FLEXOR TENDON INJURIES AND FDP AVULSION

BIG HAND EVENT 2023

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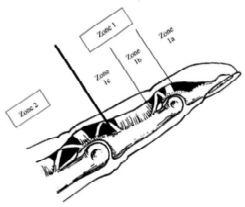
SUMMARY

ETIOLOGY
ANATOMY – PULLEY SYSTEM
NUTRITION – BLOOD SUPPLY
ZONE OF INJURY

CLINICAL PRESENTATION

TREATMENT
REHABILITATION
COMPLICATION



ZONE 1 LESIONS

ETIOLOGY

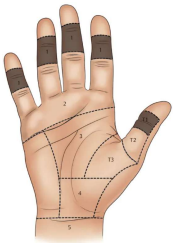
CUT

FINGER
WRIST

PROFUNDUS
SUPERFICIALIS
BOTH

MUSCLE BELLY

ZONES



LACERATION

TRAUMA

JERSEY FINGER

OTHER CAUSES

METHABOLIC INFLAMMATORY DESEASES
MANNERFELT LESION (spurs FPL)
Hamate fracture

SURGICAL PROCEDURE – volar plate

ETIOLOGY

CUT

FINGER
WRIST

PROFUNDUS
SUPERFICIALIS
BOTH

MUSCLE BELLY

SUTURE

ZONES

LACERATION

TRAUMA

JERSEY FINGER

SUTURE REINSERTION

OTHER CAUSES

METHABOLIC INFLAMMATORY DESEASES
MANNERFELT LESION (spurs FPL)
Hamate fracture

SURGICAL PROCEDURE – volar plate

TENDON TRANSFERS GRAFTS

ETIOLOGY

Other injuries

Crush injury
Thermal injury
Infection
Avulsion from the muscle

ANATOMY – MUSCLES

FPL
Blood supply: radial artery
Nerve supply: AIN

FDP
Blood supply: ulnar artery
Nerve supply: ulnar – R&L
AIN – I&M

FPL

PROFUNDUS

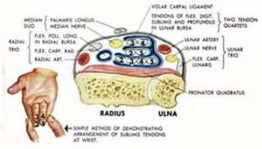
FPL
Blood supply: radial artery
Nerve supply: AIN

FDS
Blood supply: radial & ulnar arteries
Nerve supply: median

FDP
Blood supply: ulnar artery
Nerve supply: ulnar – R&L
AIN – I&M

SUPERFICIALIS

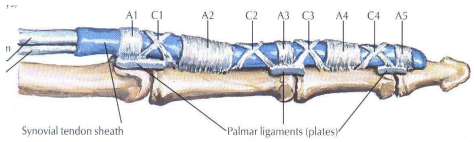
Carpal Tunnel



ANATOMY

Flexor sheaths

- approx distal palmar crease
- Predictable annular pulley arrangement
  - Protective housing
  - Gliding surface
  - Biomechanical advantage
  - Synovial layers merge at MP level
  - Flexor tendons weakly attached to sheath by vinculae



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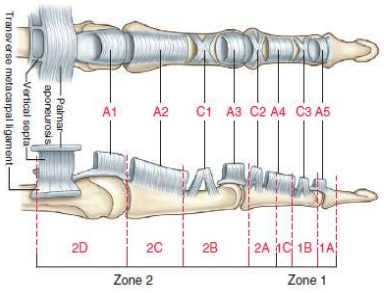
ANATOMY

TANG CLASSIFICATION



Zones of Finger Flexor Tendons (Verdan)

1. From the insertion of the FDS tendon the terminal insertion of the FDP tendon
2. From the proximal reflection of the digital synovial sheath to the FDS insertion
3. From the transverse carpal ligament to the digital synovial sheath
4. Area covered by the transverse carpal ligament
5. Proximal to the transverse carpal ligament

Zones of Thumb FPL Tendon

1. Distal to the IP joint
2. From the IP joint to the A1 pulley
3. The area of the thenar eminence

Zone 1 in Fingers (Moiemen and Elliot)

- 1A The very distal FDP tendon (usually <1 cm)
- 1B From zone 1A to distal margin of the A4 pulley
- 1C The FDP tendon within the A4 pulley

Zone 2 in Fingers (Tang)

- 2A The area of the FDS tendon insertion
- 2B From the proximal margin of the FDS insertion to the distal margin of the A2 pulley
- 2C The area covered by the A2 pulley
- 2D From the proximal margin of the A2 pulley to the proximal reflection of digital sheath

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ZONES OF INJURY

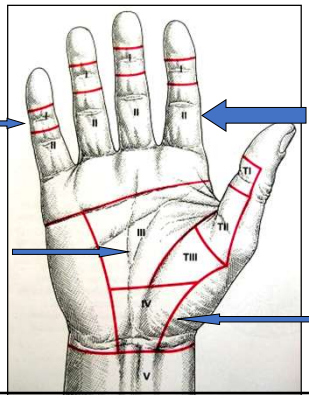
VERDAN

ZONE 1
distal to the FDS Insertion

ZONE 2
"NO MAN'S LAND"

ZONE 3
distal edge of TCL to flexor sheath origin (distal edge)

