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Review

"Unraveling the mysteries of the oblique retinacular ligament: A review of its anatomy and biomechanical characteristics"

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A R T I C L E I N F O

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A B S T R A C T

Introduction: The oblique retinacular ligament (ORL) has fascinated researchers since its first detailed description by Landsmeer in 1949. Integral to the sophisticated mechanics of finger movements, its anatomical presence and function have sparked extensive debate. Despite initial doubts about its existence, it is now recognized as a crucial structure within the hand's biomechanical system.
Materials and methods: A review was conducted to collate primary studies on the ORL, focusing on cadaveric anatomy and biomechanical analyses. Modern dissection techniques and equipment have facilitated the identification of the ORL in virtually all examined samples, moving past earlier challenges of isolating such minute structures.
Results: Research elucidates the ORL's dynamic role in coordinating movements between the proximal and distal interphalangeal joints, contradicting earlier theories that deemed it a mere static stabilizer. Recent findings, especially those by Balakrishnan et al., highlight a complex cross structure that allows the ORL to maintain its functional relevance across various joint positions. This challenges previous notions and underscores its significance in finger extension mechanisms.
Conclusion: The journey to understand the ORL underscores its pivotal role in hand biomechanics, transforming from a structure of ambiguous existence to a key element in finger movement coordination. This shift in understanding opens new possibilities for therapeutic approaches to hand deformities, emphasizing the ORL's critical function in both anatomical and clinical contexts. As research progresses, it continues to reveal the ORL's complex contributions to hand dynamics, offering insights that promise to enhance outcomes in hand surgery and rehabilitation.

1. Introduction

In the orchestra of human movement, the fingers of the hand perform a symphony of astonishing complexity, orchestrated by a biomechanical engineering of precision. Each gesture, from the most delicate to those requiring strength, depends on an intricate balance between flexion and extension, making possible the wide range of actions we take for granted every day [1–9]. At the heart of this complex network of movements are mechanisms that, although they may appear simple on the surface, hide a deep complexity beneath their skin. Among these, the finger extension mechanism warrants particular attention for its refined complexity. Scholars have spent decades examining its components, focusing specifically on the dorsal aponeurosis, one of the most fascinating structures in terms of anatomy and function. Located along the back of the proximal interphalangeal joint, the aponeurosis forms a network of connections between the extensor tendon and the tendons of the interosseous muscles, originating three tendinous bands essential for finger movement [10–12]. Beyond the tendons, the dorsal aponeurosis includes crucial ligaments such as the triangular ligament and the oblique and transverse retinacular ligaments, each playing a specific role in the delicate balance of the joints. This complex interconnection not only ensures fluidity and coordination of movements but also raises questions about the specific function of each structure, especially regarding the oblique retinacular ligament (ORL)(Fig. 2), which remains at the center

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of a scientific debate to this day. First described in the 18th century, the ORL has been the subject of thorough studies aimed at clarifying its role in the anatomy and function of the fingers. Despite numerous contributions, the discrepancy between various findings has generated confusion, leaving open questions about the exact nature and importance of the ORL [1,8,13]. This narrative review aims to synthesize the most recent research [14–20], offering an updated perspective on the anatomy and biomechanical function of the ORL, in an attempt to unveil the mysteries still surrounding this fundamental component of finger movement.

2. Materials and Methods

This review was conducted through a systematic literature search focusing on primary studies concerning the cadaveric anatomy of the Oblique Retinacular Ligament (ORL) and its biomechanical function analyzed either on cadaveric samples or through theoretical models. We excluded all articles lacking information about the study's research methodology, case reports, and analyses of the ORL's anatomy conducted via ultrasound, MRI, or other instrumental methods. Studies using MRI and other instrumental methods were excluded due to their limitations in clearly visualizing the small and complex Oblique Retinacular Ligament (ORL). These methods often lack the necessary resolution to accurately detail the ORL's anatomy, leading to a preference for cadaveric dissection and specialized imaging for precise understanding. To capture all available information, several search engines were queried including PubMed, Cochrane, and Scopus alongside the bibliography of the selected studies. Given the specificity of the subject matter, search engines were queried using highly sensitive search strings to identify all relevant studies.

2.1. Study selection

The search string included the Entry Terms: "Oblique Retinacular Ligament" OR "Landsmeer Ligament" OR "finger extensor mechanism" AND "cadaveric study" OR "Biomechanics of ORL" OR "function of oblique retinacular ligament" AND "surgical implications" OR "Dorsal aponeurosis" AND "finger joint coordination". This search strategy yielded 436 articles, of which 417 were excluded after reviewing abstracts and full texts for not specifically analyzing the oblique retinacular ligament. Thus, 16 articles were selected for inclusion in this review. The databases were searched through up to December 23, 2023, to ensure the inclusion of the most recent and relevant studies on the Oblique Retinacular Ligament (Table 1). The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines were followed in conducting this review (Fig. 1).

The selection involved a systematic approach to selecting studies for a scoping review. Initially, search results were collected and refined using ZOTERO with duplicates removed. The screening involved two levels: title and abstract review followed by full-text assessment, both conducted independently by two authors, with discrepancies resolved by a third. This rigorous methodology aimed to identify relevant articles that directly address the research question, maintaining a comprehensive and systematic approach in the review process.

Inclusion and exclusion criteria were established as follows: Primary studies focusing on the cadaveric anatomy of the Oblique Retinacular Ligament (ORL), and research analyzing the biomechanical function of the ORL on cadaveric samples or through theoretical models were included. Articles without detailed information about the study's research methodology, case reports, and studies analyzing the ORL anatomy using ultrasound, MRI, or other instrumental methods not suited for detailed visualization of the ligament's structure and function were excluded.

