



# Sutureless Conjunctiva-Sparing Posterior Ptosis Repair Surgery: A Novel Technique

RONALD MANCINI, PARSHA FOROUZAN, ZACHARY G. KEENUM, PHILLIP A. TENZEL, AND W. MATTHEW PETROLL

- **PURPOSE:** Müller muscle-conjunctival resection (MMCR) is a popular posterior/internal surgical approach to cases of mild to moderate blepharoptosis with good levator function. MMCR necessitates the removal of healthy conjunctiva and exposes the cornea to suture material. The goal of this study is to describe a novel sutureless conjunctiva-sparing Müllerectomy (CSM) surgery and demonstrate its long-term efficacy, efficiency, and safety.
- **DESIGN:** IRB approved retrospective study of patients undergoing sutureless conjunctiva-sparing posterior ptosis repair surgery.
- **METHODS:** The medical records of 100 patients (171 eyes) who underwent sutureless CSM with a minimum follow-up interval of 6 months were retrospectively reviewed. Photographs were analyzed using ImageJ software. Outcome measures were derived from margin reflex distance 1 (MRD1) and palpebral fissure height (PFH) at various postoperative timepoints.
- **RESULTS:** Mean  $\Delta$ MRD1 and  $\Delta$ PFH at 6 months were  $2.85 \pm 0.98$  mm and  $2.60 \pm 1.38$  mm, respectively. Symmetry within 1 mm was observed 91% of cases. Sutureless CSM took 4.42 minutes on average compared to 8.45 minutes for traditional MMCR. There were no corneal abrasions or ocular complications. The reoperation rate was 2.3% (1 case of overcorrection and 3 cases of undercorrection) per eye.
- **CONCLUSIONS:** Sutureless CSM is a promising alternative to traditional MMCR and sutured CSM based on long-term outcomes, symmetry, shorter operative time, and low complication rate. **NOTE:** Publication of this article is sponsored by the American Ophthalmological Society. (Am J Ophthalmol 2023;251: 77–89. © 2023 Elsevier Inc. All rights reserved.)

**B**LEPHAROPTOSIS—DERIVED FROM THE GREEK *blepharon*, or eyelid, and *ptosis*, or fall—is defined as drooping and descent of the upper eyelid.<sup>1</sup> Although there is no absolute value that defines visually significant blepharoptosis, most experts agree that a margin reflex distance 1 (MRD1), which is defined as the distance from the central corneal light reflex to the central upper eyelid margin, of 2 mm or less is visually significant. In addition, minor abnormalities in contour and symmetry of the upper eyelid can be readily perceived, as the eyes are the focal point of the face.<sup>2</sup> Therefore, the objective of blepharoptosis repair is to elevate the upper eyelid to improve the visual field while maintaining an aesthetically pleasing contour and symmetry.

There is some disagreement as to when ptosis surgery first was performed, with some arguing that ancient Arabian ophthalmologists were the first to perform the surgery<sup>3-5</sup> and others citing the first documentation of the procedure by Aulus Cornelius Celsus in his publication *De Ru Medica* around 100 AD.<sup>6</sup> Modern ptosis surgery is typically classified into anterior/external approaches, posterior/internal approaches, and linkage-type procedures that rely on the frontalis muscle in cases of poor levator function. Many iterations abound in the literature, but the most commonly performed techniques are anterior levator resection (an anterior/external approach),<sup>7</sup> Müller muscle-conjunctival resection (MMCR, a posterior/internal approach),<sup>8</sup> and frontalis suspension (a linkage-type procedure).<sup>9</sup> In patients with intact levator function, there are proponents of the anterior approach and proponents of the posterior approach.

MMCR is a popular posterior approach for cases of mild to moderate ptosis with good levator function because it provides predictable results<sup>10</sup> without extensive tissue manipulation, visible scar formation, or alteration of eyelid contour compared to anterior ptosis repair.<sup>11</sup> The first modern description of posterior ptosis repair is often attributed to Dr. William Bowman, who described transconjunctival levator resection in 1857.<sup>12,13</sup> Modifications and advancements continued with Blaskovics,<sup>14</sup> Agatson,<sup>15</sup> and countless others until 1961 when Dr. Rocko Fasanella and his fellow, Dr. Javier Servat, first described their experience with the now eponymous Fasanella–Servat procedure, a simpli-

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From the Department of Ophthalmology, University of Texas Southwestern Medical Center, Dallas, Texas, USA

Inquiries to Ronald Mancini, University of Texas Southwestern Medical Center, Dallas, Texas, USA; e-mail: [Ronald.Mancini@UTSouthwestern.edu](mailto:Ronald.Mancini@UTSouthwestern.edu)

fied method of posterior ptosis repair that involves partial resection of anatomically normal tarsus.<sup>16</sup> Further modifications and modernization of the technique was first described almost 50 years ago by Drs. Alan Putterman and Martin Urist in 1975. The procedure, termed MMCR, involves partial excision of the Müller muscle and overlying conjunctiva.<sup>8</sup> MMCR involves plicating a predetermined length of Müller muscle and conjunctiva to be excised, suturing the base of the plicated tissue, and excising the tissue outside the suture.<sup>8,17-23</sup> This procedure preserves the anatomically normal tarsus and avoids many of the problems associated with the Fasanella–Servat procedure secondary to tarsal excision, and has essentially replaced it as the posterior approach of choice for most surgeons. MMCR, however, relies on resection of anatomically normal conjunctiva and the use of suture material in contact with the ocular surface. The suture material on the posterior surface of the eyelid remains exposed to the cornea and may lead to foreign body sensation or corneal abrasion.<sup>24,25</sup> Some surgeons place bandage contact lenses prophylactically to protect the cornea<sup>26,27</sup>; some avoid posterior repairs in “high risk” patients (history of bleb, corneal transplant, and other anterior segment pathologies); and surgical variations aim to bury or externalize the knots to reduce the risk of an abrasion.<sup>28,29</sup> However, the risk of corneal irritation and damage remains, and the suture material may also cause a foreign body granuloma<sup>24</sup> or discomfort during removal at the postoperative appointment.