Carpal Tunnel



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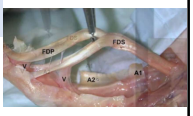
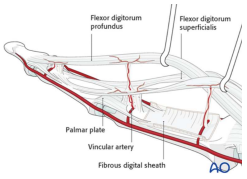
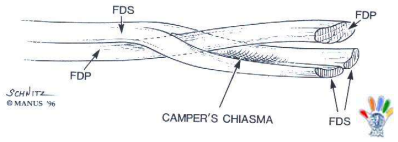
ANATOMY

- Vascular
  - **Longitudinal vessels**
    - Enter in palm
    - Enter at proximal synovial fold
  - Segmental branches from digital arteries
    - **Long and short vinculae**
  - Vessels at osseous insertions
- **Synovial fluid diffusion**
  - Imbibition (pumping mechanism)





Camper's Chiasma



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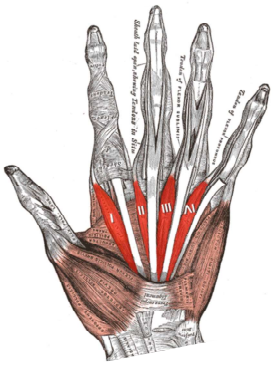
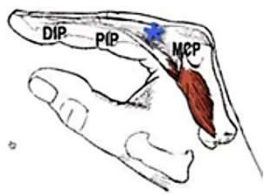
LUMBRICAL ACTION





iginate from FDP tendons.
ert on dorsal expansion extensor tendons.

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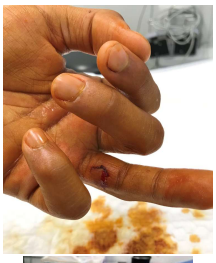
QUESTIONS TO ASK BEFORE SURGERY !

Clinical examination

- **Mechanism of injury ?**
- **Associated injuries ?**
- **Finger positioning during injury ?**
- **What if incomplete tendon division ?**

- **X-rays**



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CLINICAL EXAMINATION

LOOK ! ***inspection***

Hand/Finger posture (Cascade)

Both tendon >> full extension

FDP only >>> extended DIP

FDS only >>>> No change

CLINICAL EXAMINATION

FP **FS**

III and IV FINGER

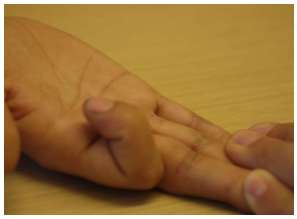
REGARDING THE FDS 5

- **Group 1**: Extend the other fingers and flex the PIP (56,4%)
- **Group II**: Relax the **ring finger** (sometimes middle or even index) to obtain PIP flexion of the little (27,3%)
- **Group III**: cannot flex the PIP 5 whatever maneuvers you perform (26,3%)

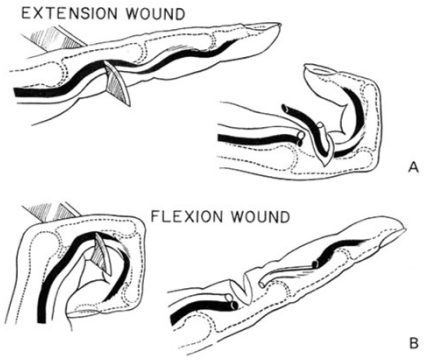
Tan JS, Oh I, Louis DS. Variations of the Flexor Digitorum Superficialis as determined by an Expanded Clinical Examination. J Hand Surg 2009;34A:900–906

TESTING THE FDS OF THE INDEX ?

- CLASSIC MANEUVER IS POSSIBLE IN MORE THAN 90% OF PATIENTS
- **THE FDP OF THE INDEX MAY BE INDEPENDENT** !
  - THEN ?



HISTORY



Merle 1993

YOU MAY HAVE A DOUBT ?

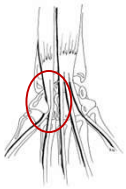
- Clinical testing
- Use the tenodesis effect
- Explore the wound !

Linburg-Comstock

- In 30-40% of patients (ethnic differences)
- ♀ / ♂= 2,5
- Bilateral 84%
- Can be painful
- Other fingers may be involved



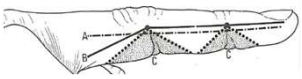
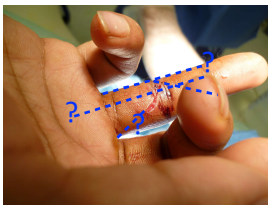




Linburg RM, Comstock BE. Anomalous tendon slips from the flexor pollicis longus to the flexor digitorum profundus. J. Hand Surg 1979 ;4A : 79-83
Yammine K, Mirela E. Linburg–Comstock variation and syndrome. A meta-analysis. Surgical and Radiologic Anatomy 2018;40(3):289-296.

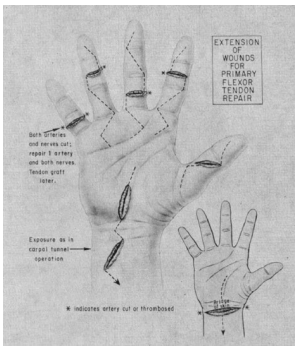
SURGICAL APPROACH

- Start with a debridement +++
- Then ?
  - Mid-lateral ?
  - Brunner ? Hemi-Brunner ?
  - W of Littler ?

