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REVIEW ARTICLE

MÜLLER'S MUSCLE-CONJUNCTIVAL RESECTION IN THE CORRECTION OF UPPER EYELID PTOSIS – A REVIEW OF SURGICAL TECHNIQUES

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Abstract: The aim of this article is to explore and systematize knowledge about Müllerectomy, a procedure for the treatment of mild and moderate ptosis. Drooping of the upper eyelid affects not only vision and appearance but also psychosocial well-being. A literature review was conducted using PubMed databases, searching for terms related to the surgical technique of Müller's muscle-conjunctival resection (MMCR). The period from 1975 to 2020 was considered. The paper discusses the differences between classical MMCR and its later modifications. The literature analysis shows that the authors of the MMCR modification have been refining surgical techniques for several decades to achieve the most optimal eyelid margin elevation effect with minimal tissue traumatization. It is anticipated that this review will aid clinicians in selecting the surgical method, thereby improving surgical outcomes.

Keywords: Müllerectomy, ptosis, surgical techniques

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INTRODUCTION

Drooping of the upper eyelid (ptosis) is a condition that significantly affects the quality of life of both adult and pediatric patients. It is not only a medical issue but also a psychosocial one, impacting professional functioning, facial appearance, perception of ptosis patients by others, and consequently, their well-being and quality of life [15].

Müller's muscle transconjunctival resection is an effective, rapid, predictable, and safe treatment for mild (0.5-1.5 mm) and moderate (2-3 mm) ptosis in patients with good levator palpebrae superioris muscle function (>10 mm) and a positive 10% phenylephrine test.

Indications for Müllerectomy include:

- acquired involutional ptosis (age-related changes, chronic use of contact lenses or epiprostheses),
- Horner's syndrome,
- persistent ptosis following anterior-access procedures.

Contraindications for classical Müllerectomy include:

- myogenic ptosis,
- ptosis with negative phenylephrine test (though modifications to the method exist),
- ptosis with poor levator function (<10 mm),
- paralytic ptosis [16].

The superior (Müller's) tarsal muscle, first described by Müller in 1858, measures approximately 10 mm in length, 15 mm in width, and 0.1-0.5 mm in thickness [7]. It is a smooth, sympathetically innervated muscle. Originating at the level of the Whitnall's ligament, within the superior fornix of the conjunctival sac, it descends parallel to the levator palpebral aponeurosis, terminating at the upper edge of the eyelid through a tendon with a diameter of 0.5-1.5 mm. The attachment of the levator aponeurosis to the tarsus is less pronounced. According to Berke and Wadsworth, Werb and Bang et al., the levator aponeurosis ter-

