Journal of Plastic, Reconstructive & Aesthetic Surgery (2019) 72, 2017–2026

JPRAS
An International Journal of Surgical Reconstruction
www.JPRASurg.com

Anatomical study of the extraocular check ligament system

Wei Zhuang[1], Shuo Fang[1], Hao Fan, Weiye Zhu, Yong Chen, Weiya Tang, Chengling Liu, Xingchen Liu, Zhen Zhang, Xin Xing*, Chao Yang*

Department of Plastic and Reconstruction, Shanghai Changhai Hospital Affiliated to Navy Medical University, 168th Chang Hai Road, Shanghai, People's Republic of China

Received 17 December 2017; accepted 9 September 2019

KEYWORDS
Anatomy;
Cadaver;
Blepharoptosis;
Check ligament;
Ocular plastic surgery;
CFS;
Immunohistochemical staining

Summary *Aim:* To clarify the gross anatomy structure of the check ligament of the palpebra superior in relation to congenital blepharoptosis operation.
Method: Seven fixed and three fresh cadavers of Chinese adults (between 53 and 76 years old; 5 males and 5 females) were used. Gross dissection was performed on fourteen eyes in seven cadavers. In three fixed cadavers, six bulbus oculi received histological sections for immunohistochemical tests.
Result: Below the levator upon the superior rectus, the check ligament described by Lockwood is found. It extends bilaterally and attaches to the orbital wall behind the inner and lateral canthus tendon. Between the inferior obliquus and the inferior rectus, we also found a sheath structure similar to the check ligament extending bilaterally to the orbital wall. These two structures form an annular fascial system surrounding the eyeball. The medial half of the fascial sheath is tenacious, and the immunohistochemical test proves that smooth muscle cells are found in this part.
Conclusion: We call this whole fascial sheath surrounding the circumocular muscle the Extraocular Check Ligament System (ECLS), and it plays a restricting and checking role in the movement of the eyeball. Surgeons should be aware of the ECLS when performing ptosis or other blepharal surgery.

Congenital blepharoptosis is a rare condition characterized by an abnormal drooping of the upper eyelid. Suspension of the eyelid to the check ligament of the superior fornix was first reported by Holmstrom as a new method to treat blepharoptosis in 2002, and this method has achieved vital success.[1] Subsequently, some doctors have used this technique to treat blepharoptosis. This operation is highly

[1]These authors contributed to the work equally and should be regarded as co-first authors.
* Corresponding authors.
E-mail addresses: 446280578@qq.com (W. Zhuang), xingxin57@163.com (X. Xing), 653860496@qq.com, 446280578@qq.com (C. Yang).

https://doi.org/10.1016/j.bjps.2019.09.002
1748-6815/

recommended because of its advantages, including wide applicability, limited dissection, rapid recovery, satisfying result, and minimal complications; some suggest that it could replace traditional techniques to correct blepharoptosis.[2,3] Although there are many anatomical studies on the check ligament of the superior fornix, controversy still exists in understanding the composition, morphology, area, and physiological functions that may impact the application of this technique. This systemic anatomical study was conducted on the extraocular muscles, their corresponding check ligaments and their surrounding tissues. We hope to further clarify their structural features and physiological functions to promote clinical application.

Materials and methods

Materials

Seven fixed and three fresh cadavers of Chinese adults (between 53 and 76 years old; 5 males and 5 females) were used. Gross dissection was performed on fourteen eyes in seven cadavers. In three cadavers, six bulbus oculi received histological sections. The cadavers were provided by the anatomy department of Second Military Medical University, which were used only in this dissection study.

Gross anatomy

From above the supraorbital foramen (1 cm to the infraorbital foramen level), the skull specimens containing orbital contents and orbital wall structures were removed from the head. The brain tissue was removed, and the skull base (i.e., the orbital parietal wall) was exposed. After the removal of the orbital parietal wall, the orbital fat was dissected carefully, and the relationships among the superior rectus, levator palpebrae superioris, check ligament of the superior fornix, and medial and lateral canthus tendons were observed separately, layer by layer, emphasizing the relationship between the check ligament of the superior fornix and orbital wall. Subsequently, the medial orbital wall, lateral orbital wall, and orbital floor wall were removed (the bony structures attached to the medial and lateral canthus tendon and inferior obliquus were retained). The relationships between the check ligaments and the medial rectus, external rectus, inferior rectus, and inferior obliquus were observed; meanwhile, the relationships between the check ligament and the adjacent structures were also defined.

Histology

After the removal of the bony orbital wall, the reserve of the orbital wall periosteum and the orbital contents, the three specimens were treated with dehydration, fixation, and paraffin embedding; then, sagittal, horizontal, and coronal sections were made. Four sections with a thickness of 5 μm were cut consecutively at each interval of 2 mm. Two were stained with hematoxylin-eosin (HE) and Masson. Some sections were stained by immunohistochemistry using antibodies such as α-SMA and h-caldesmon. A high-speed panoramic section scanning the microscope system was used to integrate the histological sections seamlessly, and the whole section image was generated.

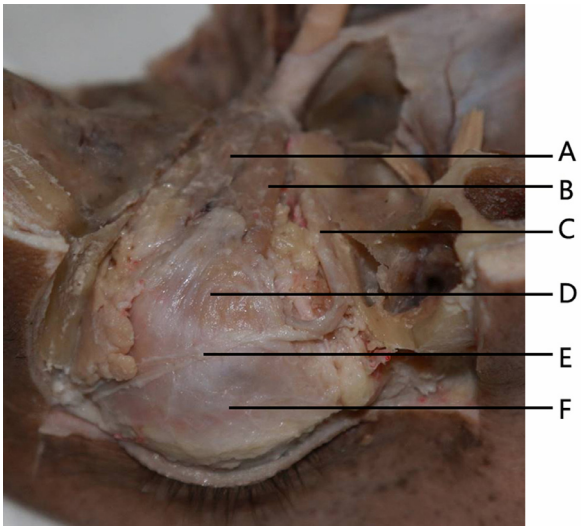


Figure 1 Observation of the levator palpebrae superioris. A = superior rectus; B = levator palpebrae superioris; C = superior oblique; D = sheath of levator; E = Whitnall's ligament; F = levator aponeurosis.