Much like the MMCR improved upon the Fasanella–Servat with the preservation of normal tarsus, we have previously described a conjunctiva-sparing Müllerectomy (CSM) that preserves anatomically normal conjunctiva.<sup>30</sup> A conjunctival flap is dissected, and the underlying Müller muscle is isolated, sutured, and excised in a manner similar to that in MMCR. The advantages of this procedure include preservation of anatomically normal conjunctival tissue, retention of goblet cells important for ocular surface health,<sup>31</sup> conservation of conjunctiva for future surgical procedures (eg, patients with glaucoma or anophthalmic socket),<sup>32,33</sup> maintenance of superior fornix depth (R. Mancini, unpublished data 2012), and prevention of corneal damage as the conjunctival flap is replaced over the sutures. The benefits of CSM are numerous, but the technique introduces an additional step of conjunctival dissection (approximately 2.5 minutes of additional operating time per eyelid in the hands of an experienced surgeon),<sup>30</sup> and relies on suturing of Müller muscle with some of the potential negatives of suture material on the back surface of the eyelid.

We have streamlined CSM by eliminating suturing to improve an already anatomically targeted and effective approach to posterior ptosis repair by making it faster, safer, and more comfortable for the patient. Previous studies have demonstrated the efficacy of sutureless methods, including simple mechanical compression of Müller muscle within a clamp,<sup>34,35</sup> cauterization of the muscle,<sup>36</sup> and even the

use of fibrin glue.<sup>37-39</sup> We adopted cauterization because of hemostasis, low cost, and the fact that a conjunctival flap would be replaced over any charred remains, providing a natural corneo-protective surface. The goal of this study is to describe the novel surgical technique of sutureless CSM and to demonstrate its long-term efficacy, efficiency, and safety.

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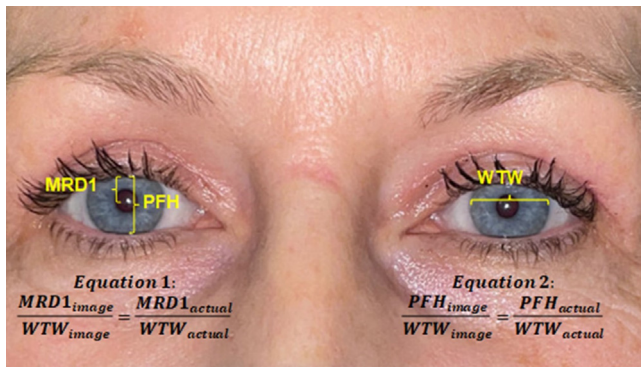
## METHODS

• **PATIENTS AND PROCEDURES:** The Institutional Review Board (IRB) at the University of Texas Southwestern Medical Center approved the collection of patient information before initiation of this retrospective study. The data collection process was compliant with the Health Insurance Portability and Accountability Act of 1996 (HIPAA). All patient information was deidentified in our records once the data collection process was complete. Informed consent was obtained in cases in which identifiable patient information such as photographs were considered for publication.

The charts of all patients who underwent ptosis repair by a single faculty oculoplastic surgeon (R.M.) from October 2019, when sutureless CSM was first implemented, until November 2021 were obtained. The charts were reviewed retrospectively to identify patients who underwent sutureless CSM and met the inclusion and exclusion criteria. Inclusion criteria were any level of ptosis with acceptable levator function ( $\geq 10$  mm) and documented follow-up with photographs of a minimum of 6 months. Exclusion criteria included prior ptosis surgery, instability of the disease process (eg, recent trauma or cranial nerve palsy, untreated myasthenia gravis), and any history of cicatricial conjunctival disease. All patients who undergo posterior ptosis repair at our institution typically meet these criteria.

Main outcome measures were derived from margin reflex distance 1 (MRD1), the distance from the corneal light reflex to the upper eyelid margin, and palpebral fissure height (PFH), the distance between the central upper and lower eyelid margins.<sup>40</sup> MRD1 was measured preoperatively and at postoperative week 1 (POW1), postoperative week 6 (POW6), postoperative month 6 (POM6), and postoperative year 1 and beyond (POY1+). PFH was measured preoperatively and at POM6. Other variables extracted from the charts included age, sex, etiology of ptosis, length of muscle plicated, concurrent eyelid procedures, duration of procedure, and postoperative complications.

MRD1 and PFH were measured using standardized photographs (patient in the frontal position, eyelids open, and facial muscles relaxed) taken by a single ophthalmic technician and publicly available image analysis software (ImageJ, US National Institutes of Health) as outlined previously.<sup>41,42</sup> MRD1 was calculated by measuring the number of pixels from the corneal light reflex to the upper eyelid



**FIGURE 1.** Estimation of the margin reflex distance 1 (MRD1) and palpebral fissure height (PFH) using standardized patient photographs. Image analysis software (ImageJ, US National Institutes of Health) was used to measure the MRD1, PFH, and horizontal corneal white-to-white (WTW) distances in pixels. The values were substituted for MRD1<sub>image</sub>, PFH<sub>image</sub>, and WTW<sub>image</sub> in Equation 1 and Equation 2. The average horizontal corneal WTW distances in male and female patients, 11.77 mm and 11.64 mm, respectively, were substituted for WTW<sub>actual</sub>.<sup>43</sup> The actual MRD1 and PFH values were estimated by solving Equation 1 for MRD1<sub>actual</sub> and Equation 2 for PFH<sub>actual</sub>. In effect, pixels in the image were converted to millimeters using the horizontal corneal WTW distance as a conversion factor.

margin and the pixels spanning the horizontal corneal diameter (Figure 1). Using average horizontal corneal diameters, 11.77 mm and 11.64 mm in men and women, respectively,<sup>43</sup> the actual MRD1 was calculated. PFH was similarly calculated by measuring the number of pixels from the central upper eyelid margin to the central lower eyelid margin and using average corneal diameters as a conversion factor to millimeters.