Brunner's approach was designed for flexor tendon injuries !

In 1965 I departed from the traditional mid-lateral approach and moved to the volar skin. This was prompted by an accidental zig-zag glass cut on the finger of a young student sustained while bar-tending. The exposure provided by this ready-made incision was so good, the result of primary tendon repair in No Man's Land so successful, and the subsequent scar so favourable that I decided to use this staggered approach for other flexor tendon repairs. Such a volar approach is direct, does not encroach on the neurovascular bundle, and may be extended into the palm as far as necessary. The digital theca is thereby widely exposed so that it can be partially excised (for either primary repair or tendon grafting), leaving whatever pulleys are necessary in the finger to prevent bow-stringing of the tendon or graft.



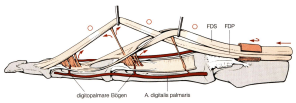
Brunner JM. The zig-zag volar-digital incision for flexor tendon surgery. J. Plast Reconstr. Surg. 40: 571-574. 1967.

INCOMPLETE DIVISION

- Literature suggest that a division **less** than **50-60%** of the tendon diameter do **not need to be repaired**
- But if you repair it, you have to protect the repair which is not as strong as the partially divided tendon before 4 weeks
- **Repair of an incomplete divided tendon may be require in some cases** (entrapment…)

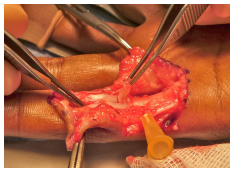
Reynolds, B., R. C. Wray, Jr. and P. M. Weeks (1976). "Should an incompletely severed tendon be sutured?" Plast Reconstr Surg **57**(1): 36-38

VINCULA ?



Outcomes of repaired tendon depend (in part) of its vascularisation

- **Protect the vincula**
- **Note if they are divided**




TENDON HEALING

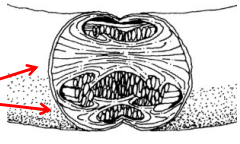
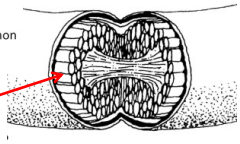
~~ESTRINSIC HEALING~~

sources of healing

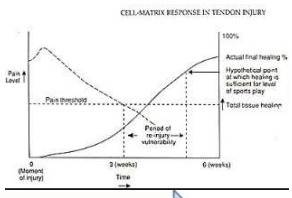
~~Extrinsic – granulation tissue from tendon sheath~~

Intrisic – cell invasion from tendon and epitenon

INTRINSIC HEALING

Tendon Healing



- **Inflammatory**: •3-5 Days •Fibrin clot produced
- **Fibroblastic**: • 1-6 Weeks • Production of collagen and matrix to form a disorganized tendon "callus".
- **Remodeling**: • 6 Weeks – 9 Months • Reorganization of collagen into cross-linked organized pattern.

TIMING

PRIMARY REPAIR
Golden period
Within 24 h ina clean wound
Best results

DELAYED PRIMARY REPAIR
24 h - 10 days
Suspicion of infection
Tendon viability

SECONDARY REPAIR
10-15 days up to 4-5 weeks

LATE SECONDARY
After 4-5 weeks
Tendon shortening and deterioration
Pulley system could be not employable

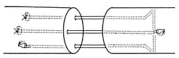
TIMING

PRIMARY REPAIR
Golden period
Within 24 h ina clean wound
Best results

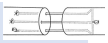
DELAYED PRIMARY REPAIR
24 h - 10 days
Suspicion of infection
Tendon viability

TECHNIQUES

DIRECT SUTURE



TIMING

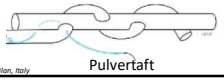
DIRECT SUTURE 

GRAFTS
LENGHTENING
TENDON TRANSFER

RECOSNSTUCTION in TWO TIMES

SECONDARY REPAIR
10-15 days up to 4-5 weeks

LATE SECONDARY
After 4-5 weeks
Tendon shortening and deterioration
Pulley system could be not employable


Pulvertaft


Friden

IDEAL REPAIR

- **Easy placement** of sutures in the tendon
- **Secure suture knots**
- **Minimal gapping** the repair site
- **Sufficient strength throughout healing to permit application of early motion stress to tendon**
- Smooth juncture of tendon ends
- Minimal interference with tendon vascularity

Strickland JW: Flexor tendon injuries: Foundation of treatment. J Am Acad Orthop Surg 3:44-54, 1995

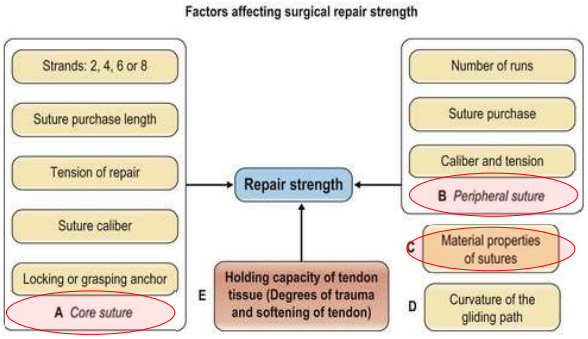
FACTORS INFLUENCING THE BIOLOGICAL AND BIOMECHANICAL PROPERTIES OF THE REPAIR

THE CONFIGURATION OF THE CORE SUTURE

THE EPITENDINOUS SUTURE: DEPTH AND PATTERN

THE SUTURE MATERIAL: SIZE AND TYPE

FACTORS INFLUENCING THE BIOLOGICAL AND BIOMECHANICAL PROPERTIES OF THE REPAIR



TECHNIQUE OF TENDON REPAIR

- Grasping or locking
- Core suture number ?
- Suture size ?
- Dorsal or volar
- Epitendinous suture ?
- Sheath repair ?
- Knot inside or outside ?
- Pulley ? Venting ?