Results

Gross anatomy observation

After removing the superior orbital wall, orbital periosteum, orbital fat, skin, orbicularis oculi muscle, and orbital septum, the levator palpebrae muscle was fully exposed. Whitnall's ligament could be observed from Whitnall's nodule to the superior oblique trochlea on the surface of the levator aponeurosis (Figure 1).

Loose fibrous adhesions between the levator and superior rectus could be observed after cutting the levator palpebrae superioris from 1 cm in front of the origin and then lifting up and forward (Figure 2). We then continued to lift the levator palpebrae superioris after dissecting the adhesion. A compact fascia-like structure—the check ligament of the superior fornix—could be observed between the superior rectus and the posterior sheath of the levator palpebrae superioris. During the separation, a close connection between the fascia and the superior rectus was found. This connection was fused with the superior rectus sheath. Its adhesion with the posterior sheath of the levator palpebrae superioris was looser (Figure 3).

After removing the lacrimal gland, the levator palpebrae, and their aponeuroses, the check ligament of the superior fornix was fully revealed. The check ligament of the upper fornix was an irregular structure, similar to a trapezoid and was fused with the sheaths of the superior rectus and levator. The ligament extended bilaterally to the lateral

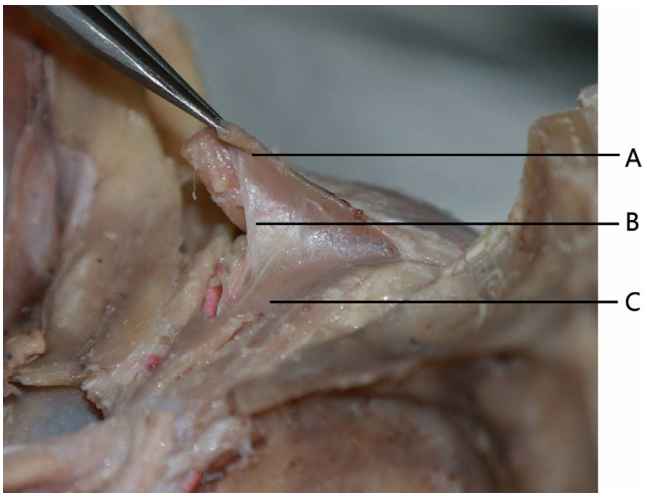


Figure 2 Posterior view after cut and lift the levator palpebrae superioris. A = levator palpebrae superioris; B = loose connective tissue between the two muscles; C = superior rectus.

and medial canthus and from the end to the superior fornix anteriorly (Figure 4).

After removing the remaining orbital walls and fat tissue between the muscles above the level of the palpebral fissure, the check ligament of the superior fornix was observed to extend bilaterally in a horizontal direction. In the lateral section, the check ligament of the superior fornix passed through the lacrimal gland; part of it fused with the check ligament of the lateral rectus and another part attached to the orbital wall behind the lateral canthus tendon with thickened, compact fibrous bundles from back-up to front-down (Figure 5).

On the medial side, the check ligament of the superior fornix surrounded the tendon portion of the trochlea of superior oblique and extended to the medial canthus tendon and the medial rectus. The extension to the medial canthus tendon thickened above it and then attached to the medial canthus tendon. The extension to the medial rectus fused with the check ligament of the medial rectus (Figure 6).

Furthermore, the superior rectus was cut from 1 cm in front of the origin and lifted up and forward. There was a compact fibrous structural connection between the superior rectus and the superior oblique (Figure 7).

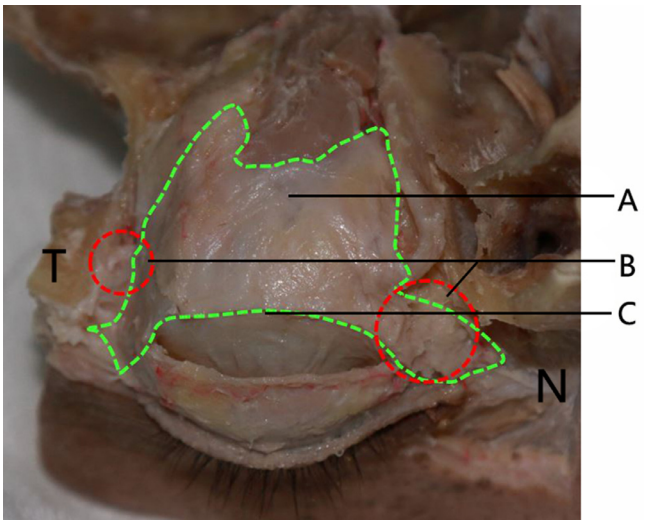


Figure 4 Observation of the check ligament of the superior fornix. A = (in the green dotted line) the check ligament of the superior fornix; B = (in the red dotted line) the connection of the check ligament with the lateral and the medial canthus tendon; C = the check ligament ended forward at the superior fornix.

After lifting the check ligament of the superior fornix, the superior rectus and Tenon's capsule, which covered the surface of the eyeball below, could both be observed. The check ligament could be easily separated from Tenon's capsule to be an independent fascial structure (Figure 8).

Beneath the eyeball, the bony orbital wall and fat were removed; the inferior oblique, the bony structures of the lower orbital wall attached to it and the associated fascial structures were preserved. The capsulopalpebral fascia surrounded the inferior oblique, and extended to the inferior palpebral margin and the medial and lateral canthus tendon. The transverse Lockwood's ligament was visible on its surface. The arcuate expansion extended from the location where the capsulopalpebral fascia surrounded the inferior oblique and stopped at the inferior lateral orbital wall (Figure 9).

After the inferior oblique was raised, a compact and thickened fascia-like structure similar to the check ligament of the superior fornix could be observed between the

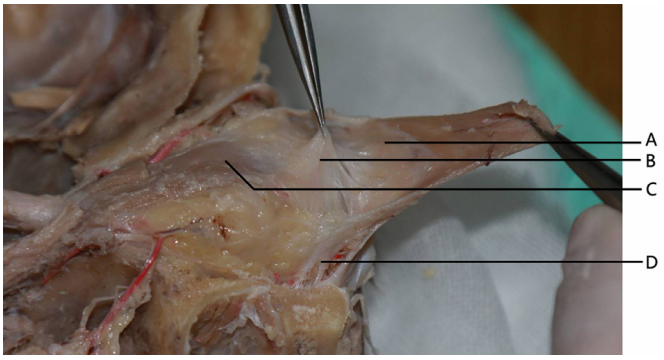


Figure 3 Separation and reveal the check ligament of the superior fornix. A = sheath of levator; B = the check ligament of the superior fornix; C = superior rectus; D = the attachment of the check ligament with the orbit.