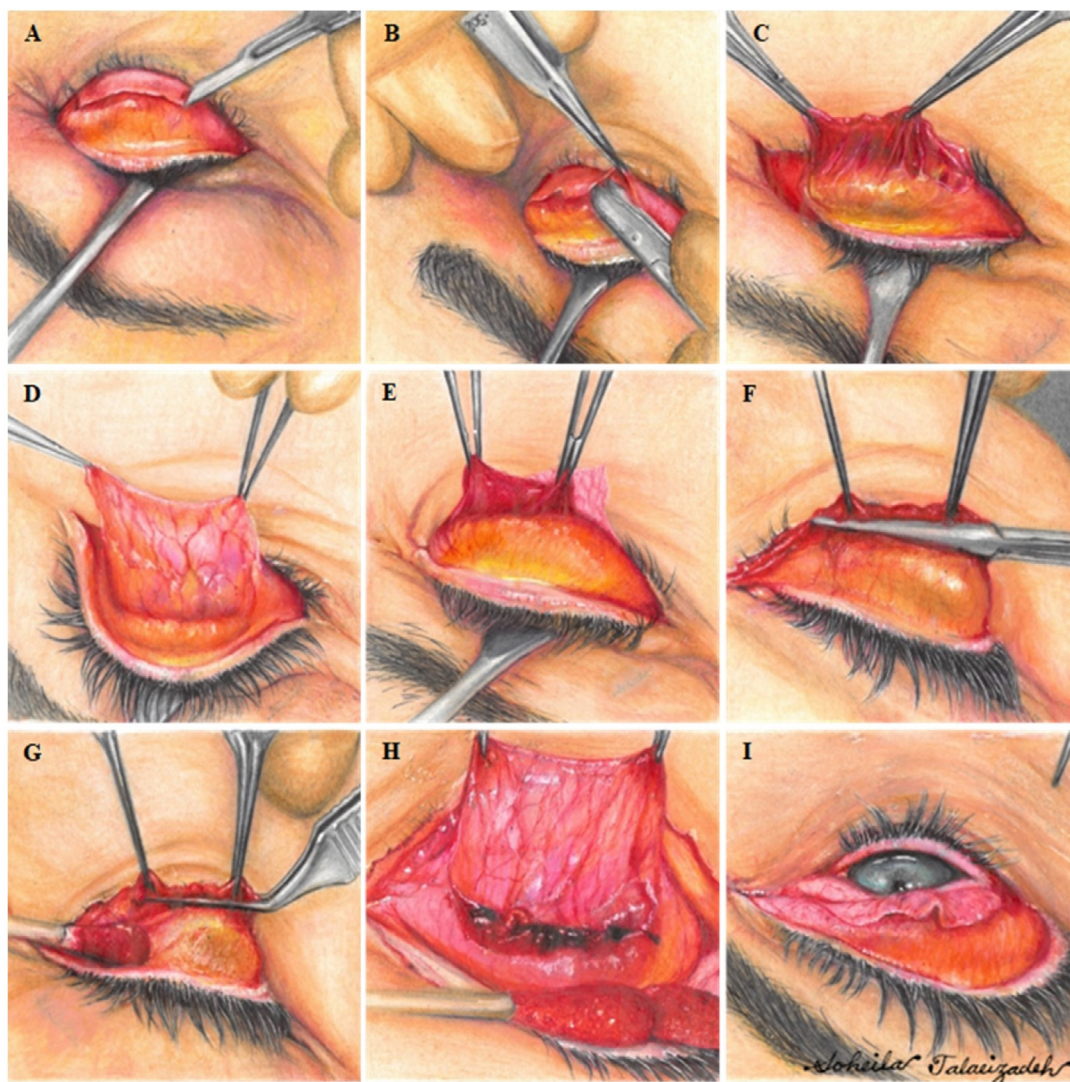
A single researcher was responsible for the chart review process and generating screenshots from previously uploaded patient photographs. Separate screenshots of each eyelid at pre- and postoperative timepoints were prepared and randomly arranged. Another researcher, blinded to the patient's identity and surgical timepoint, performed the appropriate measurements and calculations according to the protocol described above. Statistical analyses were performed using GraphPad Prism, version 9.4.1 (GraphPad Software).

- **SURGICAL TECHNIQUE:** CSM has been described previously.<sup>30</sup> The sutureless variation of the procedure is similar but with some adjustments. The surgeon sits at a superior position with the assistant temporal to the operative eye. The operative eyelid is everted over a Desmarres retractor, settling the blade of the retractor at the superior border of the tarsus. Gentle downward pressure is applied to the handle of the retractor to torque the tarsus and to place the overlying conjunctiva on tension. Caution must be taken here, as excessive force may cause further disinsertion

of the levator aponeurosis. Local anesthesia consisting of 1% lidocaine with 1:100,000 epinephrine is injected subconjunctivally, which also serves to delineate the plane of dissection and to reduce bleeding of the well-vascularized Müller muscle. Less than 0.5 mL of local anesthesia is used per eyelid to avoid chemosis, and care is taken to use a symmetric amount of local anesthesia bilaterally.

The conjunctival dissection is started with a #15 Bard-Parker blade (Figures 2, A and 3, A). Special attention must be paid to incise only the conjunctiva without disinserting the underlying Müller muscle from the superior border of the tarsus. Placing the eyelid on an appropriate amount of tension with the Desmarres retractor helps control the depth of the incision. The first incision traces the superior edge of the tarsus and spans almost its entire length. Perpendicular incisions extending superiorly are made at each end of the initial incision. Alternatively, Westcott scissors may also be used to make back-cuts at each end of the initial incision. At this point, the Desmarres retractor is passed to the assistant. The conjunctival flap is grasped at 1 corner with fine-toothed forceps, and the conjunctiva is sharply dissected free of Müller muscle using blunt-tipped Westcott scissors (Figures 2, B and 3, B). The dissection is carried along the superior edge of the tarsus toward the opposite corner of the flap. Once the corners are dissected free, the assistant grasps 1 corner while the surgeon grasps the other. The conjunctiva is pulled upward to expose adherent bands of underlying Müller muscle (Figures 2, C and 3, C). In some patients, the muscle may be tightly adherent, and a cotton-tipped applicator can be used to roll the muscle away from the conjunctiva to better expose these adherent bands. Sharp dissection is carried superiorly to expose the desired amount of muscle (Figures 2, D and 3, D). The free conjunctival flap is reflected and rested on the skin of the lower eyelid.