Table 1
Summary of research on the spiral oblique retinacular ligament (SORL) in finger function and treatment.

Author/Year	Study Purpose	Materials and Methods	Results
Landsmeer, 1949	Anatomy/ Function	Anatomical analysis with cadaver dissection. No description of dissection methodologies or analyzed samples provided. Empirical description of the ORL function based on anatomical findings	First detailed description of the ORL course (lateral sup IFP - terminal tendon) and its tenodesis function.
Haines, 1951	Function	Does not describe how the functional role of ORL was evaluated	Tenodesis function of the ORL associated with the action of the lateral bands of the dorsal aponeurosis
Landsmeer, 1963	Function	Does not describe how the functional role of ORL was evaluated	Tenodesic and coordinative role in the extension of the interphalangeal joints
Littler, 1967	Function	Does not describe how the functional role of ORL was evaluated	Analysis of the ORL course and deduction that it has no tenodesic effect as the ligament is volar to the PIP joint only when it is flexed
Harris & Rutledge, 1972	Function	Cadaver dissection	ORL has no functional role, but solely serves for support and centralization of the lateral bands
Shrewsbury, 1977	Anatomy/ Function	Cadaver dissection	ORL is not always present as a fully formed anatomical structure (40–50 %). When complete, it consists of a proximal longitudinal cord and distal oblique fibers. Functionally, the ligament is not in a state of tension during finger extension, but only when the DIP is flexed
Thompson, 1978	Treatment	10 patients with swan-neck deformity operated with SORL reconstruction	Surgery corrects the deformity. 1 patient required orthosis to achieve complete PIP extension. 1 patient developed DIP hyperextension, regressed with graft lengthening
Shrewsbury, 1980	Function	22 cadaver fingers analyzed to evaluate tenoligamentous structures responsible for passive and active range of motion of the DIP	ORL sectioning does not alter active and passive DIP movement during extension
Kleinman, 1984	Treatment	12 patients with chronic mallet finger operated with ORL reconstruction	Deformity corrected in all cases. 1 patient developed adhesions to the deep flexor tendon, 1 patient developed a 35° flexion contracture of

(continued on next page)

Table 1 (*continued*)

Author/Year	Study Purpose	Materials and Methods	Results
			the corrected PIP, corrected with surgery
Bendz, 1985	Function	Study with EMG and goniometric analysis of motor muscle activation of PIP and DIP joints	Correlation exists between electromyographic activation of lumbrical and flexor/ extensor muscles and onset of PIP and DIP movement, suggesting ORL has no role in coordinating movement between these joints
El-Gammal, 1993	Anatomy	20 index fingers sampled to evaluate presence, structure, and relationship with PIP rotation axis, with consequent functional analysis	ORL present in 90–95 % of cases. Its relationship with PIP rotation axis depends on joint position. Ligament is volar to rotation axis only when PIP is flexed. Ligament is slack when both interphalangeal joints are flexed, while it is tense when PIP is extended and DIP is flexed
Ueba, 2011	Function	Evaluate ORL contribution to DIP extension at various angles of PIP and MCP (assessed based on force required to passively flex DIP). Study on 40 fingers in normal and laboratory conditions	Force required to flex DIP is minimal when PIP is at 90° flexion, and maximal at 30°. ORL resection reduces force required to flex DIP. ORL contributes 31 % of force required to flex DIP when PIP is at 30°
Leijnse, 2012	Function with mathematical model	Construction of a mathematical model to understand ORL behavior in relation to IP joint movement	ORL is only an auxiliary structure not necessary for coupling IP joint movement
El-Sallakh, 2012	Treatment	14 patients with chronic boutonniere treated with preoperative physiotherapy and PIP extension and DIP flexion exercises to increase ORL extensibility	11 out of 12 patients (2 lost to follow-up) had excellent results, while 1 had poor results because the patient did not follow the postoperative protocol
Deml, 2019	Treatment	Comparison of Fowler's central band tenotomy and SORL technique in treating chronic mallet finger on cadaver sample	No significant differences between techniques, but in case of concomitant hyperextension deformity, SORL technique is advisable
Balakrishnan, 2019	Anatomy	100 cadaver fingers dissected for analysis	ORL presents a hammock-like volar structure at the middle phalanx with a bridle system that coordinates movements of the two IPs

Overview of studies investigating the role and treatment of the Spiral Oblique Retinacular Ligament (SORL) in finger anatomy and function.

2.2. Data extraction and data synthesis

Data extraction for the scoping review was done using a form based on the JBI tool, capturing crucial details like authorship, publication country and year, study design, patient characteristics, outcomes, interventions, procedures, and other relevant data. Descriptive analyses of this data were conducted with results presented numerically to show study distribution. The review process was clearly mapped for transparency, and data were summarized in tables for easy comparison and understanding of the studies' key aspects and findings.

3. Results

Fig. 1 Preferred reporting items for systematic reviews and meta-analyses 2020 (PRISMA) flow-diagram.