?

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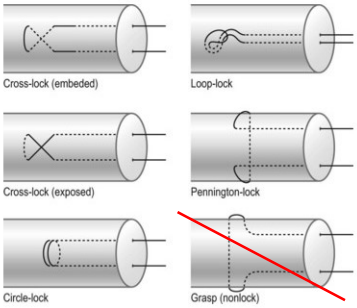
GRASPING vs LOCKING

- **Grasping generally weaker than locking**
- Exposed and embedded cross-locks have the same strength
- cross- or circle-locks appear slightly stronger than Kessler-type repairs with Pennington locks



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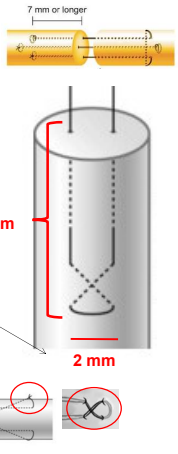
MEASURES CORE SUTURES



- **core suture purchase of at least 0.7–1.0 cm**
- **diameter of the suture locks** must reach or exceed **2 mm**
- **caliber of core suture used in adults is either 3-0 or 4-0**
- **Knots outside** repair site seems to be stronger

FORCES

- **Forces generated during normal hand action range from 1 to 35 N (0 to 4 Kg/power)**
- **cyclic loads**

2 **two**-strand maximal strength from 20 to 30 N four-strand

4 **four**-strand repairs are around or beyond 40 N

6 **six**-strand repairs fail with loads over 50–60 N

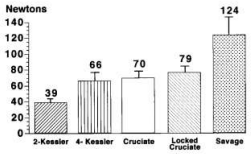
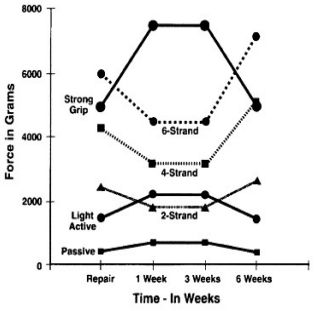


Figure 4. The ultimate tensile strength of the 6-strand repair was significantly greater than each of the 4- or 2-strand repairs. The tensile strength of each 4-strand repair was significantly greater than the 2-strand repair ($p < .05$).

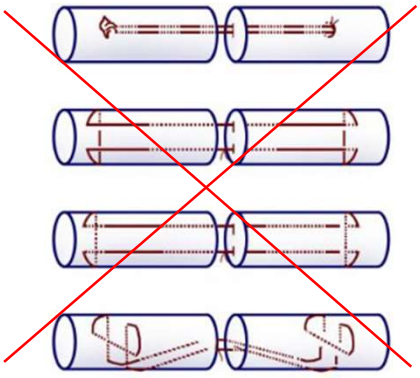
CORE SUTURE NUMBER

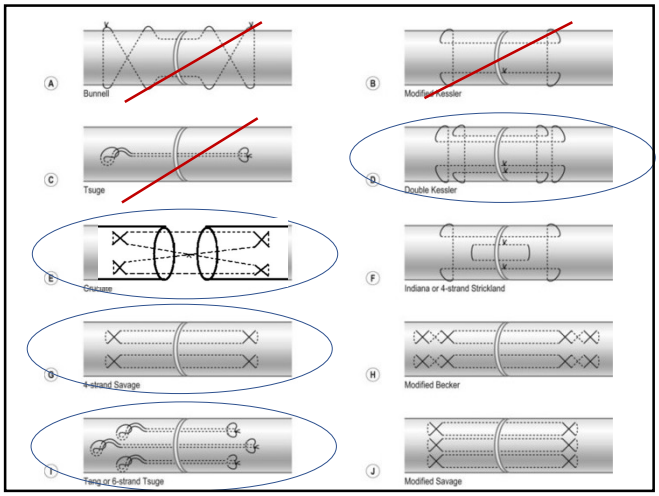
- The **strength of a repair is proportional to the numbers of core sutures**
- **6 strand** repair are more resistant to failure, but technically difficult and **may damage tendon**
- **4 strand** are **easier and strong enough to control led rehabilitation**



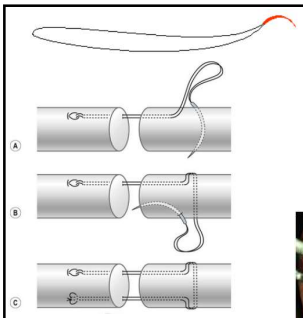
Stricland JW: Development of flexor tendon surgery : twentyfive years of progress. J H Surg (AM) 25:214-235, 2000)
Tang JB, Wang B, Chen F, et al. Biomechanical evaluation of flexor tendon repair techniques. Clin Orthop Rel Res 2001;386:252-9
Lawrence T : A biomechanical analysis of sutures matherials and their influence on a 4 strand flexor tendon repair J Hand Surg (AM) 30:836-841 2005

2 STRANDS





2 TZUGE LOOPS



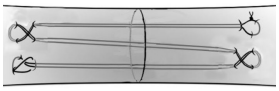
Tang evolution

OUR PREFERRED SUTURE AT THE MOMENT

TZUGE LOOP

ONLY ONE SUTURE

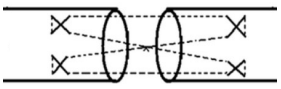
6 STRAND !