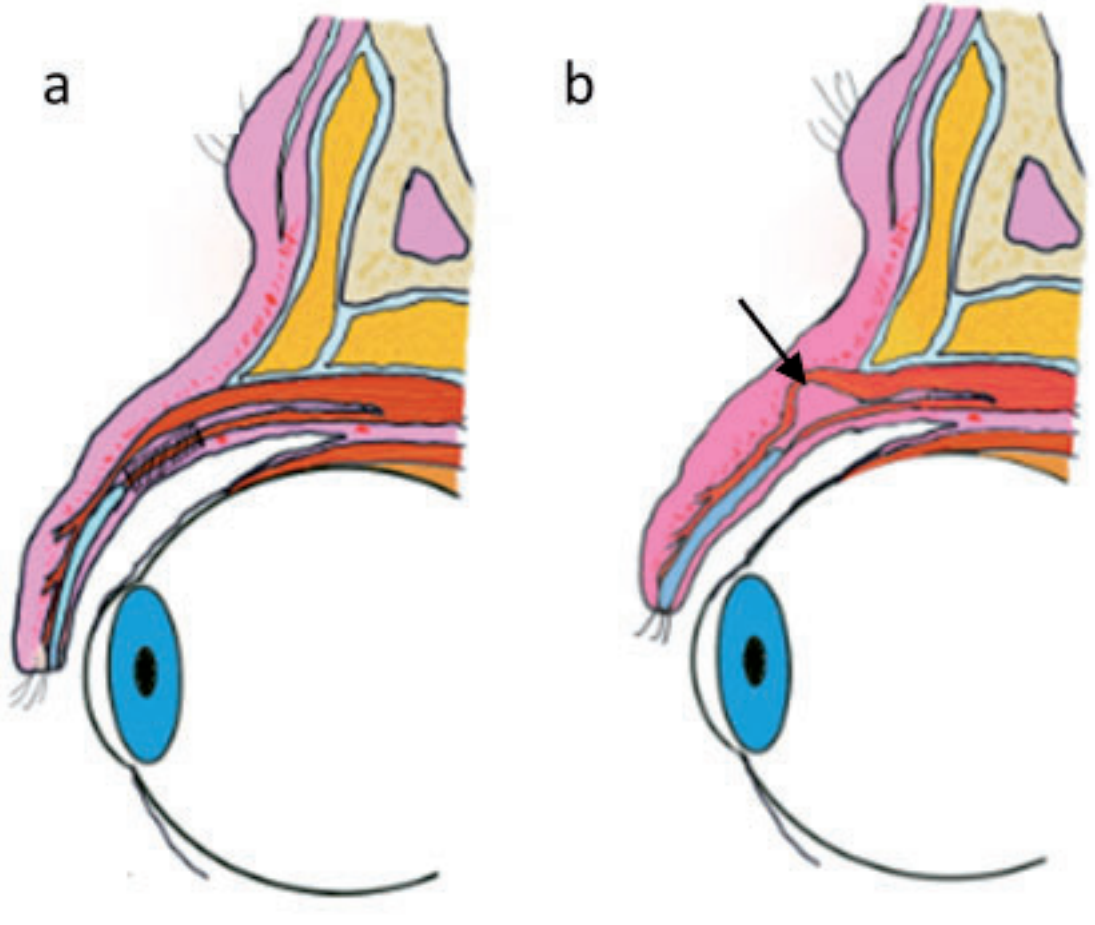

Fig.1. Schematic representation of the eyelid anatomy before (a - marked fragment of the resected Müller's muscle) and after Müllerectomy (b). Noteworthy is the plication of the aponeurosis of the levator muscle after the procedure (arrow). (Source: own material).

Tab.1. Nomogram for transconjunctival Müllerectomy according to Dresner [5].

Desired amount of eyelid lift (mm)	Range of transconjunctival Müllerectomy
1.0	4.0
1.5	6.0
2.0	8.0
3.0	10

minates blindly in a transverse fold 2-3 mm above the superior tarsal plate, supporting only the skin, orbicularis muscle and eyelashes, while the force of the levator muscle is transferred to the tarsus by Müller's muscle, which functions akin to a spindle. Consequently, Müller's muscle is involved in the lifting of the upper eyelid (about 2 mm) [1,2,5,6,8]. With advancing age, Müller's muscle becomes thinner, more elongated and becomes infiltrated with adipose tissue, directly influencing the lowering of the eyelid margin [10].

The mechanism by which Müllerectomy lifts the eyelid has been debated for decades. Histopathological examinations conducted on the cadavers of patients who underwent Müllerectomy while alive have revealed that the therapeutic success of ptosis surgery relies on several mechanisms involved in the posterior approach: 1) plication and displacement of the Müller's muscle complex and the levator aponeurosis in relation to the tarsus, 2) local volumetric effect, 3) wound scarring, which has an additional contracting effect [11,12]. These mechanisms collectively constitute the essence of Müllerectomy, i.e. lifting the upper eyelid margin by transferring the contraction force of the levator muscle directly to the tarsus, without involving the aponeurosis [8] (Fig.1).

A commonly used algorithm for determining the extent of Müller's muscle resection is the Dresner's nomogram, developed in 1991. This nomogram bases the extent of the resection on the degree of eyelid ptosis and the degree of eyelid lift (in mm) in response to 10% phenylephrine administered into the conjunctival sac (some authors use a concentration of 2.5% or, alternatively, 0.5% apraclonidine) [12]. The test is considered positive if the free edge of the upper eyelid rises by ≥2mm after 5 minutes (phenylephrine is an α-adrenergic receptor agonist, and Müller's muscle is sympathetically innervated). According to Dresner's algorithm, a 4 mm excision of Müller's muscle and conjunctiva is performed to lift 1 mm of the eyelid margin. To achieve the desired eyelid elevation of 1.5mm, 2mm, and 3mm, 6mm, 8mm and 10mm of Müller's muscle and conjunctiva should be excised, respectively [16] (Table 1). It is not recommended to correct ptosis greater than 3 mm with this method.