3.1. Anatomy of the oblique retinacular ligament

Over the years, various authors have provided their anatomical descriptions of the oblique retinacular ligament (ORL). Chronologically, the first to offer a sufficiently accurate description was Landsmeer in 1949 [13], in his study: "The anatomy of the dorsal aponeurosis of the human finger and its functional significance." Anatomically, Landsmeer describes a retinacular structure on both the ulnar and radial sides of the fingers, not part of the lateral bands of the dorsal aponeurosis, dividing it into two parts following the course of its fibers: the transverse retinacular ligament, which has a course more perpendicular to the long axis of the phalanges, and the oblique retinacular ligament. The fibers of the ORL originate proximally from the latero-volar surface of the proximal phalanx and in the pulleys of the flexor tendons, run laterally to the PIP and beneath the transverse retinacular ligament along the middle phalanx, where they progressively become more dorsal until their distal insertion on the terminal tendon of the dorsal aponeurosis. In 1977, Shrewsbury [21] provided a more accurate description of the ORL, identifying two morphologically distinct portions of the ligament: a proximal longitudinal cord and a distal oblique band. Both portions of the ligament are continuous with the capsule of the Proximal Interphalangeal Joint (PIP) joint but remain separated from the transverse retinacular ligament. The fibers forming the longitudinal cord originate from the ulnar and radial lateral crests of the proximal phalanx and the proximal annular and cruciform pulleys at the PIP; on average, the width of the cord is 2 mm, and its length is 7 mm. The longitudinal cord continues with the oblique band, which also originates from the capsule of the PIP joint and projects obliquely along the middle phalanx, inserting on the lateral band and the terminal tendon, not before reaching the base of the distal phalanx; the average length of this band is 8 mm. In total, the ORL has an average length of 15 mm.

Shrewsbury describes the existence of incomplete forms of the ligament, attributable to thin osteocapsular thickenings, or the possibility that the ligament may be entirely absent from one or both sides of a finger. According to his study on 64 fingers from 16 cadavers, the complete structure of the ORL is present in only 40–50 % of cases for both sides of the fingers, except for the ulnar side of the ring finger, where the ligament seems to be present in 93 % of cases.

In 1993, El-Gammal [22] published a study on the anatomy of the oblique retinacular ligament of the index finger. According to the author, the ORL originates from the periosteum of the middle third of the proximal phalanx, or the A2 pulley, or both; at the level of the Proximal Interphalangeal Joint (PIP), the ligament passes under the transverse retinacular ligament, between the latter and Cleland's ligaments; about 6 mm after crossing the joint line, it fans out before attaching to the lateral bands and the terminal tendon of the extensor apparatus. In general, the radial ORL is on average slightly longer than the ulnar ORL, measuring 18 mm and 16 mm, respectively; its average width is 5 mm. Although the data about the anatomical characteristics seem to be quite overlapping with what is reported by Shrewsbury [21],

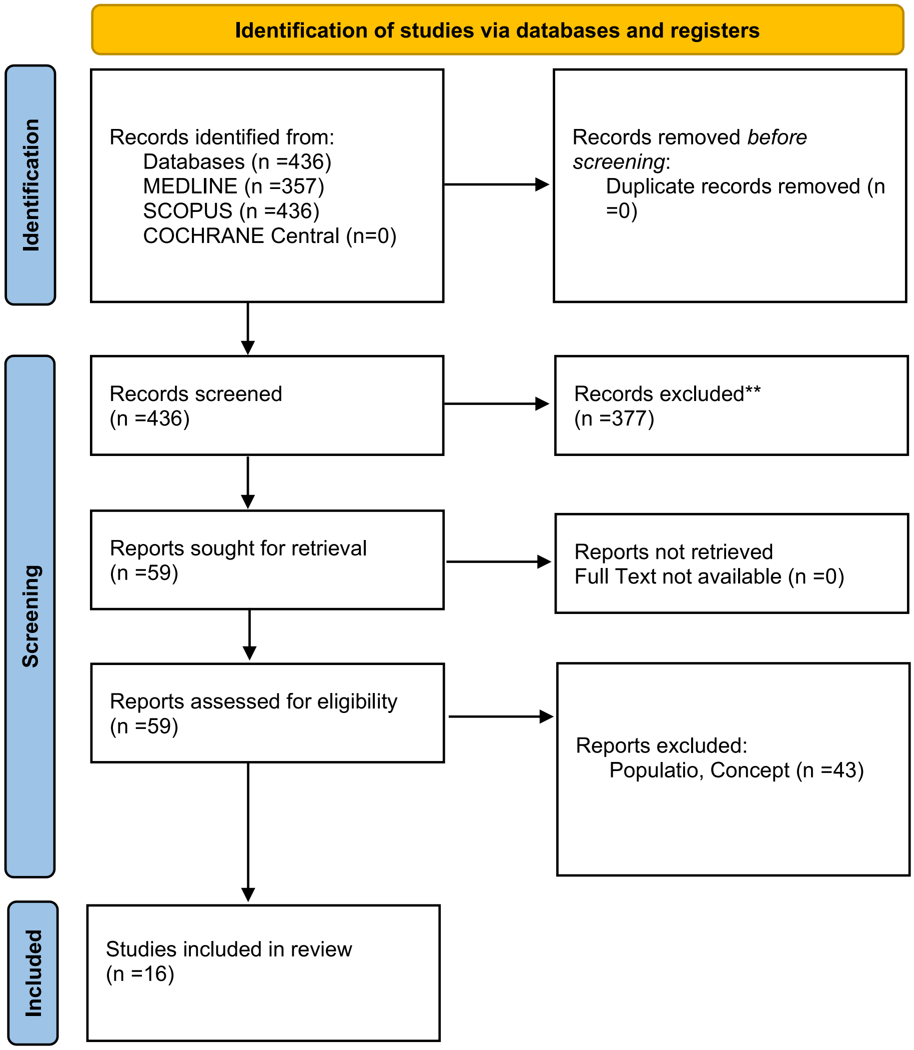

Fig. 1. Anatomical illustration.

