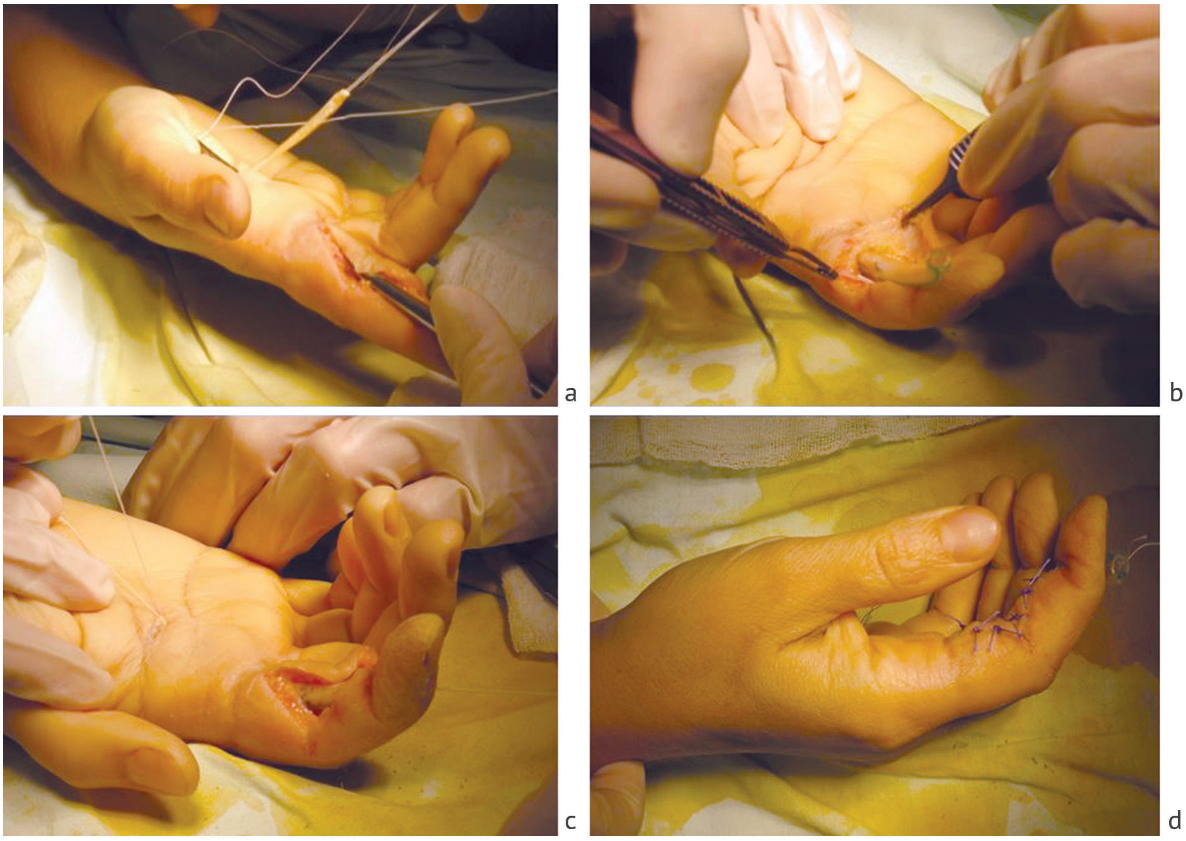

Fig. 1 Stages of the first surgical procedure showing ***a*** exposure and suture of the proximal tendon of the deep flexor tendon, ***b*** the repaired tendon covered with the split tube, ***c*** proximal and distal tube blockage, ***d*** digital position after suture placement