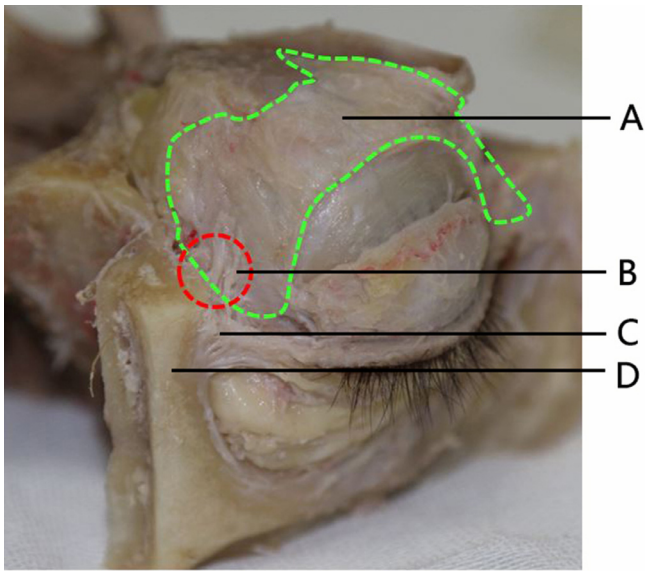


Figure 5 Observation of the traveling of the check ligament from the temporal side. A = (in the green dotted line) the check ligament; B = (in the red dotted line) bonds of fiber fixed at the orbit behind the lateral canthus tendon; C = lateral canthus tendon; D = orbit wall.

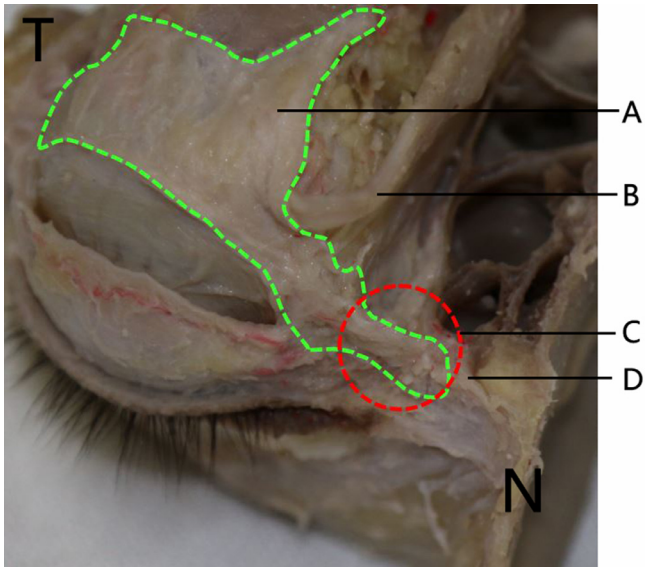


Figure 6 Observation of the travelling of the check ligament from the nasal side. A = (in the green dotted line) the check ligament; B = trochlea; C = (in the red dotted line) the enhanced attachment of the check ligament upon to the medial canthus tendon; D = medial canthus tendon.

inferior oblique and inferior rectus from the rear, stretching forward and ending at the inferior conjunctival fornix. Both sides extended to the medial and lateral canthus and fused with the check ligament of the medial and lateral rectus (Figure 10).

The average thickness of the check ligament of the superior fornix was measured to be approximately 1.0 ± 0.5 mm (range 0.7–1.5 mm); the average anteroposterior diameter

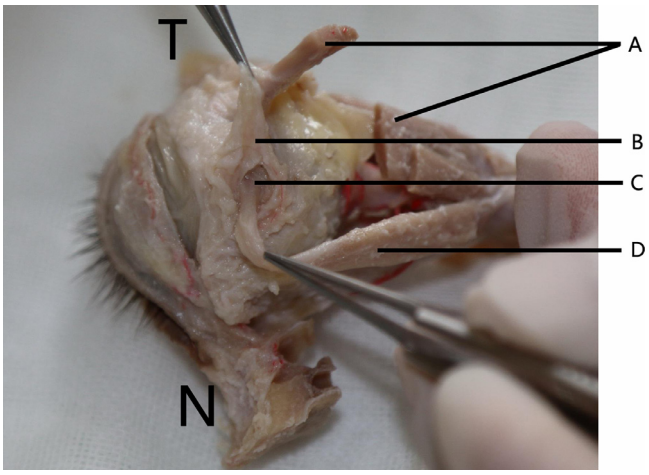


Figure 7 Observation the relationship between the check ligament and the superior oblique. A = superior rectus; B = the check ligament; C = the tendinous part of the muscle belly of the superior oblique surrounded by the check ligament; D = superior oblique.

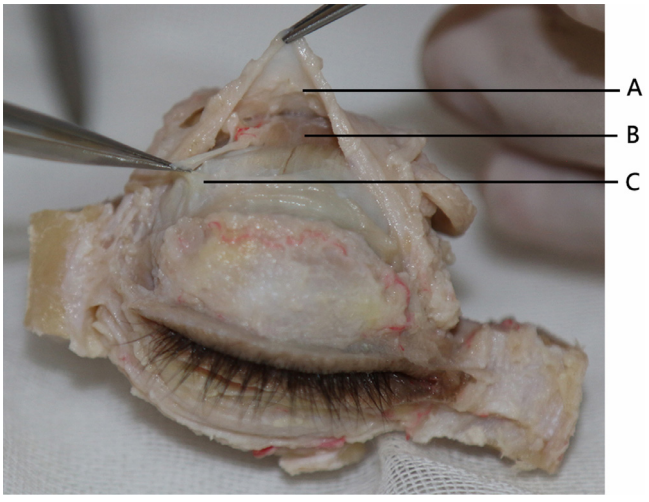


Figure 8 Anterior view of the relationship between the check ligament and the fascia tissue beneath it. A = the check ligament; B = superior rectus; C = Tenon's capsule.

was approximately 10.3 ± 3.5 mm (range 9–14 mm) at the midpupil line.

