Anatomy of Landsmeer Ligaments—Redefined

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Abstract

Introduction Landsmeer ligaments play a significant role in synchronizing the movements of the two distal phalanges of the fingers. However, there is considerable controversy in descriptions of its anatomy, function, presence, and clinical applications.
Aim To ascertain and redefine the detailed anatomy of Oblique Retinacular (ORL) and Transverse Retinacular ligaments (TRL) and their applied features.
Materials and Methods Anatomical dissection study was conducted in 100 cadaveric fingers in 42 cadavers (28 fresh specimens and remaining preserved specimens) under loupe magnification. The whole dorsal digital expansion with attached fibrous flexor sheath was dissected and specimen was examined after thorough saline wash. The dimensions, course, attachment, and configuration were noted in each specimen. The statistical mean was obtained for thickness of the ligaments. The measurements were made using a caliper at the level of the mid proximal phalanx, volar to the proximal interphalangeal (PIP) joint, and dorsal to the distal interphalangeal (DIP) joint.
Results By anatomical dissection we have found the following:

- The ORL was deep to the TRL.
- The ORL had got a check rein effect at the PIP joint, in such a way that extension of the PIP joint causes extension of the DIP joint.
- The ORL criss-crossed volar to the A3 pulley of fibrous flexor sheath and formed a good hammock for the PIP joint. This criss-crossing anatomical feature was found in all dissected fingers as an additional normal anatomical feature complementing the classical description of Landsmeer.
- Variations in configuration of the Landsmeer ligaments were observed among various fingers.
- The Landsmeer ligament was never absent as reported by several studies.

Conclusion Contrary to several studies, the ORL was omnipresent in all dissected fingers with considerable variations in dimensions. Complementing the classical description of Landsmeer, we found that there was an additional normal criss-cross anatomical feature of the ORL in all fingers volar to A3 pulley and deep to the TRL. Also, the TRL was present in all the fingers.

Keywords
- ► redefinition of Landsmeer ligament anatomy
- ► oblique retinacular ligament
- ► transverse retinacular ligament
- ► pleomorphism of the Landsmeer ligament
- ► criss-cross hammock of the oblique retinacular ligament

Introduction

In the beginning of 18thcentury, for the first time, Prof. Weitbrecht[1,2] from The University of St. Petersburg, Russia, described the oblique retinacular ligament (ORL). In 1949, Landsmeer[3] described the ORL and the transverse retinacular ligament (TRL) in detail. His seminal work on these ligaments paved the way for the better understanding of the

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pathogenesis of various clinical conditions like swan neck deformities of the fingers. Nevertheless, there is considerable controversy that shrouds the anatomy, function, presence, and applied features of these ligaments.

In the classical description by Landsmeer,[3] the ORL arises from the A2 pulley and runs obliquely volar to transverse axis of the PIP joint before inserting to the lateral aspect of the terminal tendon of the dorsal digital expansion dorsal to the DIP joint. The TRL is described by Landsmeer[3] as a band of fascia between the lateral tendons of the dorsal digital expansion and running volar to the proximal interphalangeal joint, the A3 pulley, and the ORL.

Aim of the Study

To define the anatomy in detail of the ORL and the TRL in terms of dimensions, configuration, course, attachments, and function by anatomical dissection. The study also aimed to elicit the applied anatomical features of these structures.

Materials and Methods

This anatomical dissection study was conducted in 100 cadaveric fingers in 42 cadavers from 2014 to 2016. Twenty-eight fresh specimens and 14 preserved specimens were dissected. Twenty-two male cadavers and 20 female cadavers were dissected. Twenty-five numbers of each digits (F2: n = 25, F3: n = 25, F4: n = 25, and F5: n = 25) were examined. Dissection was performed under loupe magnification of 4X. Institutional ethical committee approval was obtained for the study. Injured hand specimens and specimens with congenital hand differences were excluded.

