Müller's Muscle

A Component of the Peribulbar Smooth Muscle Network

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Purpose: To examine Müller's muscle's horizontal extensions in relation to the peribulbar smooth muscle network.

Design: Observational anatomic study.

Participants: Twenty postmortem orbits (10 right, 10 left) of 15 Asians (8 males, 7 females; age range at death, 61–93 years; mean age, 78.4 years) fixed in 10% buffered formalin.

Methods: After performing a full-thickness 360° incision of the periosteum around the circumference of the orbit, the periosteum was elevated and finally detached near to the orbital apex. Nerves, blood vessels, and the nasolacrimal duct arising from the orbital wall were cut. The lateral orbital wall then was removed at approximately 3 cm posterior to the orbital rim and the retrobulbar content was incised with a sharp scalpel in a coronal plane. The removed orbital content was incised at a plane passing from a point located 15 mm superior to the upper eyelid margin and the globe equator at 3- and 9-o'clock areas. The sliced specimens were dehydrated and embedded in paraffin, cut into 7-μm thickness sections, and then stained with Masson trichrome.

Main Outcome Measures: The medial and lateral extensions of Müller's muscle in relation to the peribulbar smooth muscle network.

Results: In all specimens, Müller's muscle extended medially and laterally. The medial extension reached the medial rectus muscle pulley, which is rich in smooth muscle fibers. The lateral extension reached the lateral rectus muscle pulley by passing through the lacrimal gland fascia of the palpebral lobe, in which 12 specimens also showed a direct extension to the lateral rectus muscle pulley in the posterior part.

Conclusions: Müller's muscle has a medial and a lateral extension to the peribulbar smooth muscle network. These new findings indicated that Müller's muscle is not an independent structure in the upper eyelid, but rather a component of the peribulbar smooth muscle network.

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Müller's supratarsal sympathetic muscle (Müller's muscle) has always been regarded as an independent smooth muscle of the upper eyelid that, together with the levator aponeurosis, constitutes the upper eyelid retractors.[1–6] Müller's muscle originates from the inferior branch of the levator palpebrae superioris (LPS) muscle,[7] lies under the posterior layer of the levator aponeurosis, and inserts onto the superior border of the tarsal plate.[1–6] These anatomic observations have contributed substantially to our understanding of the Müller's muscle function and have facilitated treatment of conditions such as blepharoptosis or upper eyelid retraction in Graves' orbitopathy.[1–6,8,9]

Müller's muscle is a smooth muscle and not a skeletal muscle,[1,2] so when it contracts, it is not to a specific direction. Previous anatomic studies on Müller's muscle have focused mainly on its vertical vector of action,[1–6,8,9] and not on its horizontal or transverse extension. Only 1 report was found in the literature that dealt with such anatomic aspects of Müller's muscle, and it was limited mainly to the muscle's lateral extension, showing that the smooth muscle fibers interdigitate with lacrimal ducts passing from the orbital to palpebral lobe of the lacrimal gland.[10]

It was shown that smooth muscle fibers are distributed in the peribulbar area and form a 3-dimensional smooth muscle network.[11] Substantial bands of smooth muscle and elastin that extend from the region between the inferior rectus muscle and inferior oblique muscle and cross to the medial rectus muscle compose a single functional structure that is known as the *inframedial peribulbar muscle*.[11] This term refers mainly to the smooth muscles around the inferometial orbit.[11] The representative orbital components of the smooth muscle network are the extraocular muscle pulleys,[11–16] which have 3-dimensionally arrayed connecting fibers to neighboring pulleys and other structures,[11,12] such as the medial and lateral aspects of the upper and lower tarsal plates.[17,18]

The upper and lower eyelids were considered analogous anatomic structures.[19,20] Both eyelids have smooth muscle components: Müller's muscle in the upper eyelid[1,2] and the inferior palpebral muscle of Müller in the lower eyelid.[11,19] Based on analysis of sagittal sections, each of these muscles was considered to be an independent structure. However, when analyzed in the coronal plane, the inferior palpebral muscle of Müller is seen as part of the peribulbar smooth muscle network.[11] In the upper eyelid, the exact relationship

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between Müller's muscle and the peribulbar smooth muscle network has not been documented in detail so far.

From an embryologic perspective, the LPS muscle can be thought of as an extraocular muscle,[4,21] and as all other extraocular muscles, it also has a pulley.[22,23] Although the LPS muscle pulley consists of Whitnall's ligament and the intermuscular transverse ligament,[22,23] it is unknown if this pulley contains smooth muscle fibers.[22,23] Müller's muscle is the smooth muscle that is most closely related to the LPS muscle, and it plays a role in active regulation of the LPS muscle,[24] similar to the extraocular muscle pulleys.[15] Müller's muscle has several characteristics that are in common with the extraocular muscle pulleys, and it also may have connections to the adjacent extraocular muscle pulleys. The present study determines if Müller's muscle has any horizontal extensions and connection to the peribulbar smooth muscle network.

Materials and Methods

Twenty postmortem orbits (10 right, 10 left) of 15 Asians (8 males, 7 females; age range at death, 61–93 years; mean age, 78.4 years), fixed in 10% buffered formalin, were analyzed. Ten orbits were studied bilaterally from 5 cadavers and 10 were studied unilaterally. None of the cadavers had any history or clinical evidence of a previous eyelid or orbital trauma, surgery, tumor, Graves' orbitopathy, cerebral nerve palsy, strabismus, or any other periocular pathologic feature. In addition, any history of general neurologic, vascular, or cardiac disease or diabetes mellitus that might have affected the anatomic results was not noted in any of the cadavers.

