Original Article

Surgical Microanatomy of the Müller Muscle-Conjunctival Resection Ptosis Procedure

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Purpose: To assess for alterations in the microscopic anatomy that occur as a result of the Müller muscle-conjunctival resection (MMCR) ptosis procedure and to better understand the mechanisms by which MMCR elevates the eyelid.

Methods: Sixteen orbits from 8 fresh frozen Caucasian cadaver heads, ranging from 38 to 100 years of age were used. For each head, MMCR was performed on one side. The contralateral, unoperated orbit served as an anatomic control. Each exenterated orbital contents and excised MMCR specimen was evaluated. The histopathology of the eyelids and MMCR specimens were studied microscopically by staining with hematoxylin-eosin, elastic, and Verhoeff-Masson trichrome.

Results: Müller muscle and conjunctiva were present in all 8 of the excised MMCR specimens. Elastic fibers consistent with Müller muscle tendon or among the smooth muscle fibers were seen within all excised MMCR specimens. The levator aponeurosis was intact in 8 of 8 operated eyelids; however, the aponeurosis was plicated in all. The accessory lacrimal gland tissues were intact in all of the operated and unoperated eyelids.

Conclusions: MMCR works by shortening the posterior lamella, which results in advancement of the levator palpebrae superioris muscle and plication of the levator aponeurosis. Plication of the levator aponeurosis likely contributes to the increased volumetric effect seen clinically after MMCR. Phenylephrine testing can help in fine-tuning the amount of resection, but given the mechanism of action of MMCR, adequate levator muscle function remains a critical factor in the success of the surgery. Moreover, MMCR preserves accessory lacrimal gland tissues.

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First described by Putterman and Urist 1 in 1975, the Müller muscle-conjunctival resection (MMCR) ptosis procedure represents a posterior approach to the correction of ptosis. The exact mechanism by which the surgery lifts the eyelid has been unclear. 2–4 It has been postulated to be secondary to a number of factors, including resection and advancement of Müller muscle (MM) and advancement of the levator aponeurosis. 2,5 This study uniquely uses a cadaveric model to characterize the microanatomic alterations produced with the MMCR procedure. By visualizing the altered microscopic anatomy, we hoped to gain insight into the mechanism of action of the surgery. In seeking a visually integrated depiction of collagen, muscle, and elastic fibers for the histopathologic evaluation, a combined Verhoeff-Masson trichrome stain was included as part of the study.

METHODS

Sixteen orbits from 8 fresh frozen Caucasian cadaver heads (2 male and 6 female) ranging in age from 38 to 100 years (average age, 78 years) were used for the study. In compliance with the University of Chicago policy on research for decedents, the study was registered with the institutional review board and conformed to the principles of the Declaration of Helsinki. An MMCR procedure was performed on one upper eyelid of each cadaver head (4 right upper eyelids and 4 left upper eyelids). The amount of MMCR ranged from 8 to 10 mm (average resection, 9.25 mm). The contralateral, unoperated side was used for anatomic comparison. The procedure was performed as previously described,1,2 including the use of the specially designed clamp (Bausch & Lomb Storz Company, Manchester, MO, U.S.A.). A 6-0 polyglactin suture was used rather than plain gut to facilitate a durable closure throughout the formalin fixation period. In addition, a second running suture, consisting of 10-0 nylon, paralleling the course of the first suture was placed as a histopathologic marker. Care was taken to avoid further plication of tissues with the placement of the second suture.

The excised segment of posterior eyelid tissue was oriented flat on a piece of filter paper and placed in 10% neutral buffered formalin. After the MMCR, both orbits were immediately exenterated and fixed with 10% neutral buffered formalin for 3 weeks. After fixation, the lower eyelid tissue and orbital fat were removed to facilitate histologic processing and sectioning. The orbits were then sectioned parasagittally through the central eyelid along the axis of the orbit. The eyelid specimens were examined grossly under surgical loupe magnification (3.5X-EF, Designs for Vision, Ronkonkoma, NY, U.S.A.).

On the 8 eyelids status post-MMCR, the running 6-0 polyglactin suture was removed, and the 10-0 nylon marking suture was left in place in one half of the parasagittal central eyelid sections. The 6-0 polyglactin suture was removed, because solid foreign material such as sutures cause streaks in the paraffin-embedded tissue block during the process of sectioning. 7

For the other half of the parasagittal central eyelid section of the operated eyelids, both the 10-0 and 6-0 sutures were removed to allow...
for examination of the uninvolved bed of tissue superior to the site of resection. The eyelid specimens were again studied grossly as described (Fig. 1A, B). In 4 of the orbits, the newly visible surface (after release of the sutures) superior to the segment of excised tissue was inked with black histologic tissue paint (#3408-3, Davidson Marking System, Bradley Products, Bloomington, MN, U.S.A.) to further enhance microscopic study of the surgical site (Fig. 1C, D). The excised tissue from the MMCR surgery was cut in a bread loaf fashion.8