Internal access procedures can be further divided into the "closed" technique using the Putterman clamp and the "open sky" technique using deeper surgical resection.

SURGICAL TECHNIQUES

Classic Müller's Muscle-Conjunctival Resection (MMCR)

First described in 1975 as a resection of Müller's muscle and tarsal conjunctiva, also known as "internal ptosis surgery" because it is performed from the posterior approach (after everting the eyelid) [10]. Depending on the needs, it can be performed simultaneously with the removal of excess eyelid skin. After marking the projection of the pupillary line (when looking straight ahead) and the extreme borders of the corneal limbus on the free edge of the upper eyelid with a marker, the eyelid is anesthetized. The procedure is usually performed under local infiltration anesthesia, e.g. 0.5-1.0 ml of 2% lignocaine with bupivacaine. Adrenaline should not be added to the anesthetic mixture as it affects the sympathetically innervated Müller's muscle. After placing a pair of rein sutures through the upper lid margin, the eyelid is everted on the Desmares retractor (Fig. 2a and b). A second parallel line is then drawn towards the superior conjunctival fornix at a distance corresponding to the predetermined extent of resection. Silk traction sutures are placed midway between the lines to help separate the conjunctiva and Müller's muscle from the underlying levator aponeurosis (Fig. 2c). The sutures are tensioned upwards with uniform force, and the Putterman clamp is tightened (omitting the tarsal plate) to ensure the desired resection of the muscle.

In the next step, sutures (polypropylene 7.0) are tied under the clamp (Fig. 2d), and then the clamped tissue is cut with a scalpel, keeping the blade diagonal to the tweezers to avoid cutting the sutures (Fig. 2e). After excision of a certain length of the Müller's muscle, the conjunctiva should be sutured with an absorbable continuous locking suture (polysorb 8-0) (Fig. 2f). It is recommended to sew from the nose to the temple and to hide the final suture under the conjunctiva [17]. The rein sutures are removed. Some surgeons

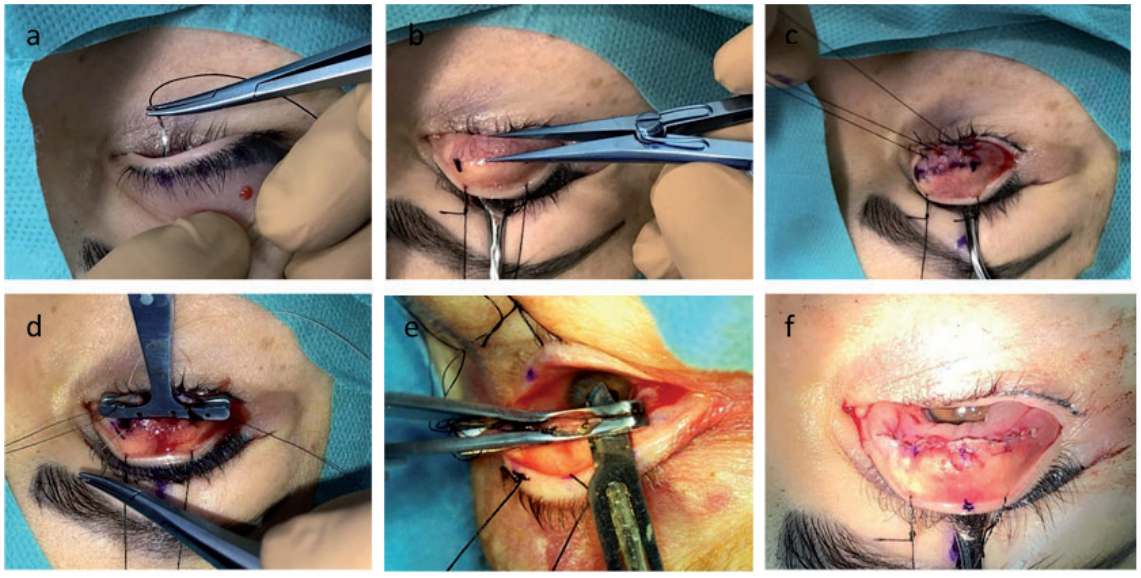

Fig. 2. Selected stages of classic Müller's muscle-conjunctival resection. Detailed description in the text (Source: own material).