Gan modified Lin Tzai

4-0 Nylon

4 STRAND !



Cruciate or Adelaide

PULLEY and VENTING

A2 AND A4 PULLEY ARE IMPORTANT

…. but ….

incision of the
A2 PULLEY UP TO ONE-HALF
or two-thirds of its length (venting)
OR OF THE ENTIRE A4 PULLEY
results in no tendon bowstringing

NO GAPPING OF THE REPAIR SITE UNDER TENSION

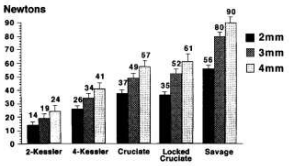


Figure 5. At 2-mm gap formation, the cruciate repairs showed no statistical difference in gap resistance compared with the 6-strand repair. At 3- and 4-mm gap formation, the 6-strand repair demonstrated a significantly greater resistance to gap formation compared with each of the other techniques. Notably, there was no difference in gap behavior between the 4- and 2-strand Kessler repairs.

Tendons with repair site gaps less than 3 mm accrue strength during the 4th to 6th week postoperatively, whereas tendons with repair site gaps greater than 3 mm show no significant increase in ultimate tensile strength during the early postoperative period.

THE SUTURE MATERIAL SIZE AND TYPE

IDEAL SUTURE MATERIAL

biologically inert

high ultimate tensile strength (UTS) **order of 35N / 4 Kg**

high modulus of elasticity

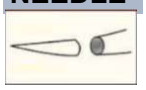
handles and ties easily and holds well when knotted

THE SUTURE MATERIAL SIZE AND TYPE

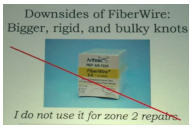
MOST COMMONLY USED MATERIALS ARE

synthetic polyester monofilament NYLON for the core suture
(usually 3-0 caliber;
depends to the different size of tendons)
monofilament for the epitendinous suture
(usually 6-0 caliber)

ROUND NEEDLE



… PDS ?



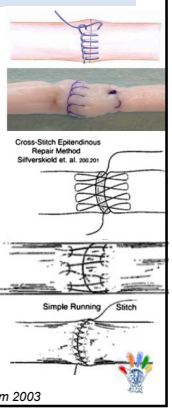
Taras JS, Raphael JS, Marczyk SC, Bauerle WB. Evaluation of suture calibre in flexor tendon repair. J Hand Surg 2001;26A:1100-4

EPITENDINEOUS SUTURE

PROVIDING A SMOOTH TENDON SURFACE AND DECREASE THE REPAIR BULK

INCREASES TENSILE STRENGTH AT THE REPAIR SITE AND DECREASES EARLY POSTOPERATIVE REPAIR GAP FORMATION

at least 2 mm on each tendon stump improves strength – 6/5-0 nylon



Merrell GA, J Hand Surg Am 2003

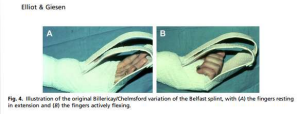
REHABILITATION

- Early passive motion
- wrist and MCP flexion
- PIP and DIP extension
- Controlled motion
- Active finger extension, passive flexion

Postoperative motion: full passive digital flexion
- is done first, followed by partial active motion
- in the first 3 weeks.

REHABILITATION

• Strickland – active-hold / place – Hold or Belfast



More aggressive protocols for advance in material and repair

Increased risk of rupture if AGGRESSIVE active motion

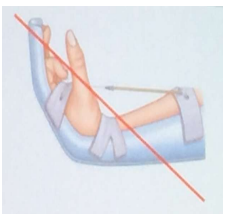
OSADA 2016

- **6 strand repairs and early active flexion**

26/27 excellent and good results

- No ruptures

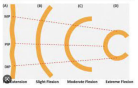
avoid ➡ Pure early passive motion, marked wrist flexion or/and rubber band after surgery



REHABILITATION

OUR ACTUAL PROTOCOL

3 days - no movement



Always **passive movement before active** (10 min)

Active motion after passive motion - Every 4-6 hours as JB Tang Protocol

Dorsal splint – **wrist extended – 25 days**

Indipendent gliding between the two tendons !

OUTCOME OF TENDON REPAIR IN THE CLINICAL SITUATION IS LESS PREDICTABLE THAN THE RESULTS OF BIOMECHANICAL STUDIES FOR SEVERAL REASONS

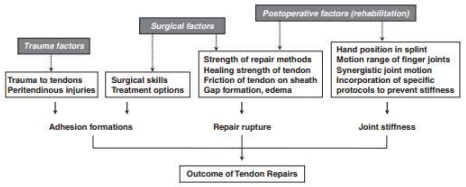


Fig. 1. Relation between factors affecting clinical outcome of flexor tendon repairs.