The 20 specimens of central eyelid tissue (8 unoperated eyelids, 8 eyelids status post-MMCR, and 4 operated eyelids with complete suture release) and 8 specimens of excised MMCR tissue were processed in paraffin and cut in serial 6-μm sections. All 28 specimens were stained with hematoxylin-eosin, elastic, and Verhoeff-Masson (Masson trichrome counterstained with Verhoeff-Van Gieson elastic stain).9 Masson trichrome stains muscle red and collagen blue, whereas Verhoeff stains elastic fibers black. The microanatomic eyelid changes secondary to the MMCR surgery were cut in a bread loaf fashion.8

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Gross Examination. An intact levator aponeurosis was present in all operated eyelids. In addition, plication of the levator aponeurosis was seen in the operated eyelids (Fig. 1A–D).

Histopathologic Examination. In the unoperated eyelids, vertical bifurcation of the striated muscle fibers of the LPS was seen near the level of Whitnall superior transverse ligament. Rarefaction of the MM was observed (Fig. 2A, B). MM and conjunctiva were present in all the excised MMCR tissue pathology specimens. Elastic fibers consistent with MM tendon or among the MM fibers were seen in all excised MMCR specimens.

The levator aponeurosis was intact in all operated eyelids (Fig. 2C). Levator aponeurosis and LPS were absent in MMCR pathology specimens. Minimal or no residual MM tendon was present on the operated eyelids. Suture closure occurred at the insertion of MM tendon on the tarsal plate (Fig. 2D). Plication of the levator aponeurosis was seen in the operated eyelids (Fig. 2C). Accessory lacrimal gland tissue of the glands of Wolfring and Krause were observed, respectively, in the tarsus and superior fornix of the operated and unoperated eyelids. The superior conjunctival fornix was intact in the operated and unoperated eyelids. The findings seen on Verhoeff-Masson stain were confirmed by the hematoxylin-eosin and elastic stains.

DISCUSSION

Historically, the levator aponeurosis has been considered the main transmitter of the retracting force the LPS exerts on the eyelid. Although early works, such as Berke and Wadsorth,10 describe the role of MM in providing the primary upward pull on the tarsal plate, conceptually ptosis repair for the last half century has been shaped by an age of aponeurotic awareness.11 Within this setting, it is not surprising that MMCR has been postulated to work by advancing the levator aponeurosis.2,5 More recently, there has been renewed interest on the pulling effect that the LPS wields on the tarsal plate through the posterior lamella.12–15

This study demonstrates that the MMCR procedure advances the LPS by shortening the posterior lamella. The anterior lamella, including the levator palpebrae superioris muscle (LPS), the course and integrity of the levator aponeurosis, the presence of accessory lacrimal tissue, and the appearance of the tarsal plate.

FIG. 1. Gross examination photograph of exenterated orbital contents seen after MMCR, parasagittal view along the axis of the orbit. A, Superior border of the tarsal plate and cut edge of conjunctiva and MM are held in place by suture closure. B, Superior border of the tarsal plate (asterisk) and cut edge of conjunctiva and MM are noted after suture release and the eyelid placed on traction. The intact levator aponeurosis is also seen superior to the surgical site (arrow). C, After the MMCR suture was released, the undersurface of the levator aponeurosis (arrow) was inked for better visualization. The superior border of the tarsal plate (dotted white line) and cut edge of conjunctiva and MM (dotted red line) can be seen. D, Plication of the levator aponeurosis (arrow) is demonstrated. Note the formalin fixed tissue without tension resumes the original position.
achieved using MMC. The results showed that the mechanism by which the procedure improves blepharoptosis is independent of the active contraction of MM. It has been postulated that the mechanism of action of the MMC may be due to advancement of the levator aponeurosis. The findings in this study do not support the notion of advancement of the levator aponeurosis if the term advancement implies that the action of the aponeurosis is strengthened. Instead, the histopathologic findings support Dresner’s theory of plication of the aponeurosis and internal advancement of the LPS.

In the phenylephrine test, the direct acting sympathomimetic drug, phenylephrine hydrochloride, is instilled on the ocular surface. The phenylephrine causes MM to contract, which results in a shortened posterior lamella and elevated upper eyelid. The phenylephrine test is read as positive in patients who have an appreciable elevation in their upper eyelid height. MMC is typically performed only in patients with a positive phenylephrine test. Given the mechanism of action of the MMC, however, the role ascribed to the phenylephrine test in assessing patient’s candidacy for the MMC ptosis procedure may be reconsidered. The findings in this study agree with the approach taken by Baldwin et al. in performing their modified MMC in phenylephrine-negative patients with intact function of the LPS.