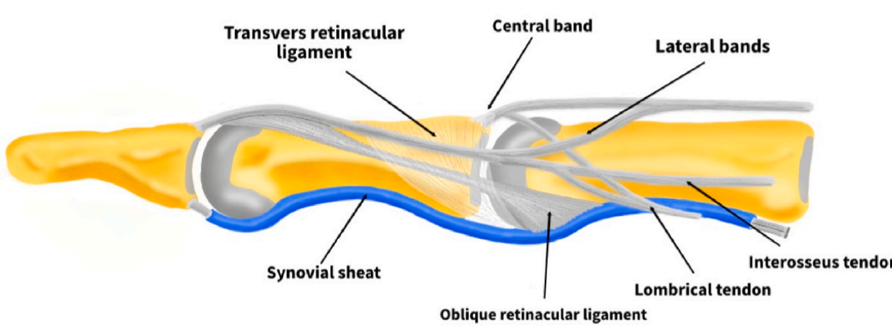

Fig. 2. Anatomical illustration.

there is a stark contrast regarding the frequency with which the ORL is detectable in the fingers since, from the 20 fingers taken from cadavers, the author found that the oblique retinacular ligament was present in 95 % of the cases on the radial side and in 90 % of the cases on the ulnar side.

The results of El-Gammal [22] seem to be in agreement also with the most recent study by Ueba, both regarding the course and the presence of the ligament. Indeed, the author reports not having identified the ORL only in two cases out of 40 fingers taken from 10 cadavers: one on the ulnar side of the middle finger and another on the ulnar side of the ring finger.

In 2019, the study by Balakrishnan [23] and colleagues redefined the knowledge acquired up to that moment about the structure and anatomical characteristics of the oblique retinacular ligament. Analyzing 100 fingers taken from 42 cadavers, in addition to having identified the ORL on the radial and volar side of every finger and noting that the radial ligament is on average longer than the ulnar ligament, the authors would have found that the ORL presents a volar cross structure at the A3 pulley and dorsal to the transverse retinacular ligament that would unite the ligament on the radial side to that on the ulnar side of the finger, forming a sort of hammock for the proximal interphalangeal joint. Within this cross structure, the proximal fibers of the radial side of the ulnar ORL reach the distal fibers of the ulnar side of the radial ORL and reverse. At its proximal origin from the A2 pulley, according to the authors, the ORL has an average size of 1.7 mm. From there, it moves distally to the volar surface of the PIP, where it develops the cross structure previously described, which has an average size of 4.2 mm. Subsequently, the ligament continues its path towards the terminal tendon of the extensor apparatus, first embracing the A4 pulley, at which level it becomes more dorsal, and inserting dorsally on the tendon at the level of the Distal Interphalangeal Joint (DIP or slightly more distal to it, with an average size of 1.8 mm.

3.2. Function and biomechanics of the oblique retinacular ligament

If the anatomical aspect has revealed several contrasts among the various authors dedicated to the study of the oblique retinacular ligament, the functional and biomechanical aspect is where the debate is most heated. In this case, too, there are several contrasts, the most important of which sees the ORL as a structure capable of coordinating the movement of the PIP and DIP. The first proponent of this thesis was indeed Landsmeer [1,13], who claimed that to extend the DIP, the extension of the PIP was necessary, and that the extension of the PIP would also involve the extension of the DIP. This relationship would be based on the course of the ORL and its biomechanics: the ligament passes volarly to the center of rotation of the PIP and dorsally to that of the DIP, so it is put under tension with the flexion of the DIP when the PIP is extended. The distal sliding of the terminal tendon that occurs with active or passive flexion of the DIP tends to also slide the lateral bands and the entire dorsal aponeurosis distally, reducing the tension at the level of the central band. Having lost the main force that allows to maintain the PIP in extension, the tension developed by the ORL favors the flexion of the PIP, unless it is passively maintained in extension. The system regains its balance around 60–70° of flexion of the PIP, where the central band regains tension and the ORL is relaxed due to the approximation of its insertions. During the extension movement, the opposite mechanism occurs: the action of the common extensor of the fingers slides the dorsal aponeurosis proximally, putting the central band under tension, which consequently brings the PIP into extension. With the extension of the PIP and the DIP still flexed, the oblique retinacular ligament returns under tension, and together with the traction exerted by the lateral bands on the terminal tendon following the proximal sliding of the dorsal aponeurosis, brings the DIP into extension. The dynamic tenodesis action of the ORL described by Landsmeer [1,13,23] is also supported by Haines and the most recent study by Balakrishnan; however, many other authors have strongly criticized it, stating that the ORL would have no role regarding the extension of the DIP. The first to doubt the dynamic tenodesis action of the ORL were Harris and Rutledge [10]. In their study, they proved how the oblique retinacular ligament is put under tension only with a flexion greater than 70° of the DIP with the PIP at 0°, so the action of extension of the DIP that the ORL could perform would be only from 90° to 70°, and for the authors, it is a range too narrow to consider this structure as "fundamental" for the extension of the DIP. Also, analyzing the movement of triple flexion and triple extension of the fingers without resistance, a difference of 70° between PIP and DIP is never recorded, so it is impossible for the ORL to develop tension during the natural movement of the fingers; in flexion, the maximum difference recorded between PIP and DIP is 30° when the metacarpophalangeal joint (MP) is at 40° of flexion, while in extension, the maximum difference between PIP and DIP is 25° when the MP is at 50°. Moreover, on other samples taken from cadavers, the ORL was sectioned to analyze the consequent behavior of the interphalangeal joints. The authors found that the absence of the ORL does not cause any alteration in the extension of the PIP and DIP, while the sectioning of the lateral bands caused an immediate fall in flexion of the DIP of 70°.These same observations on the fact that the ORL does not have a role in the coordinated extension of the interphalangeal joints were also made by Shrewsbury [21] and Bendz [24]. The latter reports how the electromyographic activation of the extrinsic and intrinsic extensors of the fingers activate without any temporal latency when the PIP and DIP begin to extend, asserting therefore that the extension of these two joints is entirely managed by these myotendinous structures and not by ligamentous structures like the ORL. In agreement with Littler's considerations, El-Gammal [22] reports that the error in Landsmeer's theory is in the relationship between the proximal interphalangeal joint and the oblique retinacular ligament. To ensure the dynamic tenodesis function, the ORL should always remain volar to the axis of rotation of the PIP, so as to allow its tensioning when the PIP is extended; in his study, Landsmeer [13] indeed supports this thesis, while Littler and El-Gammal [22] observed that the relationship between the ORL and the PIP depends on the position of the PIP, and that the ORL remains volar to the axis of rotation of the PIP only when the PIP is flexed. The extension of the PIP does not increase the tension on the ORL because the proximal excursion of the lateral bands during the extension movement keeps the ligament slack. Ueba's study [25]further deepened the function of the ORL, analyzing what the contribution of the ligament was in the extension force of the DIP at different positions of the PIP and MP, using tools capable of measuring joint angles and force very accurately. To evaluate this aspect, the force required to passively flex the DIP was measured in conditions of anatomical integrity and in experimental conditions, performing the section of the ORL and the central band. After demonstrating that the position of the MP is not a relevant factor, the author observed how the force required to flex the DIP with the PIP at 90° of flexion was significantly less than when the PIP was positioned at 0°, 30°, and 60° of flexion, and that the position that required more force was the one with the PIP at 30°. In anatomically intact samples, the force required to passively flex the DIP was always greater than in the experimental samples, except when the central band is sectioned and the PIP is positioned at 90° of flexion, where the force required to flex the DIP is much greater than in the condition of anatomical integrity. However, this difference does not seem to be due to the presence of the ORL, but to the fact that the absence of the central band does not allow the distal sliding of the dorsal aponeurosis and the lateral bands during the flexion movement of the PIP; consequently, the lateral bands develop more tension, increasing the force required to passively flex the DIP. Analyzing the differences between the intact samples and the experimental samples, the author determined that the contribution of the ORL to the force required to passively flex the DIP is 25 % when the PIP is at 0°, 31 % at 30°, 18 % at 60°, and 3 % at 90°, so this ligament would seem to increase the resistance to passive flexion of the DIP only when the PIP is extended or slightly flexed.