Histological research

The results of the histological sections of the specimens were consistent with gross anatomy. On the sagittal sections of the midline of the pupil, the thickened fascial structure between the levator palpebrae superioris and the superior rectus could be seen in the upper eyelid (the check ligament of the superior fornix) by Masson staining. Its fiber extended forward and attached to the superior conjunctival fornix, with additional fiber connections with Müller's muscle. In the lower eyelid, the capsulopalpebral fascia surrounded the inferior oblique and musculus tarsalis inferior. A

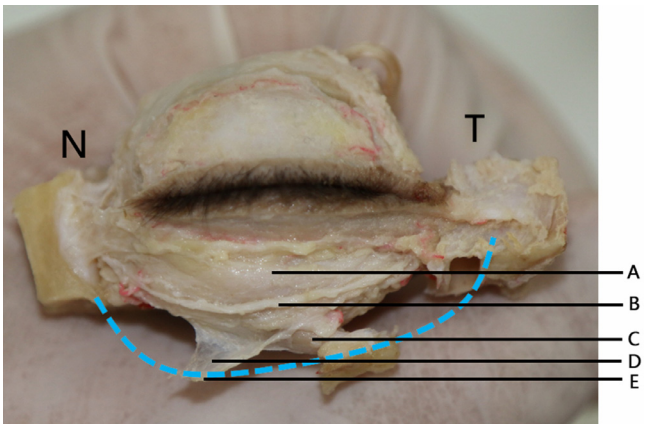


Figure 9 Anterior view of the muscles and fascia tissue beneath the orb. A = capsulopalpebral fascia; B = Lockwood's ligament; C = inferior oblique; D = arcuate expansion; E = infraorbital margin.

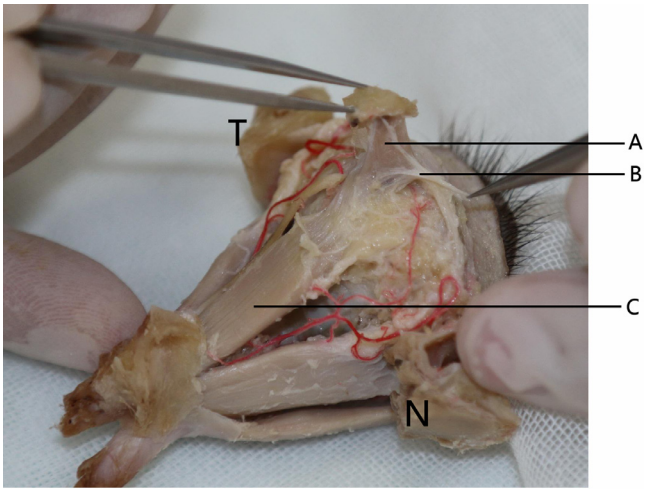


Figure 10 Posterior view of the check ligament of low eyelid; A = inferior oblique; B = the tight connection (check ligament) between the inferior oblique and inferior rectus; C = inferior rectus.

thickened fascia-like structure could be observed between the inferior rectus and the inferior oblique, with the check ligament of the palpebra inferior (Figure 11).

Using Masson staining on the horizontal section, we observed that the check ligament of the lateral rectus, attached to the orbital wall at the rear of the lateral canthus tendon, by an enhanced bundle of fibers that extended from its temporal side, and ended forward of the lateral fornix of the conjunctiva. The check ligament of the medial rectus travels along the nasal side, and sends an enhanced bundle of fibers to the deep posterior part of the medial canthus tendon and the location where the medial palpebral conjunctiva becomes the bulbar conjunctiva. Another part of the fibers continues extending forward to the conjunctiva. We observed the presence of abundant smooth muscle cells among the fibers of the check ligament of the medial rectus in this section (Figure 12).

In the coronal section, the distribution of the check ligament around the orbit could be observed. A portion of the check ligament of the superior fornix extended upward along the nasal side to the trochlea of superior oblique. The other section, which was fused with the check ligament of the medial rectus and notably thickened, extended to the medial rectus. It continued extending downward along the surface of the eyeball and ended between the inferior rectus and the inferior oblique. Abundant smooth muscle cells could be seen through amplification in this portion of the fibers. On the temporal side, the check ligament of the superior fornix that was connected to the orbital wall by an enhanced bundle of fibers moved along under the lacrimal gland and fused with the check ligament of the lateral rectus. The ligament continued to extend downward to the inferior oblique and the inferior rectus. We could not see smooth muscle cells in this fiber structure (Figure 13). To confirm the presence of smooth muscle cells, we selected sections that allowed us a complete view of the bilateral fascia-like structures at the coronal position for immunohistochemical staining. The selected antibodies were α-SMA and h-caldesmon. α-SMA (+) and h-caldesmon (+) were found in the check ligament at the nasal and lower parts of the eyeball, which verified the presence of smooth muscle cells among the fascial structures at these locations (Figure 14).

Discussion

Tenon first described the check ligament in 1805, referring to it as the tendinous fasciae of the rectus.[4] The effect of the tendinous fasciae of the superior rectus was driving the tarsus to produce eyelid movement when the eyeball spun upward because the superior rectus would pass on the traction. In 1874, Merkel first called it the check ligament.[5] In 1885, Lockweed conducted an anatomical study on the check ligament of all periocular recti, and noted that all four extraocular recti had their respective check ligaments.[6] In 1932, Whitnall called the ligament the conjoint fascial sheath (CFS) of the levator and superior rectus, and it was the prototype of the subsequently popular CFS. He particularly emphasized the closer relationship of such a fascial sheath with the levator than with the superior rectus.[7] In 1957, Fink illustrated the precise check mechanisms of all check ligaments of the eye. In particular, he described the levator-superior rectus structure as the transverse superior fascial expansion.[8] In addition, he described in detail how this structure produced the check mechanism when the eyeball spun upward. In 1996, Lukas conducted an anatomical study on two ligaments enveloping the levator through a manner of sleeves. He named the structure corresponding to Whitnall's ligament, the intermuscular transverse ligament.[9] Lukas further suggested that the two ligaments assisted in levator constriction and that they should be protected in ptosis surgery. In 2002, Holmstrom first reported correcting ptosis through suspension of the eyelid to the check ligament of the superior fornix, and he attained excellent therapeutic effects. In 2008, Kwang published an anatomical study in which the structure was called the CFS.[10] Since then, the surgical procedure reported by Holmstrom has become increasingly popular in China, and there has been some abuse of the technique.