MM and the levator aponeurosis are loosely bound together along their length. As described, the MMC procedure includes the intentional separation of MM from its weak anterior attachments to the levator aponeurosis and release of the Desmarres retractor prior to closing the clamp. These weak attachments are evident surgically when performing a Hughes tarsocconjunctival flap procedure or in anterior levator aponeurotic advancement surgery. Thus, from a surgical perspective, it is unlikely that the levator aponeurosis would easily be included within the resected tissue. Moreover, even without active separation of the lamella, inclusion of the anterior lamella tissues is less likely when one considers the widening of the postaponeurotic space and natural separation of the lamella in eyelid eversion as shown in depictions by Jones and Beard. This study affirms previous reports on surgical pathology specimens after both the MMC procedure and other related posterior lamellar approaches, such as the Fasanella-Servat. In this study, and the previous studies, levator aponeurosis has been absent from pathology specimens consistent with a resection of the posterior lamellar tissues.

With high success rates in treating patients with ptosis reported by Puttermann et al. and other surgeons, it is well recognized that shortening of the posterior lamella is an effective means of strengthening the action of the LPS surgically. Thus, the recently reported presence of levator aponeurosis in surgical pathology specimens (Milla Peñalver C, González-Candial M, Gálvez C, et al. Presented at ESOPRS Annual Meeting, Ljubljana, Slovenia, 2007) likely represents a modification of the MMC procedure in that both lamellae are resected.

While the cadaver model effectively showed the micro-anatomic alterations produced as a result of the MMC, one limitation of the study is the inability to comment on the cicatrical and reorganizational changes that take place in vivo. However, given the sparing of the anterior lamellar tissues seen in the study, it is interesting to consider the volume-enhancing
effects that are seen clinically after MMCR surgery (Fig. 4A, B). The plicated levator aponeurosis may contribute to volume enhancement similar to that described for the plication of the orbicularis oculi muscle seen in soft tissue sparing cosmetic blepharoplasty. The eyelid crease may lower due to a raised eyelid height relative to the plicated overlying levator aponeurosis. This reduced vertical pull of the anterior levator insertions in the orbicularis oculi muscle and skin may also allow the eyelid crease to sag lower. Thus, it is possible that in an involutionally ptotic eyelid, weak or rarefied posterior lamellae (MM and the levator aponeurotic tarsal insertion) result in an anterior muscle-skin aponeurotic insertion that is under greater strain to provide more of the lift for eyelid, which manifests clinically as a higher eyelid crease (Fig. 4A).

Although the MMCR ptosis procedure has a low rate of complications, concerns have been raised about patient’s developing dry eyes after the surgery based on the excision of healthy conjunctival tissues. This study demonstrates preservation of the superior conjunctival fornix and the glands of Krause. In addition, the accessory lacrimal glands of Wolfring were seen in the operated eyelids. These microanatomic findings establish a clinicopathologic correlation, with published clinical reports describing the lack of any effect on tear production by MMCR procedure.

Previous work by Collin et al. found that MM and its tendon normally became thinner and elongated with increasing age. Findings by Buckman et al. correlated the earlier description and suggested that MM migrates away from the superior tarsal border over time. Cahill et al. described fatty infiltration of MM. In this study, the rarefied portions of the MM (Fig. 2A, B) were excised, which resulted in the anatomic reapproximation of thicker, more posterior portions of the MM with the insertion of its tendon onto the tarsal plate (Fig. 2C, D).

The surgical microscopic anatomy of the suture closure in the MMCR ptosis procedure was observed using the 10-0 nylon marking suture. By removing the 6-0 polyglactin suture and leaving only the smaller diameter 10-0 nylon suture in place, the complication of streaks in the paraffin-embedded tissue block was avoided. The study demonstrated that the tarsal aspect of the MMCR takes place at the insertion of the MM tendon on the tarsus. It is interesting to consider that sutures in levator aponeurosis advancement ptosis repair are placed in the upper third of the tarsal plate. Given that the levator aponeurosis attaches to the lower third of the tarsus, it is likely that traditional levator aponeurotic advancement repairs the action of the posterior lamellar elevation of the tarsus by the LPS. It follows that the eyelid crease is re-formed where the natural functional anterior attachments of the levator aponeurosis are reconstructed.

The Verhoeff’s elastic and Masson trichrome stains have been commonly used for anatomic study. To our knowledge, however, this study is the first to use the combination Verhoeff-
Masson stain for examining eye or ocular adnexal anatomy. Combined stains use less material and save costs. However, most importantly, in this study the Verhoeff-Masson stain facilitated histopathologic assessment by providing a visually integrated depiction of collagen, muscle, and elastic fibers. In this study, a cadaver model was uniquely used to demonstrate the microanatomic alterations produced by the MMCR surgery. Aesthetically, the spared anterior lamellar tissues and plicated levator aponeurosis favorably contribute to the volume-enhancing effect of the MMCR ptosis procedure. The MMCR procedure corrects blepharoptosis by shortening the posterior lamella and thus internally advancing the LPS. Given the mechanism of action, any patient with normal levator muscle function is potentially a candidate for the MMCR ptosis procedure.

REFERENCES