In 2012, Lejinse [26] proposed a mathematical model to quantify how tendons and ligaments of the extensor apparatus become tense or slack depending on the angulation of the interphalangeal joints. From the results, it emerges how the ORL develops tension only when the PIP is between 0° and a few degrees of flexion, while in hyperextension or at higher degrees of flexion, the ligament becomes slack again, which is why the author thinks that the ORL has exclusively an auxiliary action. Given the findings made in their study about the cross anatomy of the ORL, Balakrishnan [23] and colleagues, after years in which it was thought that the ORL did not have a role in the extension of the DIP, have developed new considerations about Landsmeer's theory. Being that the finger is composed of a polyarticular chain quite difficult to control and coordinate, the presence of only two movement systems, one dorsal and one volar, are not enough to ensure its stability and coordination. For this purpose, there is the need for a third diagonal element to support the flexion and extension of the fingers: regarding the metacarpophalangeal joint, this element is represented by the lumbrical muscles, while for the PIP and DIP, the diagonal system would be formed by the transverse retinacular ligament and the oblique retinacular ligament, which is responsible for the tenodesis between the two joints and their stability; this would be due precisely to the volar and cross course of the ORL on the ulnar and radial side of the finger, which would act as a rein on the PIP, balancing the tenodesis effect on the DIP and integrating the extrinsic and intrinsic action of the muscles part of the dorsal aponeurosis. Today it is still difficult to define what the real function of the ORL is. The most accredited thesis is certainly that the function of the ORL is mainly static and stabilizing and not properly dynamic: its course would favor the lateral stabilization of the PIP in the loose-packed position of flexion and of the lateral bands above the middle phalanx, centralizing the course of these tendons. However, given also the latest discoveries made by Balakrishnan [23] about the cross anatomy of the oblique retinacular ligament, Landsmeer's theory on the tenodesis effect of the ORL on the DIP could deserve to be taken into consideration again.