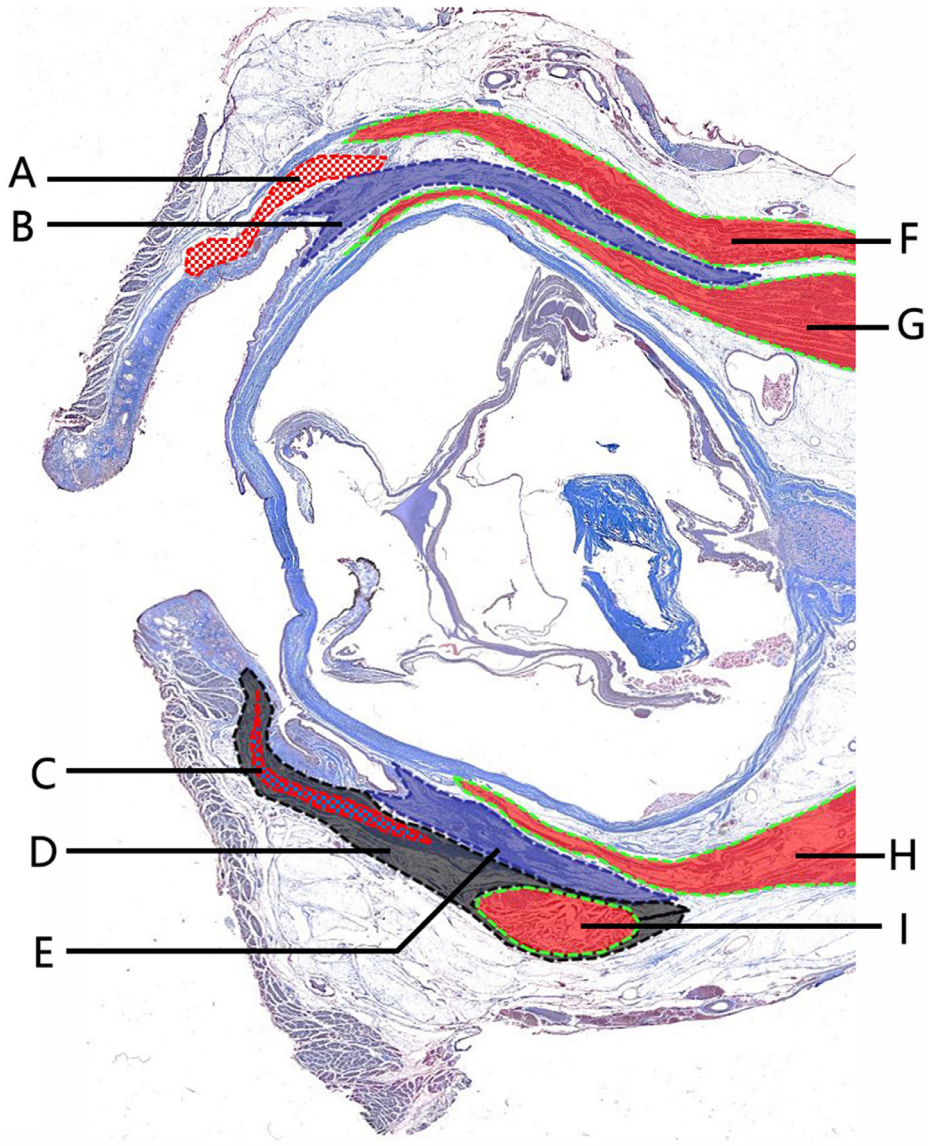


Figure 11 Histologic sections of the eyeball (sagittal view). A = Müller's muscle; B = the check ligament of the superior fornix; C = musculi tarsalis inferior; D = capsulopalpebral fascia; E = the check ligament of the palpebra inferior; F = levator palpebrae superioris; G = superior rectus; H = inferior rectus; I = inferior oblique.

Currently, the anatomical and clinical application research on check ligaments is associated with several problems. First, Lockwood et al. mentioned in their research that 4 periocular recti with respective check ligaments that were connected to the orbital wall had the suspension function. However, most studies are restricted to the surgically involved check ligament of the superior fornix. Kwang considered that this ligament approximated the CFS that Whitnall defined in his 2008 anatomical study. He noted that the CFS is a thick fibrous sheath covering the superior rectus below the levator, attached to the conjunctival fornix. The shape was an equilateral trapezoid with an anteriorly longer base. Similar studies had a lack of systemic understanding of the entire periocular fascial structure, including its distribution range, adjacency, connection with the orbital wall and histological components (with/without smooth muscle).[11] Second, the physiological function regarding the check ligament, in which the structures or movements of the eyeball and eyelid utilize the check function, and how such an effect was exerted remain unclear.[12] Third, the mechanism of correcting ptosis through suspending the eyelid to the check ligament of the superior fornix has not been clearly described by scholars.[13] In addition, the issue of whether this is a static or dynamic suspension remains controversial, with no clear evidence available. These problems have directly influenced the understanding of scholars on the role of the check ligament in eyeball movement and other physiological functions. There have been negative effects on the understanding, popularization, and modification of this operation. Therefore, we conducted these anatomical and histological studies.

We discovered in our anatomical study that the check ligaments of the eye may not only exist between the levator