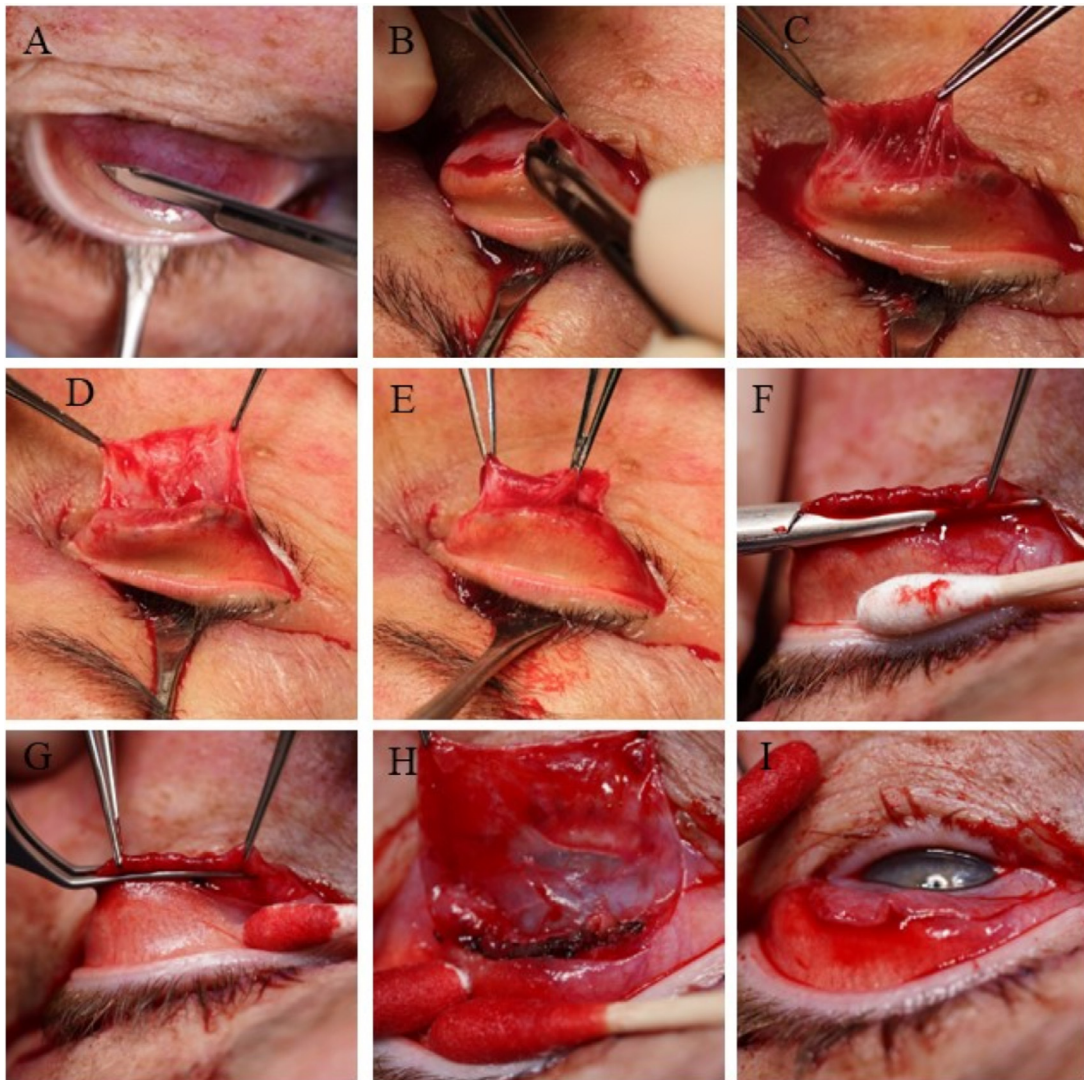
A predetermined amount of Müller muscle based on preoperative phenylephrine testing and approximating the "4:1 rule"<sup>44,45</sup> is grasped with forceps, 1 end by the surgeon and the other by the assistant (Figures 2, E and 3, E). Of note, the forceps are held closer together than would be done in a traditional MMCR, as the isolated muscle tends to sag without its overlying conjunctiva. The assistant removes the Desmarres retractor and may use a cotton-tipped applicator to isolate the muscle by pressing down on the tarsus. Fine straight hemostat forceps are applied with firm pressure to mechanically create a crush zone within the tissue (Figures 2, F and 3, F) and to leave an imprint. The imprinted tissue is treated with bipolar cautery down to the superior border of the tarsus (Figures 2, G and 3, G) and allowed to contract (Figures 2, H and 3, H). We have designed bipolar forceps unique for this purpose (described below), but simple angled-tip bipolar forceps may also be used. Care must be taken to ensure that conjunctiva and tarsus are not cauterized. The conjunctival flap is finally replaced over the plicated tissue (Figures 2, I and 3, I), and the eyelid is returned to its normal position. The conjunc-



**FIGURE 2.** A depiction of sutureless conjunctiva-sparing Müllerectomy. The operative eyelid is everted over a Desmarres retractor. A. Conjunctival dissection is started with a #15 Bard-Parker blade, with the incision tracing the superior edge of the tarsus, spanning almost its entire length. B. The conjunctival flap is grasped with fine-toothed forceps and the conjunctiva sharply dissected free of Müller muscle using blunt-tipped Westcott scissors. C. The conjunctiva is elevated to expose adherent bands of underlying Müller muscle. D. The dissection is carried superiorly 8 to 10 mm to expose an appropriate amount of muscle. E. The free conjunctival flap is reflected and rested on the skin of the lower eyelid, and a predetermined amount of Müller muscle is grasped with forceps. F. Hemostat forceps are applied with firm pressure to mechanically create a crush zone within the tissue. G, H. The imprinted tissue is treated with bipolar cautery down to the superior border of the tarsus (G) and allowed to contract (H). I. The conjunctival flap is replaced over the plicated tissue.

tiva remains in position overlying the surgical site without sutures for fixation. However, we do recommend that when multiple upper eyelid procedures are being performed, ptosis repair should be done last to minimize the chance of dislodging the conjunctival flap or stretching the adhesion formed. The plication achieved extends beyond just Müller muscle to the levator aponeurosis more anteriorly, which can be appreciated from an anterior view if upper blepharoplasty is performed concurrently (Figure 4). A narrated video of the technique in practice can be viewed at [https://youtu.be/y-TF3Q\\_BxBw](https://youtu.be/y-TF3Q_BxBw).

- **MANCINI-KEENUM BIPOLAR FORCEPS USE:** Bipolar forceps of a variety of styles can be used to achieve the Müller muscle plication. Standard size bayonet bipolar forceps as well as smaller bipolar forceps with an angled tip at the end, sometimes referred to as “hockey stick” bipolar forceps, work well but require multiple areas of treatment to achieve a consistent char across the plicated area. The authors have designed a custom bipolar forceps (Epsilon USA), which feature an elongated end that encompasses the whole width of Müller muscle while also following the gentle curve of the tarsus (Figure 5). Ergonomics with these custom for-



**FIGURE 3.** Depiction of sutureless conjunctiva-sparing Müllerectomy. Intraoperative photographs of sutureless conjunctiva-sparing Mullerectomy depicting each of the surgical steps.