CURRENT DATA SUGGESTS GOOD OR EXCELLENT OUTCOMES IN OVER 75% OF FLEXOR TENDON REPAIRS.

RUPTURE OCCURS IN 4-10% OF FINGER FLEXOR REPAIRS AND 4-17% OF LONG THUMB FLEXOR REPAIRS

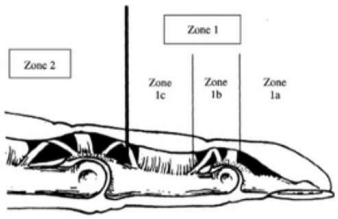
ADESHIONS ARE FREQUENT , MOSTLY IN ZONE II

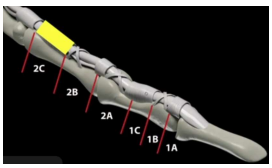
Tang J. Clinical outcomes associated with flexor tendon repair. Hand Clin 2005;21:199-210

REPAIR TIPS - THM

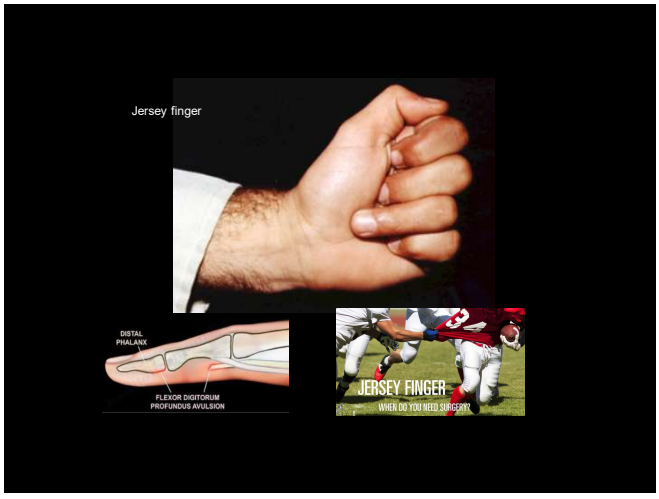
Meticolous surgical technique
Atraumatic tendon handling
Avoid ragged ends
Venting or release selected pulleys
Strong suture techniques
Decrese gap formation 10% shortening in the sutured segment.
Allow early active motion

ZONE 1 Classification



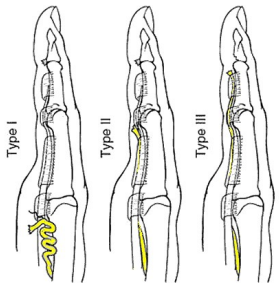


Moiemens and Elliot 2000



Classification of closed ruptures of FDP

Laddy JP, Packer JW JHS Am



TYPE 1 **TYPE 2** **TYPE 3**

MP – PALM IPP BONY

TYPE 1

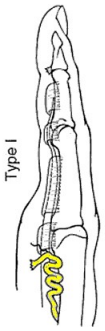
Complete devasclularization

EARLY SURGICAL REPAIR

within 7 to 10 days

ACUTE TENORRAPHY – reinsertion

DIP - FUSION



TYPE 2

Long vinculum is intact

Sometimes small bone avulsion

Sub-acute repair is possible

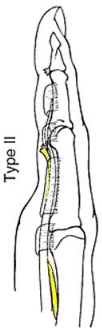
Attempt to repair within several weeks

Treatment

TENORRPHY – Reinsertion

or DIP FUSION

IF LATE PRESENTATION ….. MAYBE MUSCLE LENGHTHENING – Le Viet



TYPE 3

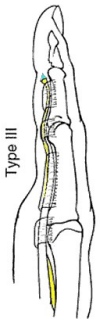
Large bone avulsion

Both vincula are intact

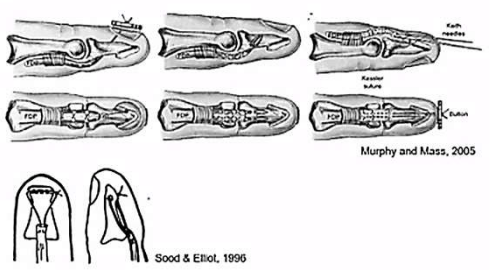
Treatment

ORIF

RE-INSERTION



FDP reinsertion in Zone 1a



ELSEVIER

JPRAS

REVIEW

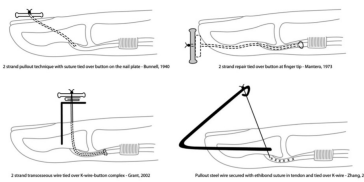
Zone 1 flexor tendon injuries: A review of the current treatment options for acute injuries

Journal of Plastic, Reconstructive & Aesthetic Surgery (2013) 66, 1023–1031

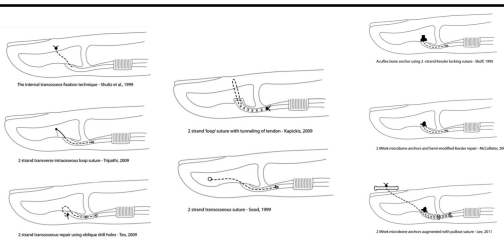
S. Huq*, S. George, D.E. Boyce

Welsh Centre for Burns and Plastic Surgery, Morriston Hospital, Hoel Maes Eglwys, Morriston, Swansea, Wales SA6 6NL, United Kingdom

Received 28 January 2013; accepted 6 April 2013



External fixation techniques.