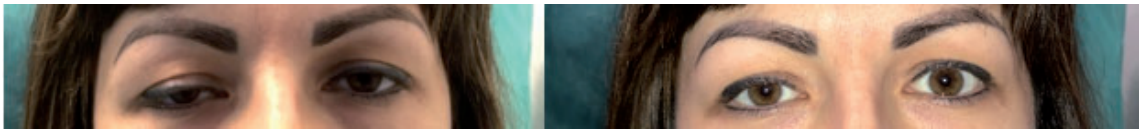

Fig. 3. On the left, a patient with right-sided ptosis of the upper eyelid. On the right, the same patient one month after a classic Müllerectomy (Source: own material. The patient's consent for image publication was obtained).

place a contact lens to protect the cornea from the irritating effects of conjunctival sutures.

There are several modifications to the suturing technique. One of them involves running the final part of the conjunctival suture through the full thickness of the eyelid and tying it outside, thereby reducing the risk of corneal erosion is reduced without the need for a contact lens [17]. Some authors suture the conjunctiva under clenched Putterman clamp, severing the Müller's muscle with Wescott scissors. Additionally, there are modifications that combine Müllerectomy with minor tarsectomy to increase the extent of ptosis correction if the phenylephrine test is negative [13].

Müllerectomy with tarsectomy

A method combining Müllerectomy and tarsectomy was introduced in 2002. Perry et al. [3] modified the Dresner nomogram (for cases with insufficient response to phenylephrine): 9 mm of conjunctiva and Müller's muscle + x mm of tarsus are excised, where x is the distance in mm of undercorrection in the phenylephrine test. Each millimeter of the excised disc represents an additional 1 mm lift of the eyelid margin. This method enables correction of ptosis greater than 3-4 mm, provided good upper eyelid levator function is maintained and the phenylephrine test results are satisfactory. The maximum acceptable disc excision is 5 mm; therefore, this method can achieve up to 7 mm elevation of the upper eyelid [6].

"Open sky" Müllerectomy

Introduced in 2003 by Lake et al. [12], this method involves visualizing Müller's muscle prior to subtotal (9 mm) resection. An incision is made in the region of the upper edge of the tarsal plate, facilitating localization of Müller's muscle and the levator aponeurosis. Müller's muscle is then easily separated from the aponeurosis (even using spongostan). After the muscle is excised, its stump is sutured with the conjunctiva and the upper edge of the tarsus. Single sutures are passed through the entire thickness of the eyelid at the level of the upper eyelid crease previously marked with a marker. The middle suture can be used for intraoperative verification and adjustment of the eyelid margin height [10].

The technique offers high predictability – excision of the 9 mm Müller's muscle lifts the eyelid margin by the same height as achieved in the 10% phenylephrine test (10). Moreover, it allows for intra- and postoperative adjustment of the eyelid margin height in case of overcorrection. The middle suture,

tied on the basis of a cotton roll, plays a crucial role. Sutures are typically removed between the 5th day and the 3rd week after surgery, depending on the position of the eyelid margin [4].

Single suture Müllerectomy

It consists in the use of an absorbable, single continuous 6-0 horizontal suture, which is carried out towards the temple (or nose, depending on preference) under Putterman clamp fastened to the conjunctiva and Müller's muscle (Fig. 4). After the suture is tied, the tissue block is cut under Putterman clamp. According to the authors, the effectiveness of this method is not inferior to the classic Müllerectomy [2].