Dissection Procedure

A single long dorsal incision was placed from the base of the distal phalanx to the head of the metacarpal bone. After the skin was dissected at subdermal level, the subcutaneous fat was filleted out. The ORLs and the TRLs were defined by the dissection with tenotomy scissors. The whole dorsal digital expansion with attached fibrous flexor sheath was dissected and specimens were examined after thorough saline wash under 4X magnification. The dimension, course, attachment, and configuration were noted in each specimen. The thickness of the ORL was measured using the calliper at the level of the mid proximal phalanx, volar to the PIP joint and dorsal to the distal interphalangeal (DIP) joint. Statistical mean was obtained for these data.

Gentian Colloid Staining

- The thick gentian colloid gel was injected between the TRL and criss-cross portion of the ORL, and also between the A3 pulley and criss-cross portion of the ORL (►**Fig. 1**).
- The fingers were dissected after freezing for 24 hours.

Results of the Study

By anatomical dissection we have found out the following:

- The ORL was deep to the TRL at the volar aspect of the PIP joint and the A3 pulley.

Fig. 1 Showing Landsmeer ligaments in left index finger.

Fig. 2 Dissection of Landsmeer ligaments in middle finger.

- The radial side of the ORL was longer than the ulnar side in all the specimens (►**Fig. 2**).
- The ORL had a checkrein effect at the PIP joint, in such a way that extension of the PIP joint caused extension of the DIP joint.

Our Significant Additionally Elicited Anatomical Feature of the ORL

The ORL criss-crossed volar to the A3 pulley of fibrous flexor sheath and formed a hammock for the PIP joint (►**Fig. 3**).

Structure of the ORL as Elicited by Our Anatomical Dissection

The ORL was present on both sides in all the fingers that were dissected (►**Table 1**). But there existed considerable dimensional variations. There was no morphological pleomorphism in the criss-cross configuration of the ORL. In all the fingers the criss-cross hammock, a digital fascial derivative, and an additional anatomical feature elicited by the lead author was present volar to the A3 pulley and dorsal to the TRL (►**Figs. 4–6**). The TRL was another structure present in all the fingers dissected. The average TRL thickness in each finger is given in ►**Table 2**. Though the thickness of the TRL decreases from the radial to ulnar aspect, it is present in all the fingers and it adds additional mechanical hammock to the criss-cross portion of the ORL. It steadies the portion of the dorsal digital expansion over the dorsum of the PIP joint.

In our dissection under magnification, there was a distinct loose areolar tissue plane that separated the criss-cross portion of the ORL from the TRL and also a similar kind of plane existed between the A3 pulley and criss-cross portion of the ORL (►**Videos 1** and **2**).

Fig. 3 Dissection of Landsmeer ligaments in progress of left index finger.

Course and Distribution of ORL

The ORL, with average of 1.7 mm dimension, began on either sides of the A2 pulley and then it was traced toward volar aspect of the proximal interphalangeal joint (with average dimension of 4.2 mm), where it distinctly criss-crossed dorsal to the transverse retinacular ligament and

Video 1

Showing criss-cross hammock portion of ORL in the index finger. Online content including video sequences viewable at: www.thieme-connect.com/products/ejournals/html/10.1055/s-0039-1695802.

Video 2

Showing criss-cross hammock in the middle finger. Online content including video sequences viewable at: www.thieme-connect.com/products/ejournals/html/10.1055/s-0039-1695802.

Fig. 4 Dissection of Landsmeer ligaments in left ring finger.

Table 1 Average dimensions of oblique retinacular ligament

S. no.	Level	Finger 2	Finger 3	Finger 4	Finger 5
1.	Proximal phalanx	2.8 mm	1.5 mm	1.35 mm	1.25 mm
2.	Volar to proximal interphalangeal joint (dimension of criss-cross hammock)	6 mm	4.2 mm	3.5 mm	3 mm
3.	Dorsal to distal interphalangeal joint	2.0 mm	1.9 mm	1.75 mm	1.70 mm

Fig. 5 Dissection of Landsmeer ligaments in middle finger.

Fig. 6 Dissection of Landsmeer ligaments in little finger.

Table 2 Average transverse retinacular ligamentdimension

Finger at pip joint level	F2	F3	F4	F5
TRL thickness in mm	4.5	4.5	3.75	2.5

Fig. 7 Showing the schematic layout diagram of oblique retinacular ligament and its parts.