Internal fixation techniques: suture only repairs.

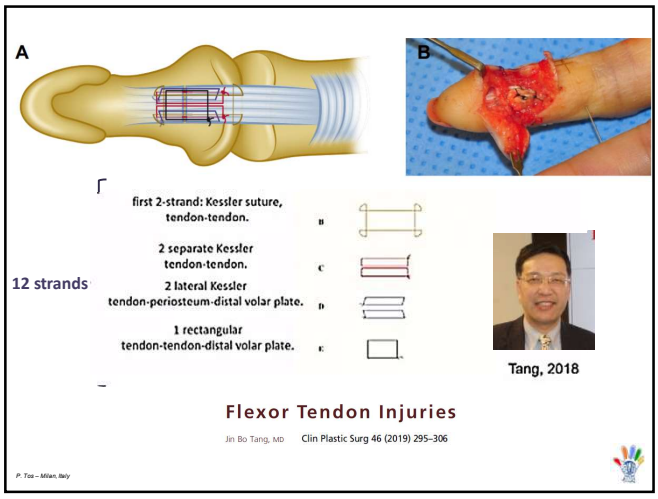
Internal fixation techniques: anchor

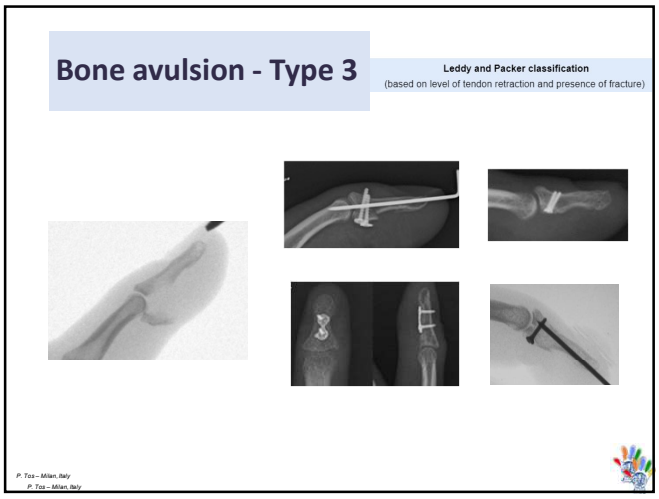
repair method for each patient. No one technique has emerged to be superior to others. This is in part due to the lack of standardized outcome data for the repair types which has been highlighted by this review. Furthermore, the patient should be made aware from the outset that no one technique has been shown to consistently produce good or excellent outcomes.