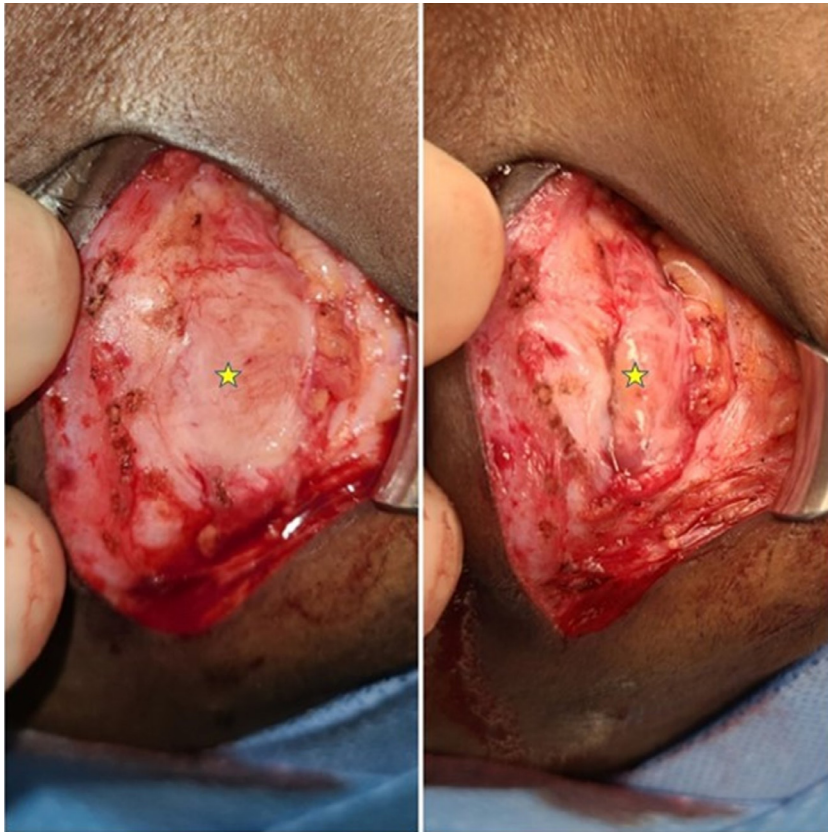
ceps is improved, and they are easier to maneuver into position to grasp Müller muscle than other conventional bipolar forceps. To achieve consistent, even plication of the Müller muscle with these forceps, a dragging motion from far to near is performed while applying energy to the forceps, which is primarily delivered at the tips. This achieves a thin, consistent plication along the Müller muscle.

## RESULTS

Between October 2019 and November 2021, a total of 144 patients underwent sutureless CSM and met the inclusion and exclusion criteria. Shortly after implementation of the sutureless method in October 2019, there was not only a decline in suture use for our CSMs but also a reduction in the number of traditional MMCRs performed altogether.

Of note, non-urgent clinic appointments and elective procedures were restricted at University of Texas Southwestern Medical Center between March and May 2020 because of the coronavirus disease of 2019 (COVID-19), leading to a paucity of data during this time. Patients were excluded if they did not meet the minimum 6-month follow-up because their appointment fell during this time.

Of the 144 patients identified, 44 did not have standardized photographs at POM6 or beyond and were excluded from the data analysis, leaving 100 patients with long-term follow-up. Of the 100 cases, 71 (71%) were bilateral, and 29 of the 100 cases (29%) were unilateral, totaling 171 eyes. Among the 29 unilateral cases, 23 (79%) involved the left eye and 6 (21%) involved the right eye. The mean age of the patients was  $66 \pm 13$  years, ranging from 19 to 87 years. The sex distribution was 71% female and 29% male. The primary etiology of ptosis was categorized as aponeurotic



**FIGURE 4.** Plication of Müller/levator complex. Anterior view after blepharoplasty showing appearance of the levator aponeurosis (star) before and after suturesless conjunctiva-sparing Müllerectomy (CSM), demonstrating the plication of the Müller/levator complex.

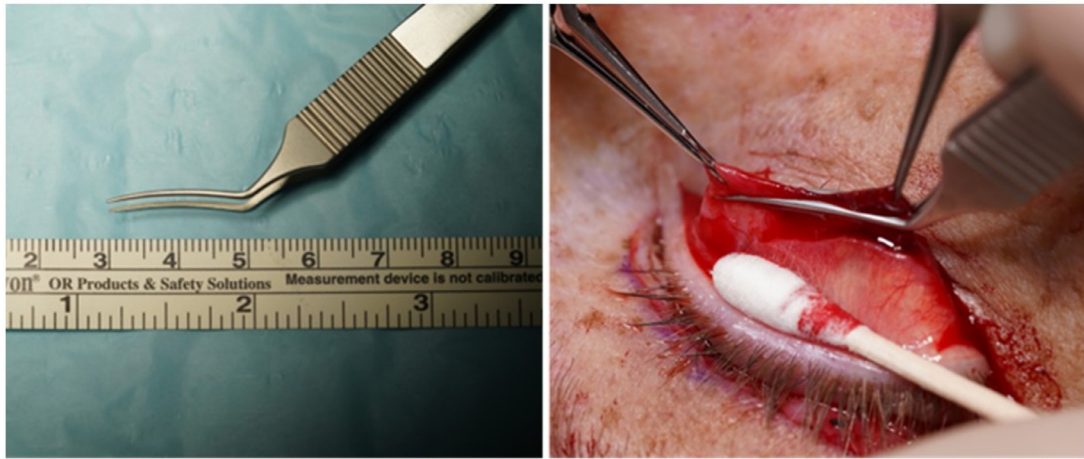
**TABLE 1.** Summary of Patient Demographics

Laterality	Unilateral: 29% (29/100) Right: 21% (6/29) Left: 79% (23/29)	Bilateral: 71% (71/100)
Age, y	Average age: 66 ± 13 Range: 19-87	
Sex	Male: 29% (29/100)	Female: 71% (71/100)
Etiology of ptosis	Aponeurotic: 89% (89/100) Myogenic: 7% (7/100) Neurogenic: 2% (2/100) Traumatic: 2% (2/100)	

(89 of 100, 89%), myogenic (7 of 100, 7%), neurogenic (2 of 100, 2%), and traumatic (2 of 100, 2%). Causes of myogenic ptosis included congenital ptosis and myasthenia gravis (Table 1).