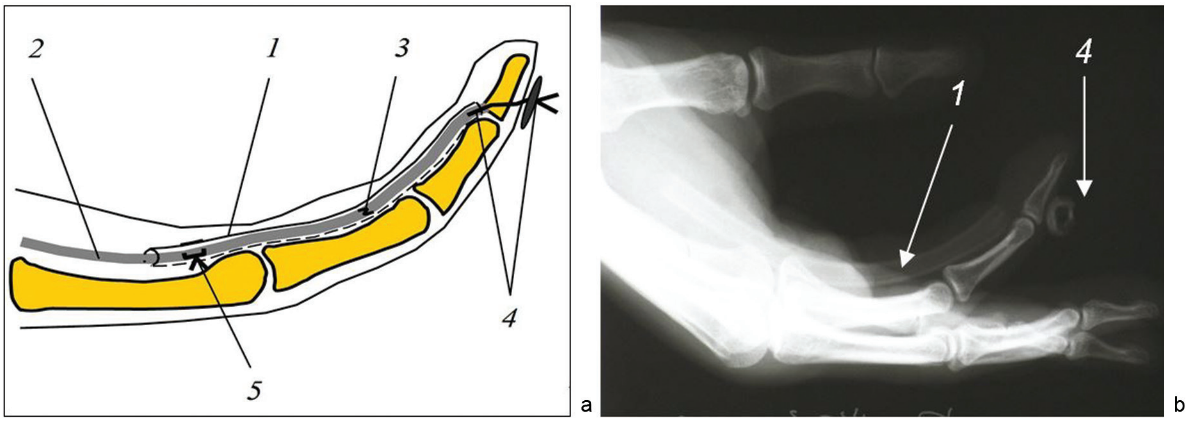

Fig. 2 Diagram ***a*** and radiograph ***b*** showing isolation tube placed over the deep digital flexor tendon with marked tube (1), tendon (2), tendon suture (3), distal blocking suture (4), proximal loop suture (5)

Pain relief and nonsteriod anti-inflammatory drugs were administered for 3–5 postoperative days with antibiotics prescribed next day postsurgery. Motion rehabilitation was initiated on the second day postsurgery. Slight passive movements in interphalangeal joints were produced by the surgeon at changing dressings for the first time. Flexor capability was confirmed with natural digital position persisted in relaxed hand as shown in Figure 1d. Passive digital flexion and active extension as pain allowed were produced 10 times per day under control of the surgeon first and then individually after 3-4 days with swelling of soft tissues diminished. The amplitude gradually increased. A light load of about 1 kg was applied for active flexion after 7–8 days (Fig. 3), 2 kg weight used after 10 days and a handgrip force of about 7 kg applied after 14 days. Physical therapy procedures were administered to regain digital and palmar skin elasticity after suture removal and patients continued passive and active digital flexion and extension with hold portion at exercising. Range of motion was restricted by strain properties of the tube.

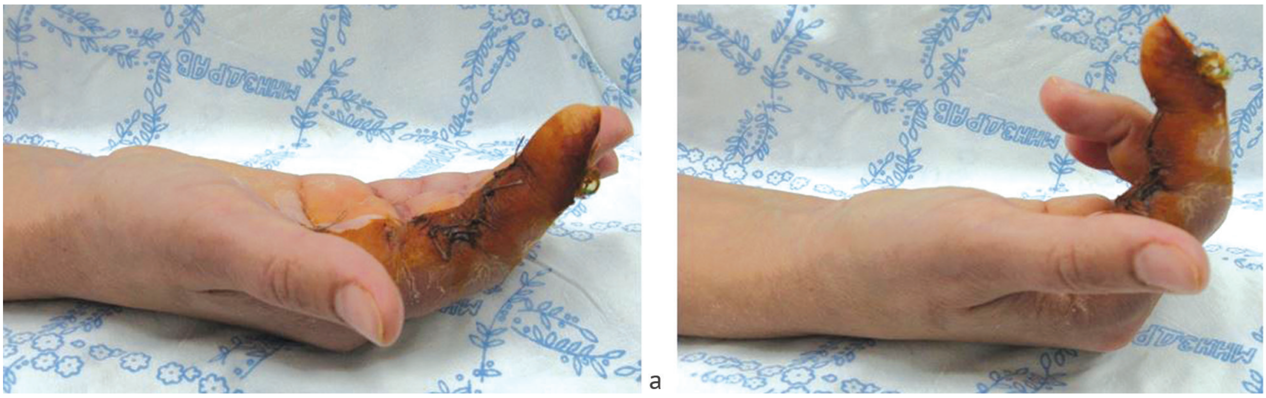

Fig. 3 Active motion of the finger after 8 postoperative days showing (a) maximal extension and (b) maximal flexion

The second procedure performed after a 4 week interval included removal of the distal blocking suture from the ungual phalanx, the proximal loop suture and the tube under local anesthesia through an incision of 1 to 11/2 cm at the distal palmar crease (Fig. 4). The wound was sutured under control of hemostasis and patients could demonstrate the range of motion achieved postsugery.