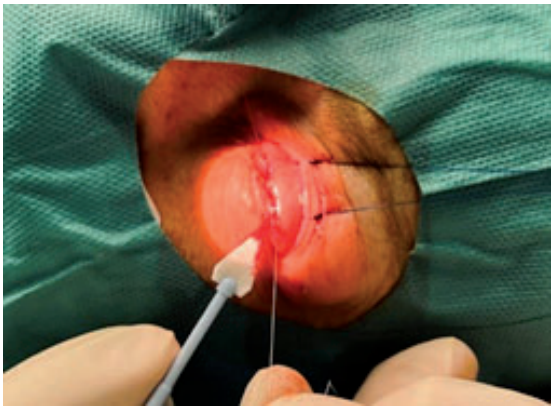

Fig. 4. Single suture Müllerectomy (Source: own material).

Sutureless Müllerectomy

This method is based on the now widely accepted theory of the intrinsic adhesive properties of the upper eyelid tarsal complex, which becomes particularly evident after excessive resection of Müller's muscle (overcorrection). Conjunctival traction sutures are not used during the procedure. Instead, two pairs of forceps are used, attached to the conjunctiva and Müller's muscle marked with a marker on the temporal and nasal side. A Putterman clamp is placed and a long, straight hemostat is clamped directly underneath. Tissue is excised between the hemostat and Puterman clamp. The tissue is then gently cauterized while removing the hemostat [5]. This modification was designed with postoperative corneal protection in mind. The absence of a conjunctival suture minimizes the risk of corneal erosion.

Müllerectomy with fibrin sealant

Another modification is the Müllerectomy with Tisseel fibrin sealant (Baxter International, Inc., Deerfield, IL). This preparation is used at the end of the procedure instead of conjunctival sutures to close the surgical wound. In addition to its adhesive effect, Tisseel primarily has hemostatic properties. The essence of fibrin glue is to mimic the final stages of the coagulation cascade, where fibrinogen is activated by thrombin, leading to the formation of a fibrin clot. The method was developed by Foster et al. in 2006, demonstrating high effectiveness (comparable to methods using sutures) and low complication rates, including the absence of corneal epitheliopathy [5].

TTMT – Transconjunctival Müller's Muscle Tucking

This procedure is performed without excision of the conjunctival-muscular block. Instead, sutures are used to shorten Müller's muscle by ligating it under the palpebral conjunctiva. According to the authors of this method, tucking the 7-8 mm Müller's muscle lifts the eyelid margin by 1 mm [6]. TTMT is now more widely known and used in East Asian countries, especially South Korea, although the correct nomogram has not been definitively established. This procedure is popular because it allows for the simultaneous creation of the upper eyelid crease (about 50% of Asians do not have it). On the skin of the upper eyelid, at the planned course of the future palpebral crease, six horizontal lines are marked in a sitting position, indicating where the sutures will be placed. One millimeter below this line, two 2 mm lines are marked in the projection of the limbus on the eyelid, both lateral and medial (Fig. 5a). These lines guide the sutures for tucking Müller's muscle. Nylon 7-0 sutures are passed through the full thickness of the eyelid, starting near the upper margin of the tarsus, passing under Müller's muscle and the conjunctiva, and back to the exit point of the tarsus – 2–3 mm from it, creating a fulcrum for tucking. The suture is tied from the skin side, and the procedure is repeated at the second point marked 2 mm further (Fig. 5b). The advantages of this method include intraoperative verification of the eyelid margin height, less invasiveness, speed, and relative ease of performance. However, limitations include a small range of ptosis correction (<2 mm), recurrent ptosis in 8.8% of patients, and asymmetry of the upper eyelid margin [6].

CONCLUSION

Recently, modifications of the classic Müller's muscle-conjunctival resection have been gaining popularity due to increasing functional and aesthetic demands. As early as the 1980s, Guyron