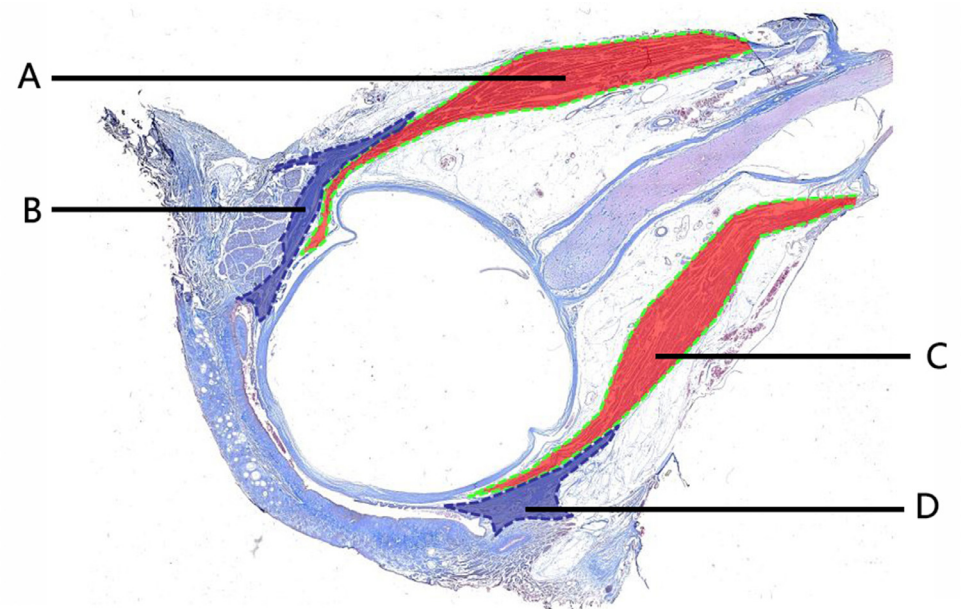


Figure 12 Histologic sections of the eyeball (horizontal view). The check ligament of lateral rectus attaches to the lateral fornix and the orbital wall contains no smooth muscles cells; while the check ligament of medial rectus attaches behind to the deep part of the medial canthus tendon and the transitional part of the medial palpebral and bulbar conjunctiva is rich in smooth muscles cells. A = lateral rectus; B = check ligament of lateral rectus; C = medial rectus; D = check ligament of medial rectus.

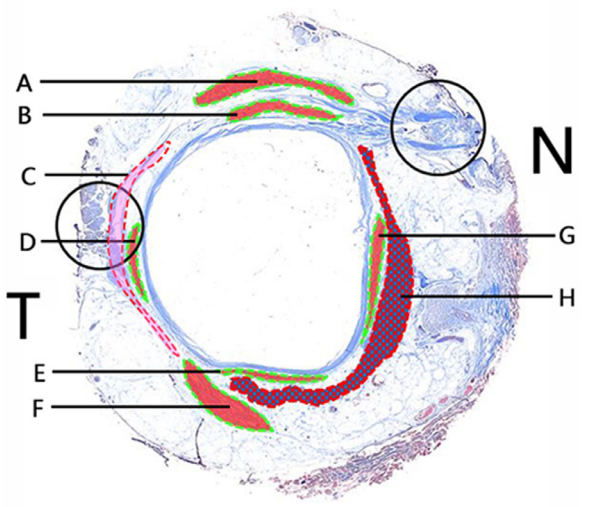


Figure 13 Histological section of the orb (coronal view). The check ligament system. In the two black circle there is the check ligament incrassation and surround the trochlea at the nasal side and enhances at the temporal side. A = levator palpebrae superioris; B = superior rectus; C = the check ligament of lateral rectus; D = lateral rectus; E = inferior rectus; F = inferior oblique; G = medial rectus; H = the check ligament of medial rectus and palpebra inferior.

and superior rectus. All 4 extraocular recti possess respective check ligaments, which are also associated closely with 2 oblique muscles. The superior fornix check ligament between the levator and superior rectus fuses with the check ligaments of the medial rectus and the lateral rectus on both sides. This ligament is connected to the orbital wall with the positions of medial and lateral canthus tendons through enhanced fiber bundles. The lower eyelid check ligament extends between the inferior oblique and inferior rectus, and ceases forward in the inferior fornix conjunctivae. This ligament is fused with the check ligaments of the medial rectus and lateral rectus on both sides.[14] The superior fornix check ligament is suggested to derive from Tenon's capsule.[15] On the basis of our anatomical results, however, it may be an independent fascia-like structure outside Tenon's capsule; both are components of the periocular connective tissue system. The nasal side is rich in smooth muscle cells. Kono once observed the presence of smooth muscle in the medial and inferior intraocular connective tissues through MRI and immunohistochemistry.[16] This observation is consistent with our findings. Thus, we believe that periocular check ligaments form a circular fascial system around the eyeball, ending at the conjunctivae fornix and connecting closely to the medial and lateral canthus tendons as well as the orbital wall. In addition, some parts of it are rich in smooth muscle cells. We call this structure the Extraocular Check Ligament System (ECLS, Figure 15).

We speculated that the ECLS possesses the following physiological functions based on its anatomical structure. First, the ECLS can restrict the range of eyeball movement. Extraocular muscles are the antagonistic muscles, and the contraction direction is opposite in the superior and inferior rectus, lateral and medial rectus, and superior and inferior oblique. Eyeball movement is directly affected by the extraocular muscles, and the ECLS can restrict the movement of extraocular muscles, thus restricting the movement of the eyeball (Figure 16).

Second, the ECLS plays an important role in stabilizing the position of the conjunctival fornix. The ECLS ends at the conjunctival fornix and applies a continuously backward tension on the conjunctivae fornix to maintain the position of the conjunctivae fornix. Third, the ECLS is involved in