The main outcome measures, MRD1 and PFH, as well as their derivatives are summarized in Table 2. RD1 was measured preoperatively and at POW1, POW6, POM6, and

POY1+ ( $\geq 1$  year). PFH was measured preoperatively and at POM6. The final surgical outcome was considered at POM6 or beyond; if POM6 data were unavailable, POY1+ data were substituted. The mean postoperative interval was approximately 8 months, ranging from 6 to 29 months. Photographs were available for all 100 patients preoperatively: 46 patients (46%) at POW1, 47 patients (47%) at POW6,



**FIGURE 5.** Mancini–Keenum bipolar forceps. The Mancini–Keenum bipolar forceps, shown (left) in isolation and (right) intraoperatively, were developed specifically for sutureless conjunctiva-sparing Müllerectomy. The long tip is designed to hold the entire length of the Müller muscle and allows for uniform cauterization.

**TABLE 2.** Surgical Outcome Measures Over the Operative Period

Outcome Measures		Operative Timepoint				
		Preoperative	POW1	POW6	POM6	POY1+
Follow-up rate		—	46%	47%	93%	28%
Mean MRD1 (mm)		0.45 ± 0.86	3.06 ± 1.21 <sup>a</sup>	3.14 ± 1.24 <sup>a</sup>	3.35 ± 0.93 <sup>a</sup>	3.52 ± 1.03 <sup>a</sup>
Mean PFH (mm)		5.72 ± 1.45	—	—	8.32 ± 1.52 <sup>a</sup>	—
Mean ΔMRD1 (mm)		—	—	—	+2.85 ± 0.98	—
Mean ΔPFH (mm)		—	—	—	+2.60 ± 1.38	—
Mean symmetry of MRD1 (mm)		—	—	—	0.41 ± 0.44 NS	—
Mean symmetry of PFH (mm)		—	—	—	0.52 ± 0.48 NS	—

NS = not significant ( $P > .05$ ), indicating symmetry.

<sup>a</sup>Significantly increased as compared to preoperative value,  $P < .001$ . All data included are gathered from 100 cases (171 eyes) with at least 6 months of postoperative follow-up (if data at postoperative month 6 were unavailable, data from postoperative year 1 and beyond were substituted). Main outcome measures were derived from margin reflex distance 1 (MRD1), the distance from the corneal light reflex to the upper eyelid margin, and palpebral fissure height (PFH), the distance between the central upper and lower eyelid margins.<sup>40</sup> MRD1 was measured preoperatively and at postoperative week 1 (POW1), postoperative week 6 (POW6), postoperative month 6 (POM6), and postoperative year 1 and beyond (POY1+). PFH was measured preoperatively and at POM6. The overall change in MRD1 and PFH in each eye ( $\Delta$ MRD1 and  $\Delta$ PFH, respectively) was the difference in MRD1 and PFH at POM6 compared to the preoperative timepoint. Symmetry was evaluated by taking the absolute value of the difference in MRD1 and PFH between each eyelid in both unilateral and bilateral cases.

93 patients (93%) at POM6, and 28 patients (28%) at POY1+. Photographs were less likely to be taken during the early postoperative period. In addition, COVID-19 had an impact on the follow-up rate through clinic-initiated appointment cancellations and individual patient isolation practices. Patients were excluded if they did not have pho-

tographs with a minimum 6 month follow-up because their appointment fell during this time.

Among all 171 eyes, the mean MRD1 at time of presentation was 0.45 ± 0.86 mm and improved to 3.06 ± 1.21 mm, 3.14 ± 1.24 mm, 3.35 ± 0.93 mm, and 3.52 ± 1.02 mm at POW1, POW6, POM6, and POY1+, respectively. A statistically significant increase in MRD1 was observed

at each postoperative timepoint as compared to baseline (Tukey multiple comparison test,  $P < .0001$ ), but there was no significant difference found among the different postoperative timepoints (Tukey multiple comparison test,  $P > .05$ ). The mean change in MRD1 from time of presentation to POM6 ( $\Delta$ MRD1) was  $+2.85 \pm 0.98$  mm. The mean PFH at time of presentation was  $5.72 \pm 1.45$  mm and improved to  $8.32 \pm 1.52$  mm by POM6 (paired  $t$  test,  $P < .001$ ). The mean change in PFH from time of presentation to POM6 ( $\Delta$ PFH) was  $+2.60 \pm 1.38$  mm. When considering right eyes alone, left eyes alone, and all eyes together, there was no statistically significant difference in mean preoperative MRD1, postoperative MRD1,  $\Delta$ MRD1, preoperative PFH, postoperative PFH, or  $\Delta$ PFH when comparing all 3 groups (analysis of variance [ANOVA],  $P > .05$ ).

Common concurrent procedures included upper eyelid blepharoplasty (ULB), lower eyelid blepharoplasty (LLB), and lower eyelid ectropion repair (LLE). There were too few cases combined with LLB or LLE alone to include in the statistical analysis. As a result, there were 4 groups of procedures performed: CSM-only group, CSM with ULB (ULB group), CSM with ULB and LLB (ULB+LLB group), and CSM with ULB and LLE (ULB+LLE group). There were 32 cases (42 eyes) of isolated sutureless CSM for which the mean  $\Delta$ MRD1 and  $\Delta$ PFH were  $+2.69 \pm 1.29$  mm and  $+2.58 \pm 1.64$  mm, respectively. There were 20 cases (32 eyes) that were combined with ULB for which the mean  $\Delta$ MRD1 and  $\Delta$ PFH were  $+3.05 \pm 1.03$  mm and  $+2.91 \pm 1.35$  mm, respectively. There were 24 cases (31 eyes) that were combined with ULB and LLB for which the mean  $\Delta$ MRD1 and  $\Delta$ PFH were  $+2.70 \pm 0.85$  mm and  $+2.40 \pm 1.12$  mm, respectively. There were 17 cases (32 eyes) that were combined with ULB and LLE for which the mean  $\Delta$ MRD1 and  $\Delta$ PFH were  $+2.37 \pm 0.89$  mm and  $+1.84 \pm 1.55$  mm, respectively. There was no difference in mean  $\Delta$ MRD1 among the 4 groups (ANOVA,  $P > .05$ ). There was a difference, however, in mean  $\Delta$ PFH (ANOVA,  $P < .05$ ), likely due to the significant effect of LLE on lower eyelid position. Subgroup analysis revealed a difference in mean  $\Delta$ PFH only when comparing the ULB to the ULB+LLE group (Tukey multiple comparison test,  $P < .05$ ).