3.3. Clinical implications of the oblique retinacular ligament in pathological deformity conditions

The ORL is a structure that adapts to the various positions of the interphalangeal joints, so even in pathological deformity conditions, adaptations occur. The interphalangeal joints are interdependent on each other, even if their link does not seem to be conditioned by the presence of the ORL. This interdependence means that, in case of deformity of one joint, the imbalance created between the dorsal extensor structures and the volar flexor structures leads to a consequent compensation also in the other joint, as in the case of boutonniere deformity, swan-neck deformity, and mallet finger. Boutonniere deformity is defined by the flexion of the PIP and the hyperextension of the DIP that occurs during the active extension movement of the fingers. This deformity occurs following the lesion of the central band of the extensor mechanism, which is inserted on the base of the middle phalanx to extend the PIP. The lack of this structure results in a lateral migration of the lateral bands and the predominance of the volar forces on the PIP exerted by the superficial flexor of the fingers. Migrating laterally, the lateral bands become volar to the center of rotation of the PIP, so they become a force of flexion of the PIP; over time, the lateral bands contract and exert an increased force of extension on the DIP, causing its typical hyperextension. In all this mechanism, the retinacular ligaments also have a role: the typical relationship between PIP and DIP that occurs in boutonniere deformity reduces the tensioning of both the oblique retinacular ligament and the transverse retinacular ligament; over time, a retraction of these ligaments occurs, which participate in the maintenance of such deformity. Swan-neck deformity is defined with the opposite pattern to that of boutonniere deformity, namely the hyperextension of the PIP and the flexion of the DIP. There are countless causes that can lead to the development of this deformity, but the most frequent is chronic mallet finger. Following this condition, the DIP loses its dorsal traction force, and the activation of the extensor mechanism is entirely reflected on the central band and the PIP. Over time, this behavior leads to a stretching of the volar plate of the PIP, which therefore loses its function of passive limitation in hyperextension of the same joint. In all this, the retinacular ligaments develop considerable elasticity because they are constantly put under tension: the transverse retinacular ligament is stretched by the dorsalization of the lateral bands consequent to the hyperextension of the PIP, while the oblique retinacular ligament is put under tension by the reciprocal position assumed by the PIP and DIP.

3.4. Therapeutic options for the treatment of deformities

In boutonniere deformity, over time the ORL tends to retract and further stabilize the position assumed by the interphalangeal joints [27]. In these cases, restoring the elasticity of the retinacular ligaments and the distal sliding of the dorsal aponeurosis assumes primary importance, both in attempts at conservative treatment and before a surgical approach. In acute deformities, where the soft tissues are not yet retracted, conservative treatment can proceed by immobilizing the PIP at 0° and leaving the DIP free to flex, in order to maintain the elasticity of the retinacular ligaments and the lateral bands and promote the distal sliding of the entire dorsal aponeurosis. After 6 weeks of complete immobilization, the brace can be removed to proceed with the recovery of the flexion of the PIP; however, as a precaution, it is advisable to carry out daytime weaning from the brace and continue to wear it at night for a further 6 weeks. In the case of chronic deformities, conservative treatment can also be performed when the deformity is not passively correctable due to retracted tissues. In these cases, the goal will be to recover the elasticity of the volar structures of the PIP (volar plate, transverse retinacular ligament, flexor tendon sheath), through active extension exercises of the PIP and with the help of static-progressive braces to bring the PIP back to 0°, as well as the ORL and the lateral bands, through active flexion of the DIP while keeping the PIP at 0°. Once 0° of the PIP is reached, it is necessary to keep it immobilized for 6–12 weeks in this position with a splint, leaving the DIP free [28]. If conservative treatment proves ineffective in correcting the deformity, the recovery of the elasticity of the retracted tissues remains a fundamental prerequisite for the success of surgical treatment; the conservative pathway for the recovery of passive mobility of the PIP and the elasticity of the tissues should be completed at least 2 weeks before surgery, otherwise, surgery may be unsuccessful.

Even swan-neck deformities developed following the onset of mallet finger can be approached, at least initially, with conservative treatment, which consists of creating a brace that immobilizes the DIP at 0° or 10° of hyperextension and that has a dorsal block to the extension of the PIP of −40/-60° [29]. The splint must be worn continuously for 8 weeks, with subsequent weaning of an additional 6 weeks, and worn at night for up to 3 months. However, there are valid surgical alternatives in case conservative treatment proves ineffective. One of these takes up the principle of dynamic tenodesis of the ORL hypothesized by Landsmeer [13]. The surgical technique involves the creation of a spiral oblique retinacular ligament (SORL) and was published by Thompson [30] in 1978 for the treatment of mallet finger associated or not with swan-neck deformity. In this procedure, two holes are created, one dorso-volar at the base of the distal phalanx and one latero-lateral at the base of the proximal phalanx. The neo-ligament, often taken from the long palmar tendon, is fixed to the base of the distal phalanx, passed dorsally to the middle phalanx, between the two lateral bands and dorsally to Cleland's ligament, up to the PIP, where the ligament is made spiral by passing the ligament volarly between the neurovascular bundle and the flexor tendon sheath, until it is fixed at the level of the second hole on the base of the proximal phalanx. The most critical part for the success of the procedure is the tensioning of the neoligament: if it is too slack, it would not correct the deformity, while if it is too tense, it would cause the flexion of the PIP and the hyperextension of the DIP, just like in boutonniere deformity. This type of intervention is based on the foundations laid by Littler, who used a laterally sectioned band proximally and left intact in its distal insertion to recreate the tenodesis effect of the ORL, and seems to be the most effective for the correction of mallet finger and swan-neck deformity. In 1984, Kleinman [31] published an alternative technique where the neo-ligament is fixed to the osteo-fibrous canal where the flexor tendons pass at the level of the proximal phalanx, rather than inside a tunnel passing through the phalanx itself, defining it as simpler to perform and equally effective.