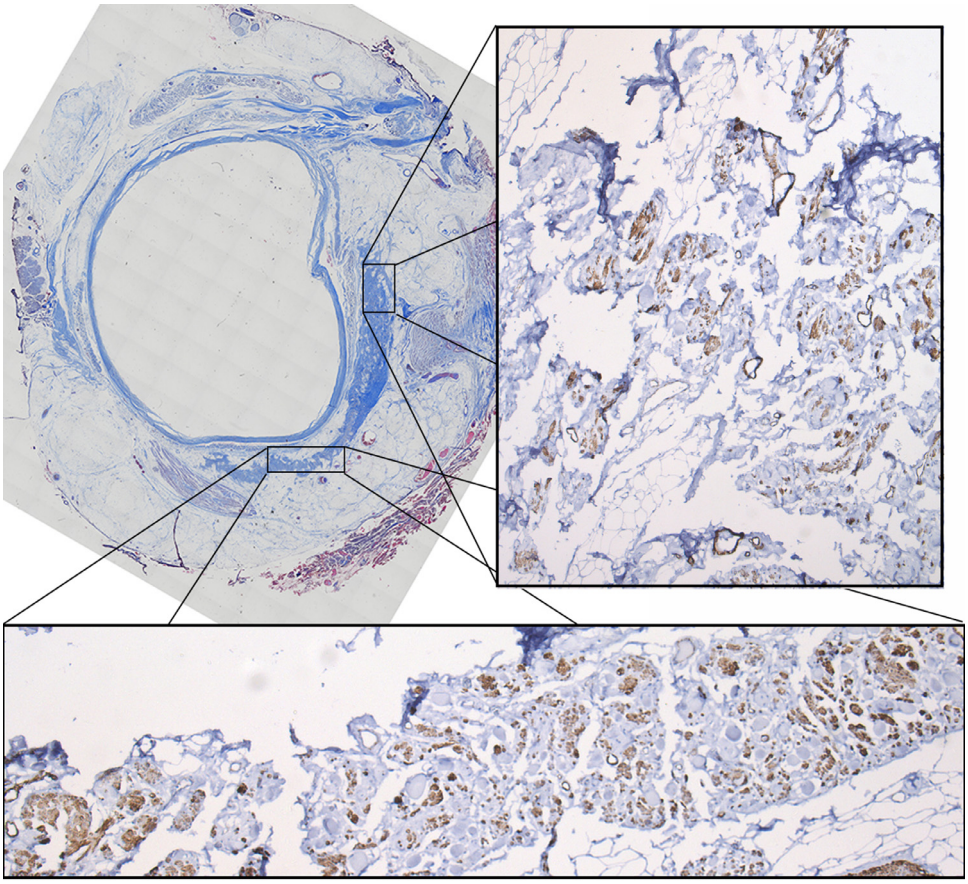
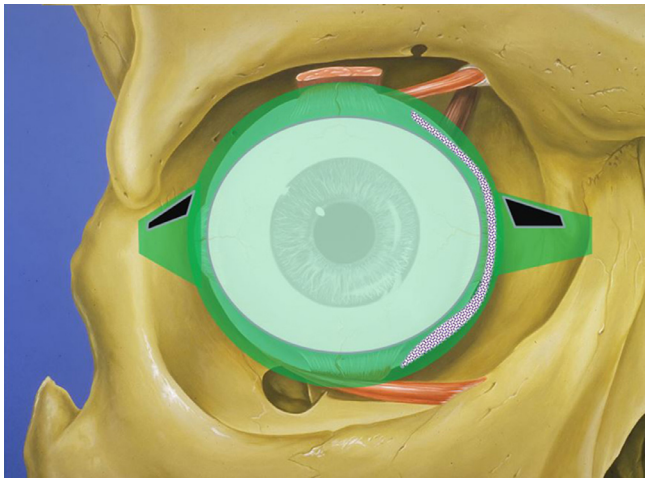


Figure 14 IHC (α-SMA & h-caldemon) of the eyeball.



Figue 15 Extraocular check ligament system, ECLS.

maintaining the relative position of the eyeball in the orbit. As part of the extraocular connective tissue system, the circular ECLS suspends the eyeball in a relatively fixed position in the orbit together with fascial and ligament structures, such as the capsule-palpebral fascia and Lockwood's ligament (Figure 15). The smooth muscle structure inside may play a vital role in maintaining ECLS tension.

As mentioned earlier, the ECLS plays a role as a "stopper" in eye movements, maintains the position of the conjunctival fornix, and together with other fascia and ligament structures maintains the position of the eyeball like a hammock. If the ECLS is lost (this is, of course, rare in clinical cases; in our autopsies, we found this structure in every specimen), eye movements during rotation may become excessive. The location of the eye in the eye socket could become less stable and result in diplopia or other complications. The conjunctival fornix may prolapse without the backward tension of the ECLS. Of course, Holmström's surgery is no longer an option.

In-depth investigation of the ECLS will further help us to understand the surgical mechanism of correcting ptosis through a suspension of the eyelid to the check ligament of the superior fornix. We suggest that the superior fornix check ligament ends at the superior fornix conjunctivae, and exerts a continuously backward suspension force on the conjunctivae fornix. The operation fixes the superior fornix check ligament onto the upper tarsus; thus directly passing such suspension force onto the upper tarsus and correcting the ptosis. The main controversy of this operation is the power source of suspension, and whether the procedure is a dynamic or static suspension. On the basis of anatomical research results, we maintain that such a suspension force derives from the levator, superior rectus, and superior oblique together and is dominated by the levator and the superior rectus. When the myodynamia of the levator is normal, the eyelid elevates with the contraction of the levator; meanwhile, the contraction of the superior rectus caused