Level of symmetry was assessed by observing the differences in postoperative MRD1 and PFH between right and left eyelids. There was no significant difference in mean MRD1 or PFH between right and left eyelids at POM6 (2-sample  $t$  test,  $P > .05$ ). Among unilateral cases, the mean differences in postoperative MRD1 and PFH between operative and nonoperative eyelids were  $0.49 \pm 0.54$  mm and  $0.66 \pm 0.53$  mm, respectively. Among bilateral cases, the mean differences in postoperative MRD1 and PFH between each eyelid were  $0.38 \pm 0.39$  mm and  $0.47 \pm 0.45$  mm, respectively. Among all cases, the differences were  $0.41 \pm 0.44$  mm and  $0.52 \pm 0.48$  mm, respectively. On average,

each eyelid fell within approximately 0.5 mm of the other, regardless of the laterality of the case.

Ten random cases of traditional MMCR were timed before entirely converting to sutureless CSM with a mean duration of 8.45 minutes. Our previously described sutured CSM is essentially the same as MMCR but is preceded by a conjunctival flap dissection. The additional conjunctival dissection takes approximately 2.5 minutes,<sup>30</sup> estimating the sutured CSM duration to be 11.0 minutes. Our novel sutureless CSM is remarkably faster than both MMCR and sutured CSM, with an average duration of 4.42 minutes.

Of the 171 eyes of 100 patients, there was 1 occurrence of unilateral medial eyelid peaking and overcorrection that was directly attributable to the procedure. The eyelid contour improved with downward eyelid massage over several months but ultimately required a full-thickness blepharotomy to achieve satisfactory cosmesis. There were 3 unilateral undercorrections that resulted in an asymmetry in MRD1  $>1.5$  mm compared to the non-ptotic side, which required an additional surgery to achieve symmetry to within 0.5 mm. The overall reoperation rate was 2.3% (1 case of overcorrection and 3 cases of undercorrection) per eye. There were 2 adverse reactions to postoperative topical antibiotics, an allergic reaction to moxifloxacin and an accumulation of ciprofloxacin deposits in the cornea, both of which completely resolved after medication cessation. One patient reported nonspecific irritation but no significant findings were seen on slitlamp examination or eyelid eversion. There were no corneal abrasions.

The amount of Müllerectomy plication performed was compared to the final amount of MRD1 achieved. This was compared to the widely accepted 4:1 rule in which every 4 mm of Müller muscle excised is thought to result in 1 mm of ptosis correction.<sup>44,45</sup> There was a statistically significant difference in means when comparing the expected  $\Delta$ MRD1 according to the 4:1 rule to the actual  $\Delta$ MRD1 (2-sample  $t$  test,  $P < .05$ ). The mean difference between the actual and expected  $\Delta$ MRD1 was  $0.94 \pm 1.03$  mm. On average, the eyelid position improved approximately 1 mm more than would be predicted by the 4:1 rule.

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## DISCUSSION

Blepharoptosis is 1 of the most common chief complaints presenting to oculoplastic surgeons. Anterior or external ptosis repair, although effective in cases of severe ptosis or in those with moderate levator function, requires meticulous dissection and can lead to less predictable results, with visible scar formation and irregularities in eyelid contour, longer operation time, as well as need for intraoperative patient cooperation.<sup>11,46-48</sup> Consequently, posterior or internal approaches to ptosis repair involving excision of Müller muscle have gained popularity<sup>49</sup> for cases of mild to moderate ptosis with good levator function because of their ease,

predictability, shorter operating time, and lack of visible scar formation or alteration of eyelid contour.

Modern iterations of posterior ptosis repair can be traced to Fasanella and Servat in 1961.<sup>16</sup> In 1975, Putterman and Urist introduced MMCR,<sup>8</sup> which avoided the potential disadvantages of tarsal excision and remains the most well-described approach to modern posterior ptosis repair.<sup>17-23</sup> Much like the Fasanella–Servat procedure, which involves partial excision of anatomically normal tarsus, MMCR involves excision of anatomically normal conjunctiva. Isolated excision of Müller muscle, termed “open sky” MMCR, has been described but involves the creation of 2 dissection planes, 1 plane along the levator aponeurosis and 1 plane along the conjunctiva, to isolate and excise Müller muscle.<sup>50,51</sup> This technique requires reapproximation of tissues with suture, and care must be taken to maintain appropriate eyelid contour through multiple tarsal sutures. We have previously described a conjunctiva-sparing approach, or CSM, using a single subconjunctival dissection plane as a safe and effective variation of posterior ptosis repair if conjunctival tissue needs to be conserved.<sup>30</sup> In the senior author’s (R.M.) practice, the procedure is implemented in young patients with acceptable levator function, those with ocular surface disease, and ocular hypertensive patients who may require glaucoma surgery in the future. The only barrier to wider implementation among our ptotic patients is the additional step of conjunctival dissection as well as suturing in the presence of a thin adherent conjunctival flap. To generalize the procedure to other patients, we sought to simplify the method by cauterizing Müller muscle instead of suturing it.