4. Discussion

Since its first description by Landsmeer in 1949 [13], the oblique retinacular ligament (ORL) has been the subject of many opinions regarding its actual existence, its anatomy, and its function. Today, there is no longer any doubt about its existence as a well-defined ligament, not just a fibro-ligamentous recess linked to the dorsal aponeurosis. Past difficulties in identifying and isolating it on cadavers were likely due to the use of inadequate tools and dissection techniques for working on such small structures, rather than a real absence; indeed, with modern dissection techniques and equipment, the ORL is practically identified in all examined samples. More complex is defining the real function of the ORL. The dynamic tenodesis theory between the PIP and DIP developed by Landsmeer [1,13] arises from the incorrect observation that the ligament is always volar to the axis of rotation of the PIP, when in fact, it becomes volar only when the PIP is flexed. Many works have been published along these lines, which would report that the ORL has no dynamic function but instead acts as a static stabilizer in the lateral movements of the PIP and a centralizer of the lateral bands dorsally to the middle phalanx. However, Balakrishnan's study [23] demonstrated how the ORL could indeed remain volar to the PIP even when the joint is in extension due to the cross structure that runs volarly to the middle phalanx. This discovery, never described by other authors [24,26], allows for a reevaluation of the tenodesis function of the ORL in support of primary structures for the extension of PIP and DIP, such as the central and lateral bands. In cases of pathological deformities, especially in chronic situations where soft tissues develop non-physiological adaptations to the new biomechanical condition, the literature quite clearly supports the importance of restoring correct elasticity and tensile capacity of the dorsal aponeurosis and retinacular ligaments, both as conservative treatment and as preparation for corrective surgery. Regarding mallet finger and swan-neck deformity, surgical correction involves creating a dynamic tenodesis between PIP and DIP that conceptually follows the course of the ORL. Given the clinical results obtained by authors who performed the SORL procedure, it can be affirmed that dynamic tenodesis represents an excellent solution in these deformities [2–4,22,27,32]. This ongoing debate highlights the evolving understanding of the ORL's role within the complex biomechanical environment of the hand. Despite past disagreements, recent findings contribute to a more nuanced appreciation of the ORL's importance, not just as a passive structural component but as an active participant in the sophisticated orchestration of finger movement. As our comprehension deepens, the potential for innovative therapeutic strategies to address hand deformities and improve patient outcomes becomes increasingly apparent, underscoring the ORL's significance in both the anatomical and clinical realms.

The limitations of the study include a focus solely on primary cadaveric anatomy and biomechanical analyses, excluding studies using ultrasound, MRI, or other imaging techniques due to their lower resolution for detailed visualization of the ORL. The review also omitted articles without detailed research methodology, case reports, and those not specifically analyzing the ORL. The use of modern dissection techniques may have introduced a selection bias, favoring clear identification of the ORL in most samples. The dynamic tenodesis theory of the ORL, while gaining support, remains contested and further research might be needed to fully understand its biomechanical role, especially in living subjects.

5. Conclusion

In conclusion, the journey to understand the oblique retinacular ligament (ORL) has traversed a path filled with debate and discovery. From its existence to its anatomical and functional nuances, the ORL has proven to be more than a mere anatomical curiosity; it plays a critical role in the complex biomechanics of finger movement. Recent studies, particularly those highlighting its dynamic tenodesis effect and its role in stabilizing the proximal interphalangeal joint, have shed new light on its importance. This enhanced understanding not only enriches our anatomical knowledge but also opens up new avenues for treating pathological deformities of the hand. As we continue to explore the intricate dance of the human hand's structures, the ORL stands out as a key player, guiding us toward more effective interventions and ultimately improving patient care in hand surgery and rehabilitation.

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Mattia Bulli: Conceptualization. **Paolo Boccolari:** Supervision. **Danilo Donati:** Supervision. **Roberto Tedeschi:** Writing – review & editing.

Declaration of competing interest

None.

References

[1] J.M. Landsmeer, The coordination OF finger-joint MOTIONS, J Bone Joint Surg Am 45 (1963) 1654–1662.

[2] R.J. Smith, Balance and kinetics of the fingers under normal and pathological conditions, Clin. Orthop. Relat. Res. (1974) 92–111, https://doi.org/10.1097/00003086-197410000-00010.

[3] K. Park, Effects of wearing functional foot orthotic on pelvic angle among college students in their 20s with flatfoot, J. Phys. Ther. Sci. 29 (2017) 438–441, https://doi.org/10.1589/jpts.29.438.

[4] P. Boccolari, F. Pantaleoni, D. Donati, R. Tedeschi, Non-surgical treatment of oblique diaphyseal fractures of the fourth and fifth metacarpals in a professional athlete: a case report, Int J Surg Case Rep 115 (2024) 109256, https://doi.org/10.1016/j.ijscr.2024.109256.

[5] E. Lanfranchi, T. Fairplay, R. Tedeschi, A case report: pain in the hand and tingling of the upper limb may be a symptom of a schwannoma in the supraclavicular region, Int J Surg Case Rep 110 (2023) 108664, https://doi.org/10.1016/j.ijscr.2023.108664.

[6] S. Santandrea, M. Benassi, R. Tedeschi, Comparison of short-stretch bandage and long-stretch bandage for post-traumatic hand edema, Int J Surg Case Rep 111 (2023) 108854, https://doi.org/10.1016/j.ijscr.2023.108854.

[7] E. Lanfranchi, S. Vandelli, P. Boccolari, D. Donati, D. Platano, R. Tedeschi, Efficacy and patient acceptability of 3 orthosis models for radial nerve palsy, Hand Surg Rehabil (2024) 101677, https://doi.org/10.1016/j.hansur.2024.101677.

[8] P. Boccolari, F. Pantaleoni, R. Tedeschi, D. Donati, The mechanics of the collateral ligaments in the metacarpophalangeal joints: a scoping review, Morphologie 108 (2024), https://doi.org/10.1016/j.morpho.2024.100770.

[9] R. Tedeschi, L. Berti, D. Platano, Transcranial Direct Current Stimulation (tDCS) in managing pain and recovery: a clinical case of radial capitellum fracture, International Journal of Surgery Case Reports 114 (2024), https://doi.org/10.1016/j.ijscr.2023.109120.