Fig. 4 Removal of isolation tube

Patients continued rehabilitation after removal of the tube to achieve full range of active digital flexion and extension and the strength of active flexion of the ungual phalanx with a resisting force of about 12 kg. The result was obtained at average of 3 months after the beginning of treatment. Figure 5 shows a long-term follow-up of the right index finger treated with the new technique (the same hand shown in Figures 1–4). Photographs were taken at 2 years and courtesy of the patient. Functional evaluation with the K.Tsuge method showed a sum of angles in digital active flexion measuring 225° rated as an excellent outcome, the distance from the digital tip to the distal palmar crease of 1.5 cm and extension deficiency of 25° rated as a good result. Cumulative range of active motion in interphalangeal joints measured with the method of J.W. Strickland was 130° and 74 % of the normal amplitude rated as a good outcome. Extension of the ungual phalanx was restricted by inelastic soft-tissue scar over flexion surface of the distal interphalangeal joint.

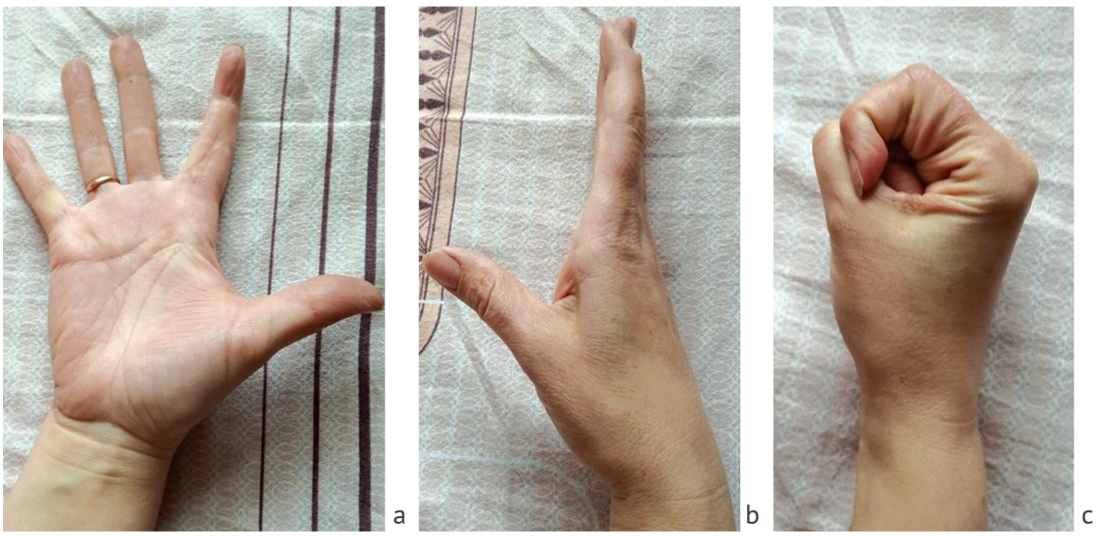

Fig. 5 Two-year follow-up showing ***a*** digital extension, ***b*** extension of the joints of the operated finger, ***c*** digital flexion

Both digital flexor tendons were treated at 5 weeks of injury at the level of mid third of index phalanx in the clinical instance. Scars and ligaments of the fibro-osseous canal were excised during surgery. Ligaments were not repaired over the sutured deep flexor tendon covered with the tube. The patient continued motor rehabilitation by himself after removal of the tube and returned to his job as a cook after 3 months of delayed repair. Treatment with the new technique did not result in bowstring deformity of the finger in absent pulleys with gripping function restored. Neither inflammation nor purulent infection was observed in treatment of patients with the new technique.

DISCUSSION

Healing of the digital flexor tendons following delayed repair at the fibrous-osseous canal is inevitably associated with blocking adhesions of gliding surfaces and tenogenic contractures of the interphalangeal joints to be treated with mobilizing procedures [11]. Early controlled passive motion was shown to stimulate an intrinsic healing response in tendon repair [6]. However, early motion stress can be limited by low strength of tendon repair, high level of pain, psychological instability, etc. Uncontrolled and extremely intense motion in digital edema, in particular, supports and aggravates formation of peritendinous adhesions or leads to tendon rupture. The technique presented in the article and offered for surgical repair of the deep digital flexor tendons has been developed to address the above problems and can be viewed as an alternative to the two-stage tendon reconstruction (Fig. 6).