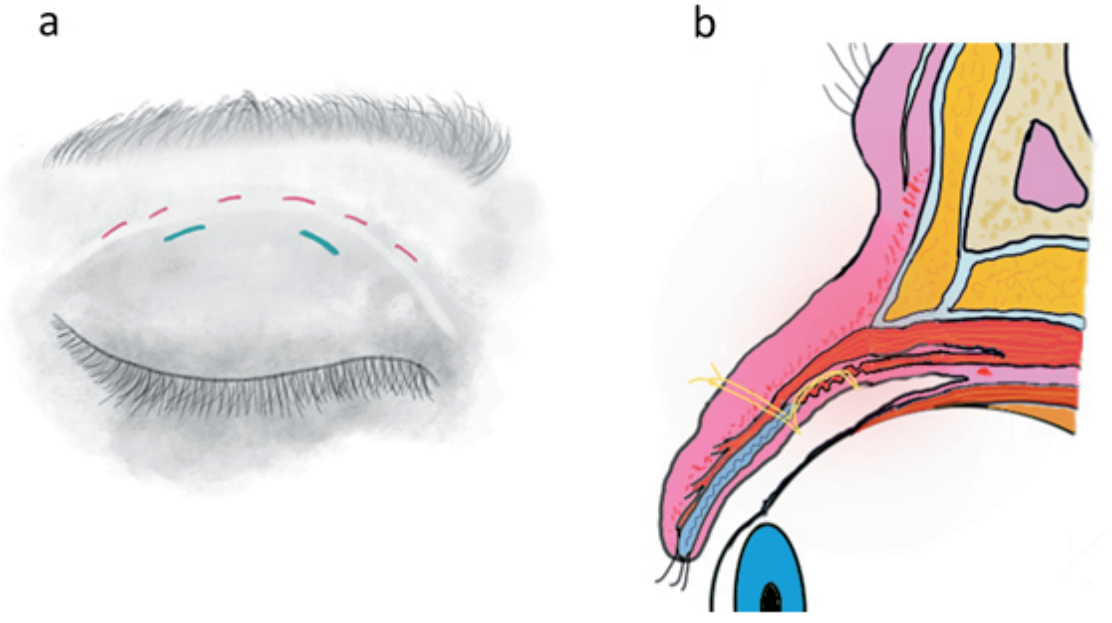

Fig. 5a. Marked guide lines for Müller's muscle tucking (blue) and suture insertion to create the palpebral crease (pink).
Fig. 5b. Schematic representation of the Müller's muscle tucking concept (Source: own sketch, modified according to [6]).

and Davies modified the conjunctival mattress suture technique by ending it on the skin of the upper eyelid, thereby reducing the risk of corneal epitheliopathy [10]. In turn, the "open sky" technique allows direct visualization of the anatomical structures of the eyelid, including Müller's muscle and its easy separation from the levator without the use of a Putterman clamp. This reduces the risk of damage to the levator aponeurosis. The procedure does not affect the shape of the eyelid margin and is predictable. This method also allows perioperative verification of the extent eyelid margin lift – if overcorrection occurs, sutures tied on the skin of the eyelid can be removed at a safe interval [14].

Single suture techniques, sutureless Müllerectomy, and the use of tissue sealants have further increased the safety profile of posterior surgery. These methods have proven to be not only as effective as the classical method but also much faster and reduce the discomfort associated with the sensation of a foreign body and the risk of corneal abrasion. An additional advantage is their relative ease of performance and a quick learning curve, even for novice surgeons [5].

The Müllerectomy procedure can be performed simultaneously with aesthetic procedures such as blepharoplasty or upper eyelid crease formation, which is popular among some Asians with monolids. This is feasible thanks to the minimally invasive TTMT method, which is performed without cutting the tissue, using only a nylon suture to tuck Muller's muscle. According to the authors of this method, the effect lasts longer than 6 months (patient observation is still ongoing) [6].

To sum up, Müllerectomy is an effective, simple, and safe method for the surgical treatment of mild and moderate ptosis. It is less invasive compared to levator aponeurosis procedures. The Müllerectomy procedure does not involve the orbital septum and fat pads, which is particularly beneficial for patients with a high upper eyelid sulcus and fat atrophy [4,14]. As a posterior approach procedure, it does not leave visible scars, does not distort the upper eyelid margin, and does not require the removal of a large range of tissues, thereby reducing the duration of surgery, convalescence period, and the risk of hemorrhage into the orbit. Müllerectomy requires reoperation less frequently (<3%) compared to anterior approach (17%) [13,14]. Post-operative complications such as dry eye are rare and, according to recent studies, statistically insignificant in the long postoperative period [1], making Müllerectomy a safe procedure for the ocular surface.

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