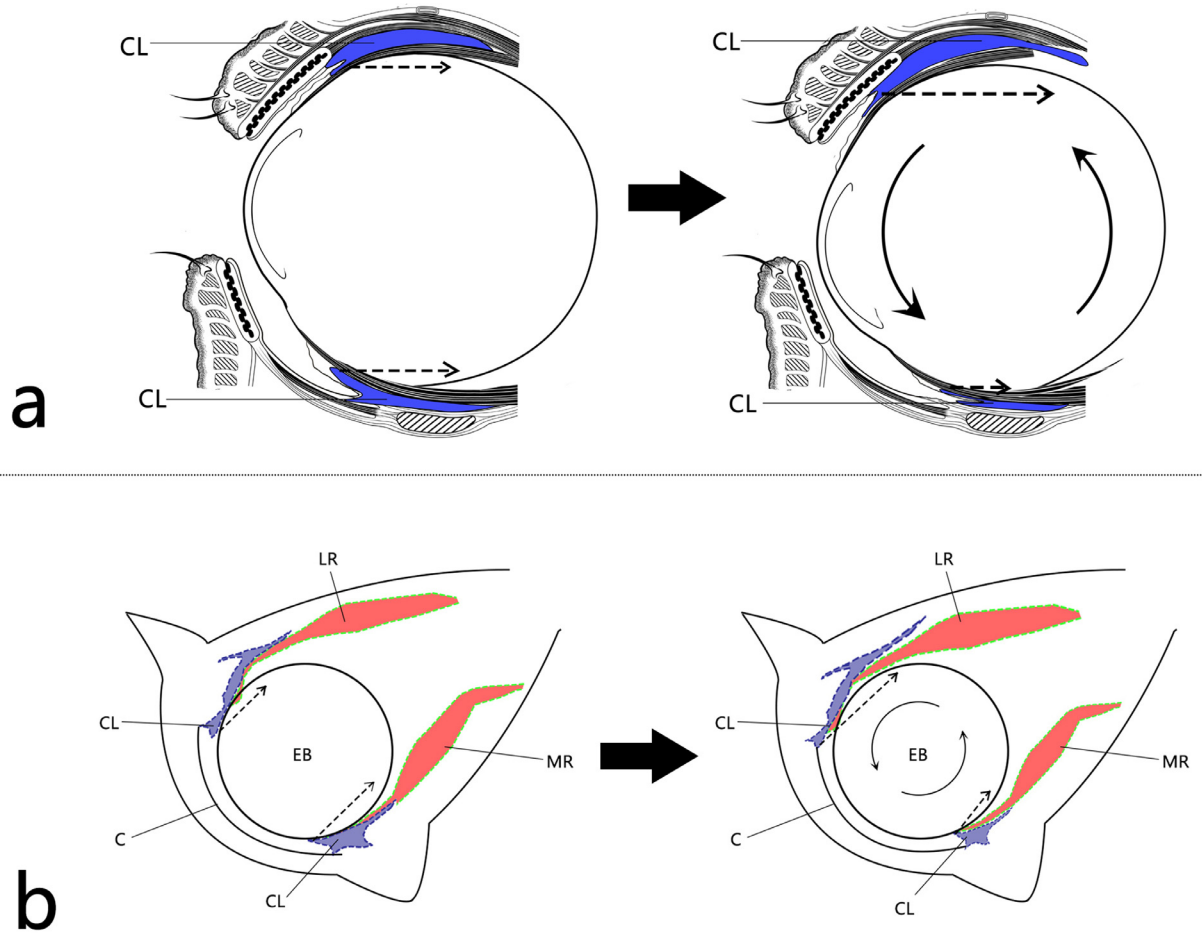


Figure 16 In our study, we found that under normal circumstances, the tension direction of the ECLS is pulling backward to maintain the position of the conjunctival fornix. As shown in figure a, when the eyeball is rotated downward, the inferior rectus muscles contract, and the superior rectus relaxes and is elongated. The backward tension of the check ligament of the superior rectus pulls the superior rectus. Together, these two structures work against the tension of the inferior rectus, which rotates the eye downward upon contraction, limiting the downward rotation of the eye. Additionally, when the eyeball rotates inward or outward (figure b), the ECLS pulls the elongated extraocular muscle backward, increasing its force against the strength of the contralateral extraocular muscles and playing an important role in limiting excessive movement of the eyeball (CL = check ligament; EB = eyeball; LR = lateral rectus; MR = medial rectus; C = conjunctival).

by eyeball movement also affects the position of the eyelid. When the levator has myasthenia, there is only a static suspension power passed to the tarsus through the check ligament by the levator and the superior rectus. While in this situation, the levator cannot contract to lift the eyelid; the eyelid can still be raised when the eyeball spins upward as the superior rectus contracts. We speculate that the operation includes both dynamic and static suspensions.

Many questions remain regarding exactly how each muscle plays a role in this process; the dynamic suspensions and the static suspensions each account for a number of parts. This finding should be further studied through surgical simulation with fresh specimens. This will also establish a foundation for our understanding, improvement, and application of this operation. An anatomical study of the ECLS should be further pursued. Its significance lies not only in the understanding and improvement of a certain surgical procedure but also in the greater understanding of the eyeball and eyelid movement as well as the diagnosis and treatment of related diseases.

Funding

The National Natural Science Foundation of China (no. 81701923).

Ethical approval

Not required.

Declaration of Competing Interest

None declared.

References

1. Holmström H, Santanelli F. Suspension of the eyelid to the check ligament of the superior fornix for congenital blepharoptosis. *Scand J Plast Reconstr Surg Hand Surg* 2002;**36**(3):149–56.

2. Santanelli F, Paolini G, Renzi LF, Longo B, Pagnoni M, Holmström H. Correction of myopathic blepharoptosis by check ligament suspension: clinical evaluation of 89 eyelids. *J Plast Surg Hand Surg* 2011;**45**(4–5):194–9.
3. Chen W, Liu Z, Tian Q, et al. Levator resection with suspensory ligament of the superior fornix suspension for correction of pediatric congenital ptosis with poor levator function. *Eye (Lond)* 2016;**30**(11):1490–5.
4. Tenon JR, Naus J, Blanken R. Anatomical observations on some parts of the eye and eyelids. *Strabismus* 2003;**11**(1):63–8.
5. Whitnall SE. A ligament acting as a check to the action of the levator palpebrae superioris muscle. *J Anat Physiol* 1911;**45**(Pt 2):131–9.
6. Lockwood CB. The anatomy of the muscles, ligaments, and fasciae of the orbit, including an account of the capsule of Tenon, the check ligaments of the recti, and of the suspensory ligament of the eye. *J Anat Physiol* 1885;**20**:1–25 Strabismus 2008;16(4):176–88.
7. Whitnall SE. *Anatomy of the human orbit and accessory organs of vision*. Krieger Publishing Company; 1932.
8. FINK WH. An anatomic study of the check mechanism of the vertical muscles of the eyes. *Am J Ophthalmol* 1957;**44**(6):800–9.
9. Lukas JR, Priglinger S, Denk M, Mayr R. Two fibromuscular transverse ligaments related to the levator palpebrae superioris: Whitnall's ligament and an intermuscular transverse ligament. *Anat Rec* 1996;**246**(3):415–22.
10. Hwang K, Shin YH, Kim DJ. Conjoint fascial sheath of the levator and superior rectus attached to the conjunctival fornix. *J Craniofac Surg* 2008;**19**(1):241–5.
11. Jones LT. A new concept of the orbital fascia and rectus muscle sheaths and its surgical implications. *Trans Am Acad Ophthalmol Otolaryngol* 1968;**72**(5):755–64.
12. Manson PN, Clifford CM, Su CT, Iliff NT, Morgan R. Mechanisms of global support and posttraumatic enophthalmos. I. The anatomy of the ligament sling and its relation to intramuscular cone orbital fat. *Plast Reconstr Surg.* 1986;**77**(2):193–202.
13. Holmström H, Bernström-Lundberg C, Oldfors A. Anatomical study of the structures at the roof of the orbit with special reference to the check ligament of the superior fornix. *Scand J Plast Reconstr Surg Hand Surg* 2002;**36**(3):157–9.
14. Osanai H, Murakami G, Ohtsuka A, Suzuki D, Nakagawa T, Tatsumi H. Histotopographical study of human periocular elastic fibers using aldehyde-fuchsin staining with special reference to the sleeve and pulley system for extraocular rectus muscles. *Anat Sci Int* 2009;**84**(3):129–40.
15. Lemke BN, Stasior OG, Rosenberg PN. The surgical relations of the levator palpebrae superioris muscle. *Ophthal Plast Reconstr Surg* 1988;**4**(1):25–30.
16. Kono R, Poukens V, Demer JL. Quantitative analysis of the structure of the human extraocular muscle pulley system. *Invest Ophthalmol Vis Sci* 2002;**43**(9):2923–32.