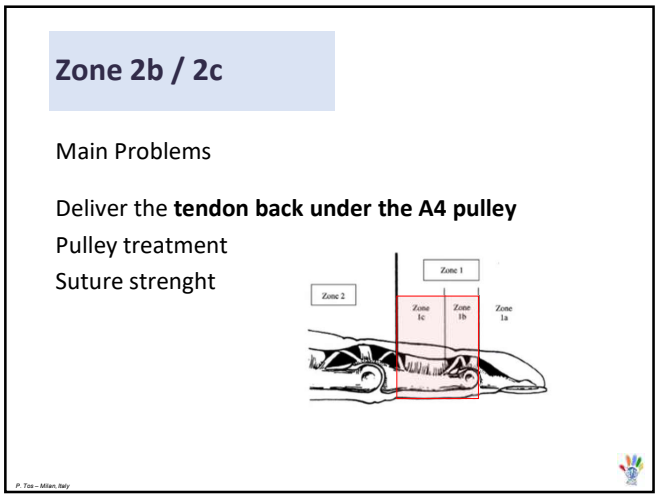
All techniques **similar results**

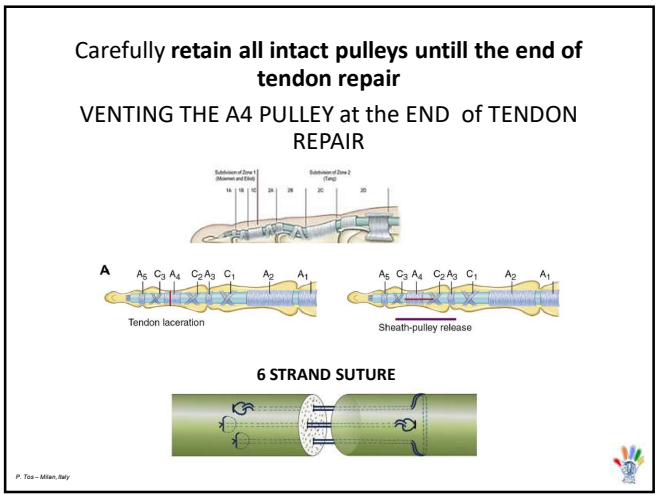
Any gives good results

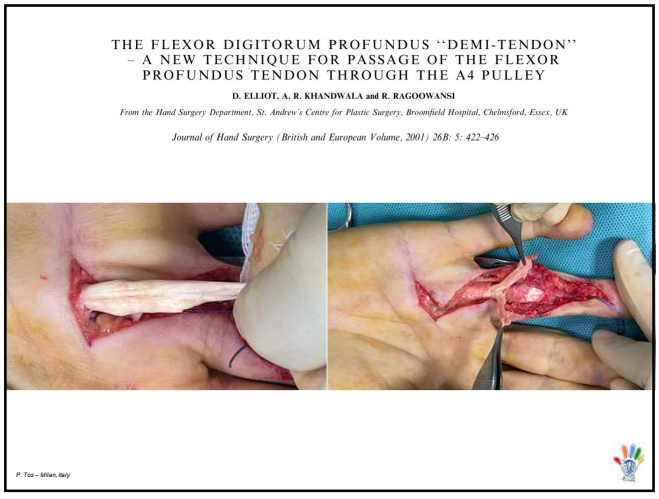
Bone anchor has a critical direction of insertion for good results

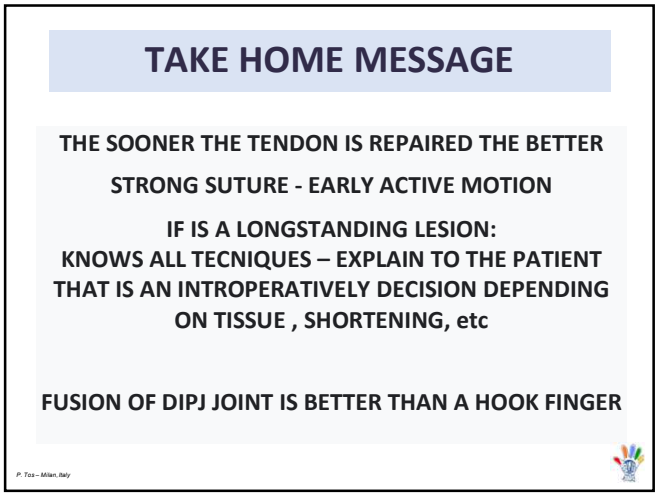

A
B
12 strands
first 2-strand: Kessler suture, tendon-tendon.
2 separate Kessler tendon-tendon.
2 lateral Kessler tendon-periosteum-distal volar plate.
1 rectangular tendon-tendon-distal volar plate.
Tang, 2018
Flexor Tendon Injuries
Jin Bo Tang, MD
Clin Plastic Surg 46 (2019) 295–306
P. Tos – Milan, Italy


Bone avulsion - Type 3
Leddy and Packer classification
(based on level of tendon retraction and presence of fracture)
P. Tos – Milan, Italy
P. Tos – Milan, Italy


Zone 2b / 2c
Main Problems
Deliver the tendon back under the A4 pulley
Pulley treatment
Suture strenght
Zone 1
Zone 2
Zone 1c
Zone 1b
Zone 1a
P. Tos – Milan, Italy


Carefully retain all intact pulleys untill the end of tendon repair
VENTING THE A4 PULLEY at the END of TENDON REPAIR
A
Tendon laceration
Sheath-pulley release
6 STRAND SUTURE
P. Tos – Milan, Italy


THE FLEXOR DIGITORUM PROFUNDUS ''DEMI-TENDON'' – A NEW TECHNIQUE FOR PASSAGE OF THE FLEXOR PROFUNDUS TENDON THROUGH THE A4 PULLEY
D. ELLIOT, A. R. KHANDWALA and R. RAGOOWANSI
From the Hand Surgery Department, St. Andrew's Centre for Plastic Surgery, Broomfield Hospital, Chelmsford, Essex, UK
Journal of Hand Surgery (British and European Volume, 2001) 26B: 5: 422-426
P. Tos – Milan, Italy


TAKE HOME MESSAGE
THE SOONER THE TENDON IS REPAIRED THE BETTER
STRONG SUTURE - EARLY ACTIVE MOTION
IF IS A LONGSTANDING LESION:
KNOWS ALL TECNIQUES – EXPLAIN TO THE PATIENT
THAT IS AN INTROPERATIVELY DECISION DEPENDING ON TISSUE , SHORTENING, etc
FUSION OF DIPJ JOINT IS BETTER THAN A HOOK FINGER
P. Tos – Milan, Italy

Thanks

PROF. DR. J. HENK COERT

DR. TON A.R. SCHREUDERS

DR. JOOST W. COLARIS

DR. NIELS SCHEP

DR. PETER HOOGVLIET

DR. WILLEM D. RINKEL

BIG HAND EVENT 2023

Friday, 22 September 2023

Dr Pierluigi **Tos**
Dr.ssa Matilde **Cacianti**
Dr. Vittorio **Cefalo**
Dr. Alessandro **Crosio**
Dr. Sergio **De Santis**
Dr. Mauro **Magnani**
Dr.Francesco **Locatelli**
Dr.ssa Letizia **Marenghi**
Dr.ssa Simona **Odella**
Dr.ssa Maria Grazia **Zecca**
Dr.ssa Fabiana **Zura Puntaroni**

Pierluigi Tos

Hand Surgery and Reconstructive Microsurgery Unit

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Centro Specialistico Ortopedico Traumatologico
Gaetano Pini-CTO

Sistema Socio Sanitario
Regione Lombardia
ASST Gaetano Pini