Tube implantation and fixation is likely to increase the operating time by not more than 5 minutes. The implanted tube made of bioinert synthetic material serves a mechanical obstruction to adhesion of the tendon and the anterior and lateral walls of the tunnel with a blood clot being dislodged by the implant and localized between the implant and the tunnel wall facilitating less adhesion of fibrin and smooth surface of the tube. A contact between the dorsal surface and the tunnel wall measuring 2-3 mm persists in the dissection area providing nutrition recovery for the tendon with ingrowth of the connective tissue and blood vessels being transformed into mesenterium [8]. Basic science studies have concluded that in experimental animals the repair site is revascularized by approximately 17 days after repair. Vessels form along the surface of the tendon and migrate to the repair site. The channel created by passage of the suture material for repair is also characterized by dense neovascularization [12]. Tendon healing with partial isolation being accomplished by intrinsic fibroblasts from the tendon itself is compatible with a pattern of restoration maintained in a cell free tissue environment [8, 13–15].

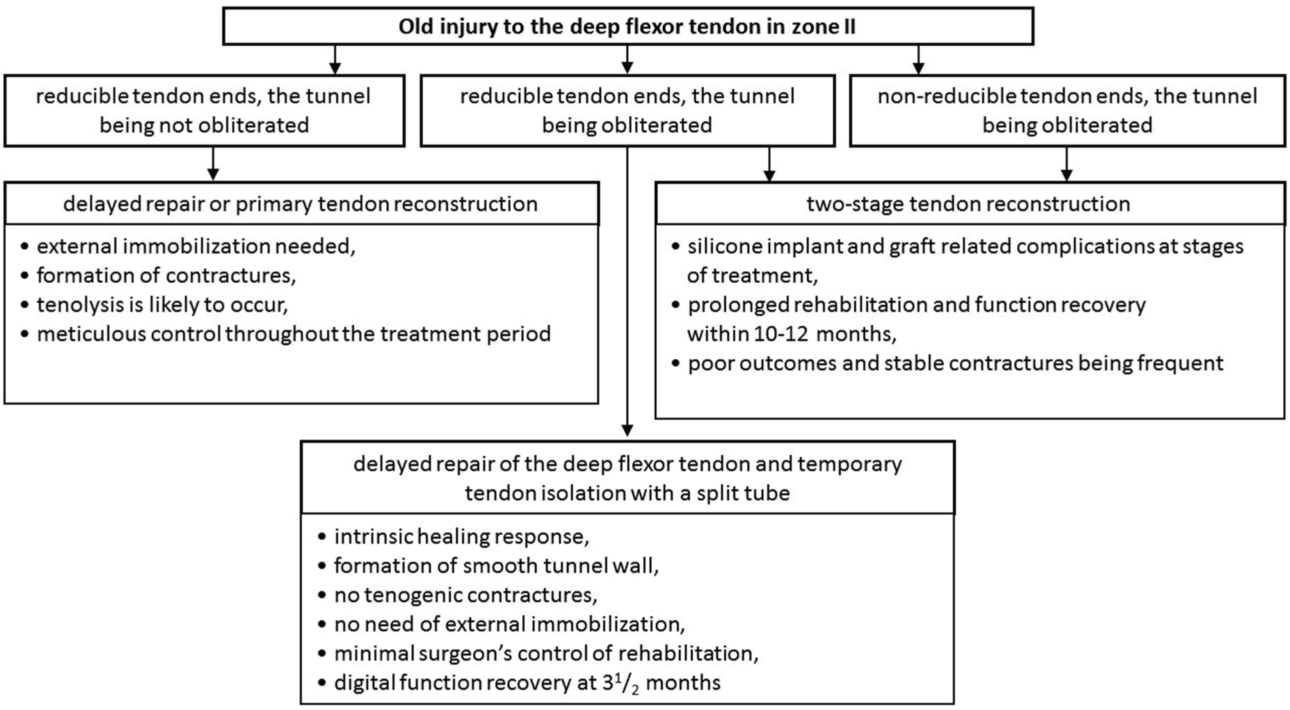

Fig. 6 Diagram-algorithm for a choice of delayed repair of the deep digital flexor tendon