Consent and approval to use all cadavers for educational purposes and studies was obtained, and all cadavers were registered with the cadaveric service of Aichi Medical University. All methods for securing human tissue were humane and complied with the tenets of the Declaration of Helsinki.

The orbital contents were removed using binocular loupes (high-resolution prismatic [HRP] ×2.5, 340 mm/13 inches; Heine, Herrsching, Germany). After performing a full-thickness 360° incision of the periosteum around the circumference of the orbit, the periosteum was elevated and finally detached near to the orbital apex. Nerves, blood vessels, and the nasolacrimal duct arising from the orbital wall were cut. The lateral orbital wall then was removed at approximately 3 cm posterior to the orbital rim, and the retrobulbar content was incised with a sharp scalpel in a coronal plane. This step enables harvesting an appropriate volume of orbital content while avoiding tissue destruction. The removed orbital content was incised at a plane passing from a point located 15 mm superior to the upper eyelid margin and the globe equator at 3- and 9-o'clock areas (Fig 1).

The specimens were dehydrated, embedded in paraffin, and cut into 7-μm thickness slices. These then were stained with Masson trichrome. Photographs were taken with a digital camera system attached to a microscope (Moticam 2000; Shimadzu Rika Kikai, Tokyo, Japan). Photomerging was carried out with Adobe Photoshop CS2 software (Adobe Systems Co. Ltd., Tokyo, Japan).

Statistical analysis was based on the Mann–Whitney U test. Statistical significance was defined as $P<0.05$. All statistical analysis was carried out using the SPSS II for Windows (SPSS Japan Inc., Tokyo, Japan).

Results

In all specimens, Müller's muscle extended medially and laterally (Fig 2A). The medial extension continued to the medial rectus muscle pulley, which is rich in smooth muscle fibers (Fig 2B). The lateral extension reached the lateral rectus muscle pulley by passing through the lacrimal gland fascia of the palpebral lobe (Fig 2C), and in 12 specimens extended directly to the lateral rectus muscle pulley in the posterior part (Fig 3). Because the lateral extension passes through the lacrimal gland, it appeared thinner than the medial extension, which is not attenuated throughout its course.

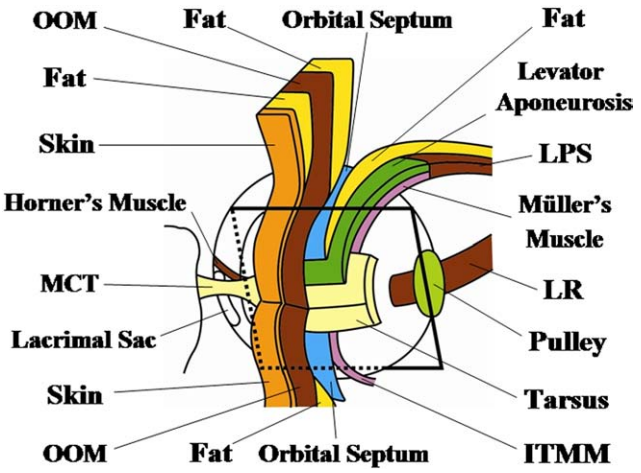

Figure 1. Diagram of the left eyelid and orbit with the lateral part of the eyelid and the lacrimal gland removed showing how to incise the orbital content. The removed orbital content is incised at a plane passing from a point located 15 mm superior to the upper eyelid margin and the globe equator at 3- and 9-o'clock areas. ITTM = inferior tarsal muscle of Müller; LPS = levator palpebrae superioris muscle; LR = lateral rectus muscle; OOM = orbicularis oculi muscle; MCT = medial canthal tendon.

There was no difference in age ($P = 0.424$), gender ($P = 0.480$), or the shape of the lateral extension ($P = 0.374$) between unilateral and bilateral orbit specimens. In addition, no difference was shown in age ($P = 0.244$) and gender ($P = 0.526$) between the 12 specimens that showed a direct lateral extension and the other 8 that did not.

Discussion

Müller's muscle has been considered to be an independent structure in the upper eyelid[1,2,5] and not part of the peribulbar smooth muscle network. The present study shows, however, that Müller's muscle has medial and lateral extensions that reach the medial and lateral rectus muscle pulleys, respectively. Müller's muscle therefore is not just a simple upper eyelid retractor component, but rather a component of the peribulbar smooth muscle network.

We now know that Müller's muscle reaches the medial and lateral rectus muscles' pulleys as well as the upper tarsal plate.[1,2] This is similar to what was documented on the different extraocular muscle pulleys, which also seem to have attachments to adjacent pulleys[11] as well as the tarsal plates.[17–19] However, in contrast to the other pulleys, Müller's muscle does not change the course of the adjacent LPS muscle,[22,23] which is the only anatomic difference between the Müller's muscle and the other extraocular muscle pulleys.

Only 12 specimens demonstrated direct extension of Müller's muscle to the lateral rectus muscle pulley, whereas all 20 specimens showed direct medial extension to the