[10] C. Harris, G.L. Rutledge, The functional anatomy of the extensor mechanism of the finger, J Bone Joint Surg Am 54 (1972) 713–726.

[11] C.L. McCarthy, Ultrasound of normal and Injured ligaments and Retinacula of the hand, Semin. Muscoskel. Radiol. 24 (2020) 83–100, https://doi.org/10.1055/s-0039-3402051.

[12] P. Boccolari, R. Tedeschi, D. Platano, D. Donati, Review of contemporary non-surgical management techniques for metacarpal fractures: anatomy and rehabilitation strategies, Orthop. Surg. (2024), https://doi.org/10.1016/j.orthop.2024.02.001.

[13] J.M. Landsmeer, Anatomical and functional investigations on the articulation of the human fingers, Acta Anat. Suppl. 25 (1955) 1–69.

[14] A. Turolla, A.A. Guccione, R. Tedeschi, P. Pillastrini, Is clinical research as helpful to Clinicians as it could Be? Phys. Ther. 103 (2023) https://doi.org/10.1093/ptj/pzad060.

[15] R. Tedeschi, Briser le cycle nocebo : stratégies pour améliorer les résultats en podiatrie, Douleurs 24 (2023) 241–247, https://doi.org/10.1016/j.douler.2023.10.006.

[16] R. Tedeschi, Unveiling the potential of Trigger Point Therapy: Exploring its Efficacy in managing Muscular Spasticity - a scoping review, muscles, Ligaments and Tendons Journal 13 (2023) 564–573, https://doi.org/10.32098/mltj.04.2023.07.

[17] R. Tedeschi, Mapping the current research on Mindfulness interventions for Individuals with Cerebral palsy: a scoping review, Neuropediatrics (2024), https://doi.org/10.1055/a-2239-1936.

[18] R. Tedeschi, Unlocking the power of motor imagery: a comprehensive review on its application in alleviating foot pain, Acta Neurol. Belg. (2024), https://doi.org/10.1007/s13760-024-02492-2.

[19] R. Tedeschi, Transcranial direct current stimulation for chronic foot pain: a comprehensive review, eNeurologicalSci 35 (2024), https://doi.org/10.1016/j.ensci.2024.100498.
[20] R. Tedeschi, Unlocking the power of motor imagery: a comprehensive review on its application in alleviating foot pain, Acta Neurol. Belg. (2024), https://doi.org/10.1007/s13760-024-02492-2.
[21] M.M. Shrewsbury, R.K. Johnson, A systematic study of the oblique retinacular ligament of the human finger: its structure and function, J Hand Surg Am 2 (1977) 194–199, https://doi.org/10.1016/s0363-5023(77)80069-5.
[22] T.A. El-Gammal, C.M. Steyers, W.F. Blair, J.A. Maynard, Anatomy of the oblique retinacular ligament of the index finger, J. Hand Surg. 18 (1993) 717–721, https://doi.org/10.1016/0363-5023(93)90326-X.
[23] T.M. Balakrishnan, H. Subbaraj, J. Jaganmohan, Anatomy of landsmeer ligaments—redefined, Indian J. Plast. Surg. 52 (2019) 195–200, https://doi.org/10.1055/s-0039-1695802.
[24] P. Bendz, The functional significance of the oblique retinacular ligament of Landsmeer. A review and new proposals, J Hand Surg Br 10 (1985) 25–29, https://doi.org/10.1016/s0266-7681(85)80009-7.
[25] U. H, M. N, E. Hc, G. Tr, S. Rj, An anatomic and biomechanical study of the oblique retinacular ligament and its role in finger extension, J. Hand Surg. 36 (2011), https://doi.org/10.1016/j.jhsa.2011.09.033.
[26] J.N.A.L. Leijnse, C.W. Spoor, Reverse engineering finger extensor apparatus morphology from measured coupled interphalangeal joint angle trajectories — a generic 2D kinematic model, J. Biomech. 45 (2012) 569–578, https://doi.org/10.1016/j.jbiomech.2011.11.002.
[27] S. El-Sallakh, T. Aly, O. Amin, M. Hegazi, Surgical management of chronic boutonniere deformity, Hand Surg. 17 (2012) 359–364, https://doi.org/10.1142/S0218810412500311.
[28] K. Elzinga, K.C. Chung, Managing swan neck and boutonniere deformities, Clin. Plast. Surg. 46 (2019) 329–337, https://doi.org/10.1016/j.cps.2019.02.006.
[29] C. Deml, A. Baradaran, N. Chen, M. Nasr, A.R. Kachooei, Fowler central slip tenotomy or spiral oblique retinacular ligament reconstruction? A cadaveric biomechanical study in swan-neck deformity, Hand (N Y) 15 (2020) 620–624, https://doi.org/10.1177/1558944719834643.
[30] J.S. Thompson, J.W. Littler, J. Upton, The spiral oblique retinacular ligament (SORL), J Hand Surg Am 3 (1978) 482–487, https://doi.org/10.1016/s0363-5023(78)80144-0.
[31] W.B. Kleinman, D.P. Petersen, Oblique retinacular ligament reconstruction for chronic mallet finger deformity, J Hand Surg Am 9 (1984) 399–404, https://doi.org/10.1016/s0363-5023(84)80231-2.
[32] I. Catellani, P. Arcuri, F. Vita, D. Platano, P. Boccolari, E. Lanfranchi, T. Fairplay, R. Tedeschi, An overview of rehabilitation approaches for focal hand dystonia in musicians: a scoping review, Clin. Rehabil. (2024) 2692155231225705, https://doi.org/10.1177/02692155231225705.