A2 and A4 pulleys reconstruction in 5 fingers showed no differences and advantages over 8 cases without pulley repair over the tube suturing cellular tissue and the skin only. Both surgical procedures resulted in neither dislocations of the repaired tendon nor bowstring deformity. This could be ascribed to the tube being capable of regaining baseline shape after deformity caused by digital motion, and, second, moving parallel to phalangeal and articular surface without sagging in motor muscle contraction even in absent pulleys. The tube was shown to prevent scarry stenosis and decrease in the tunnel diameter during soft-tissue healing [8]. Connective tissue solid enough to retain the tendon and gliding surface appeared to form around the tube during 4 postoperative weeks. Neither complications nor adverse reactions in temporarily implanted tubes were recorded in the patients. The tube attached to the tendon was a specific inner splint that redistributed tendon loading from zone II outwards and protected the suture from abrasion. Unresisted active digital motion could be sufficiently produced immediately after surgery. Regular natural movements primarily performed with motor muscle contraction allowed its functioning throughout the postoperative period.

Tensile strength of the tube was approximately 200 N (20.4 kg) being twice the force exerted by the deep flexor tendon during a strong handshake (70 N, 7.14 kg) [3, 5] and hard hold of the ungula phalanx (120 N, 12.24 kg) [3]. An extreme tension applied to the less strong 2-strand intrastem Cuneo suture and braided epitendinous suture and the tendon blocked with tube during the first four weeks can result in injury to kinematic chain at the proximal loop suture (tensile strength of about 10 kg) first due to the suture cutting through the tendon and then at the tendon suture sustaining the force of about 2 kg. Further experimental studies are required to determine the strength and mechanisms of ruptured sutures produced with different techniques and threads made from different materials in various loading modes of tube blockage.

Effect of motion stress is traditionally related to remodeling of a scar around the repaired tendon [16]. However, no adhesion is observed to form between the tendon and the tunnel wall with the split tube isolation. Thus, beneficial effects exerted by motion stress in new conditions include: 1) the delivery of nutrients is accomplished by a pumping mechanism known as imbibition [5] in which fluid is forced into the interstices of the tendon through small conduits in the tendon surface via the split part of the tube as the digit is flexed and extended; 2) adhesions stretch and remodel in non-isolated portion of the tendon due to motion with the ingrowth of vessels and formation of mesenterium; 3) functioning of motor flexor muscle and motion of interphalangeal joints are not restricted. Slot-like space is sufficient for the free tendon transport after removal of the tube. Further rehabilitation features of gradually increasing amplitude to regain full range of motion in the digital joints displacing and remodeling scarce connective tissue adhesions on the dorsal side of tendon. Zigzag scar on flexion surface of the digit do not hinder recovery of digital extension with the scar being elastic and extensible as the surrounding skin in the course of time. Working capacity of patients and good digital functioning have been shown to recover at 2.5 to 3.5 months of delayed repair of the deep flexor tendon [7]. The above technique is contraindicated in severe open and closed digital injuries with phalangeal fractures, in the presence of a single neurovascular trunk, arthrogenic contractures of interphalangeal and metacarpophalangeal joints and a hand infection. The technique cannot be used in primary tendon repair in open injury due a high risk of infection.

CONCLUSION

The technique described in the article can be employed to restore tendon gliding with delayed flexor tendon suture in the scarry fibro-osseous canal. The technology can be an alternative to a two-stage flexor tendon reconstruction when tendon ends can be connected and sutured under slight tension. There is no need to repair pulleys with implanted tube due to connective tissue forming around the tube during 4 weeks of isolation and being solid enough to prevent tendon from sagging. Early motion rehabilitation of patients without external fixation is not associated with suture rupture even in absent surgeon's control because the isolating tube overlaps the tendon in the tunnel and redistributes loading outwards. In the case suture rupture can occur with an effort that the patient would be unable to produce. Motion is encouraged from the first days following delayed repair of the deep flexor tendon repair facilitating good functionsl recovery and ability to return to work after 2.5–3.5 months.

The authors declare no conflict of interests.

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Received: 20.06.2019

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