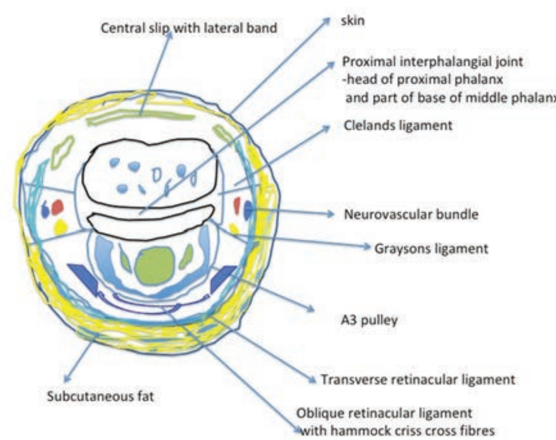

Fig. 8 Showing schematic layout diagram of the oblique retinacular ligament at the PIP joint level.

volar to the A3 pulley in a broad manner (►**Figs. 3**, **7**, and **8**). The proximal radial fibers of the ulnar ORL reached the ulnar distal side of the radial ORL and vice versa with the ulnar proximal fibers of the radial ORL. Then distally, the ORL embracing on either sides of the A4 pulley joined the sides of distal terminal tendon at or just distal to distal interphalangeal joint on the dorsal aspect (with average dimension of 1.8 mm).

Course and Distribution of TRL

The TRL existed as a transverse band of an average thickness (with average thickness of 3.8 mm) volar to the ORL criss-cross segment and A3 pulley, extending from one lateral band of dorsal digital expansion to the other (**Table 2**). This was also found in all dissected fingers.

Discussion

Ever since Prof. Weitbrecht of Russia,[1,2] in the beginning of 18th century,[1] described the ORL, incertitude shrouded the anatomy of oblique and transverse retinacular ligaments. In 1949, Landsmeer[3] published his landmark article that vividly described the TRL and the ORL. In addition, that authors' anatomical study unraveled the criss-cross critical biomechanic anatomy of the ORL. It was described as a check rein ligament which brings about passive extension of the DIP joint on extension of the PIP joint. The authors' description of criss-cross anatomy of the ORL reinforces this biomechanic function of the ORL.

The seminal work of Landsmeer pointed out that hand is a polyarticular ossicular chain with joints in serial arrangement.[3] For a stable and integrated, co-ordinated movement, there is need of a third diagonal element supporting the flexion and extension at each hinge joint in the ulnar four rays of the hand. These structures contribute to prevent Z collapse of the joint during the action of the extrinsic tendons. For the metacarpophalangeal joint the diagonal system comes in the form of lumbricals. In PIP and DIP joints the ORL and TRL formed the third diagonal system that is responsible for the tenodesis effect and stability. This true diagonal system comes in the form of our additional anatomical structure elicited in our study. Though these ligaments were small, their omnipresence as pointed out by author's study provides stability and integration of movement with other periarticuar structures like a "lamination effect."

The criss-crossing biomechanical anatomy of the ORL, first brought into light by the lead author's study is an addition to the classical description of Landsmeer.[3] Subsequently, in studies by Shrewsbury et al,[4,5] Thompson et al,[6] and Tubiana et al,[7] who made dedicated efforts on the anatomy of ORL there was no mention of this distinct anatomical picture.

Shrewsberry et al[4,5] noted that in 3 of 16 hand specimens studied, the ORL was absent in all fingers, except the ulnar aspect of the ring finger. Despite smaller dimension on the ulnar side, the ORL was found in all 100 cadaveric fingers dissected in author's study.

Applied features: The applied feature of our additional anatomical findings are as follows:

- These dynamic check rein ligaments which are omnipresent according to our anatomical study, with considerable dimensional variations, suggest that it has got a definite role in dynamic tenodesis effect[2,6-8] as suggested by Landsmeer—"Extension of the PIP joint causes extension of the DIP joint." The criss-cross portion of the ORL balances the tenodesis effect on radial and ulnar side of the ray and also effectively integrates the intrinsic and extrinsic actions.
- Littler's ORL reconstruction surgery for the treatment of Swan neck deformity following Mallet finger injury is the perfect anatomical reconstruction of ORL.[6] One lateral band is cut and brought obliquely across the PIP joint on volar aspect to reconstruct the ORL, exactly reconstituting the missing criss-cross anatomy mentioned by the lead author in this study. In Thompson ORL reconstruction using the palmaris longus tendon graft a nonanatomical reconstruction of ORL is performed to treat the swan neck deformity.[6] All these are standing evidence supporting and reinforcing the anatomical morphology of ORL (especially the criss-cross hammock portion of ORL) elicited by the lead author's study. In Fowler's release operation to balance the dorsal digital expansion in swan neck deformity, central slip tenotomy is done. So after the tenotomy residual ORL takes care of extension of DIP joint by its tenodesis effect in non-Mallet fingers.
- The dorsal digital expansion is the expanded terminal portion of the extensor tendons. Author now considers its anatomy in three portions: (1) central slip and its lateral extension, (2) lateral band with intrinsic insertions and its oblique extensions, and (c) the diagonal tenodesis system—the ORL and TRL. The third dimension added to the anatomy of dorsal digital expansion brings a new perspective in better understanding of the kinesiology of the serial joints of the hand. The TRL steadies the position of the lateral band over the dorsolateral aspect of PIP joint. The terminal tendon with distal end of ORL does the extension of DIP joint. In the central slip injury leading on to Boutonniers deformity, there is foreshortening of the TRL and ORL. This is confirmed by Boutonniers test,[9] which stands as the evidence for anatomical description of ORL criss-cross anatomy described by the lead author. As a part of Boutonnieres deformity correction the contracted elements (the assembly lines formation) have to be released on the volar aspect of PIP joint. In Fowlers release operation for the treatment of Boutonnieres deformity, tenotomy is done on the middle of the middle phalanx to rebalance the dorsal digital expansion. After the tenotomy release, the extension of the PIP joint occurs with extension of the DIP joint, executed by the ORL by tenodesis effect.[10] Engelhardt et al[11] in their study described about the ORL as the derivative of digital fascia and confirmed the functional aspect of the ORL. Their dissection study doesn't reveal any criss-cross hammock portion, which is also functionally important in steadying of the distal phalanx at the distal interphalangeal joint during the axial loading across the joint. Stack et al[12] in their work again defined the functional contribution of the ORL in the cadaveric studies. ORL was described to provide the tenodesis effect across the DIP joint. Our additional anatomical revelation of the ORL reinforces its functional significance.
- The decreasing dimensions of the Landsmeer ligaments from radial to ulnar side in our study, must be related to the Littler's functional unit of hand, wherein the stable units have more stubborn supportive ligaments than the mobile units and also related to overall phalangeal dimensions in each finger.
- Our next study proposed is to dissect and demonstrate this anatomy in pathological scenario of Swan neck deformity to confirm the hypothesis that, "[t]he ORL is indeed an indispensible digital fascia derived anatomical

structure, preventing the hyper extension of the PIP joint."

- The various operative procedures for swan neck and Boutonniere deformity belong to the era of hand surgery that followed soon after Landsmeer. Our additional anatomical elicitation helps in the better understanding of those procedures.

Strengths and Limitations of the Study

The strengths of the study are the elucidation of additional normal anatomical criss-cross hammock supportive feature of the ORL and its omnipresence. But the limitation of this anatomical study is that it was conducted only in 42 cadavers (examining only 100 fingers). The author's group intends to continue this study. Nevertheless this omnipresent additional anatomical feature of the ORL found by the author in all 100 examined fingers is a significant finding by the statistical analysis also (p = 0.045).

Conclusion

- The finding of omnipresent ORL in our study among 100 cadaveric fingers has raised the controversy regarding the absence of ORL in 20% of cases. A large-scale study needs to be conducted for an evidence-based establishment of our findings.
- The classical description of Landsmeer says "ORL, on flexion of the PIP joint, luxates volar to the axis and on extension, displaces dorsally." There was no mention about the criss-cross anatomy that exists, volar to A3 pulley and deep to TRL. So our study is the first anatomical study to throw light on this distinct additional anatomical picture.
- And finally, TRL is present in all fingers.

Conflict of Interest
None.

Disclosure
The authors have no financial interest to declare in relation to the content of this article. No external funding was received.

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