Sutureless CSM was found to be effective when comparing preoperative and postoperative MRD1 and PFH. Among 171 eyes, the mean MRD1 upon presentation was  $0.45 \pm 0.86$  mm and improved to  $3.35 \pm 0.93$  mm by POM6. Similarly, PFH improved from  $5.72 \pm 1.45$  mm to  $8.32 \pm 1.52$  mm. Differences in means were found to be statistically significant with  $P < .001$ . In addition, there was an adequate and consistent improvement in ptosis based on mean  $\Delta$ MRD1 and  $\Delta$ PFH of  $+2.85 \pm 0.98$  mm and  $+2.60 \pm 1.38$  mm, respectively. The effect of the procedure was found to be long lasting. All 100 patients maintained follow-up for at least 6 months, and some maintained follow-up for more than 2 years, the longest of which was approximately 2.5 years. The effect of concurrent procedures on postoperative MRD1 was found to be negligible. When comparing the isolated ptosis repair group to groups that underwent upper eyelid blepharoplasty, lower eyelid blepharoplasty, and/or lower eyelid ectropion repair, there was no statistically significant difference in mean  $\Delta$ MRD1 ( $P > .05$ ). However, there was an effect on postoperative PFH with concurrent lower eyelid ectropion repair. As expected, mean  $\Delta$ PFH was significantly smaller when the lower eyelid was tightened ( $P < .05$ ). This has previously been demonstrated in the literature, as ectropion repair has been shown to elevate the lower eyelid and to reduce the

MRD2 and PFH, and we have also noted this effect in our sutured CSM patients as well.<sup>52</sup>

Symmetry of eyelid position is also important when considering the efficacy of ptosis repair. Eyelid position has the most sensitive discriminatory threshold (2 mm) among all facial features.<sup>53</sup> Studies evaluating eyelid symmetry following ptosis repair define an acceptable threshold between 0.5 and 1.5 mm, with the most common limit being 1 mm.<sup>19,37-39,42,54-61</sup> Among 29 unilateral cases, the mean difference in postoperative MRD1 between operative and nonoperative eyelids was  $0.49 \pm 0.54$  mm. Among 71 bilateral cases, the mean difference in postoperative MRD1 between eyelids was  $0.38 \pm 0.39$  mm. Among all 100 cases, the difference was  $0.41 \pm 0.44$  mm. Most cases demonstrated adequate symmetry with even the strictest threshold of 0.5 mm. When considering all 171 eyelids, 72% were within 0.5 mm, 91% were within 1 mm, and 96% were within 1.5 mm.

It is important to note that MRD1 and eyelid symmetry appeared to change over the postoperative period. In some cases, the surgical outcome at POW1 fell short of the expected goal based on preoperative phenylephrine response, but most of these cases appeared to normalize by POM6. Late postoperative changes following MMCR have been reported elsewhere.<sup>62</sup> It has been hypothesized that these delayed changes, which are not seen with anterior ptosis repair, may be attributable to localized cicatricial changes or adjustments in neurologic input from the central nervous system. Regardless of the etiology of these changes, patients must be reassured if results are not adequate upon initial postoperative follow-up. It is recommended that surgical readjustments be delayed at least 3 to 6 months to allow for late postoperative changes to take place. Although a statistically significant increase in MRD1 was observed at each postoperative timepoint as compared to baseline ( $P < .0001$ ), we were not able to demonstrate a significant difference between the different postoperative timepoints ( $P > .05$ ). The discrepancy between anecdotally observed and statistical outcomes can be attributed to small sample size at the POW1 and POW6 timepoints because of COVID19-related interruptions.

In the senior author’s hands, sutureless CSM was found to be more efficient than sutured CSM and traditional MMCR. Ten random cases of traditional MMCR were timed with a mean duration of 8.45 minutes per eyelid. Sutured CSM adds 2.5 minutes<sup>30</sup> to traditional MMCR for the creation of a conjunctival flap, estimating the duration to be 11.0 minutes. In contrast, sutureless CSM takes only 4.42 minutes per eyelid, based on the mean duration of 10 random cases. Although it still requires the dissection of a conjunctival flap, sutureless CSM is more time-effective because of the efficiency of cautery compared to traditional suturing. There is also a cost savings due to the lack of suture material and the decreased operative time, although these financial aspects were not quantified in this study.



**FIGURE 6.** Depiction of isolated ptosis repair at postoperative day 6. (Left) Preoperative and (right) postoperative day 6 photographs demonstrating minimal edema and ecchymosis following isolated sutureless conjunctiva-sparing Müllerectomy of both eyes.

We found the procedure to be safe as well. There were no corneal abrasions, and no prophylactic bandage contact lenses needed to be placed. In contrast, the senior author noted a corneal abrasion rate of 3.6% (4 of 112 eyelids) and intraoperative contact lens use rate of 17% (19 of 112 eyelids) with traditional MMCR.<sup>30</sup> The reduction in corneal adverse events can be attributed to the absence of suture material and the natural protective barrier afforded by the conjunctival flap, which covers any charred post-cautery remnants that may theoretically abrade the corneal surface. One patient reported nonspecific irritation, but no significant findings were seen on slitlamp examination or eyelid eversion. The overall reoperation rate was 2.3% (1 case of overcorrection and 3 cases of undercorrection) per eye.

In general, we noted that patients who had undergone isolated ptosis repair had healed remarkably well by the first postoperative visit, with minimal swelling or bruising (a representative case is depicted in Figure 6). Edema is likely reduced by leaving a free conjunctival flap through which excess fluid can drain and by avoiding the proinflammatory effect of suture material (we routinely use chromic gut suture for MMCR). Ecchymosis is likely reduced because of definitive hemostasis from cauterization and avoidance of blood vessel perforation from the suture needle. Patients were also pleased to avoid the usually irritating and sometimes painful process of removing the serpentine suture. These are only anecdotal findings, and the goal would be to quantify our observations in a future study.

Since the inception of MMCR, various algorithms have been proposed to relate the length of Müller muscle resection to the amount of ptosis correction.<sup>8,19,20,24,44,45,53,63-66</sup> A survey of American Society of Ophthalmic Plastic and Reconstructive Surgeons (ASOPRS) members revealed that 55.6% of respondents used a variable amount of resection based on phenylephrine response, 46.5% performed a variable resection based on the amount of ptosis present, and only 13.2% used a standard amount of resection.<sup>49</sup> The senior author uses a nomogram that is a slight modification of that presented in the original MMCR paper by Putterman and Urist<sup>8</sup>; 2 drops of phenylephrine 2.5% are placed into the superior fornix and, after 10 minutes, the eyelid

height is evaluated. If phenylephrine testing lifts the eyelid to the desired height, an 8-mm plication is planned. For every 0.5 mm of undercorrection or overcorrection, 1 mm is added to or subtracted from the resection amount, respectively, for a total resection of 4 mm to 10 mm. The surgical outcomes of this study did not support a variable 4:1 ratio used by many surgeons. There was a statistically significant difference in means when comparing the expected  $\Delta$ MRD1 to the actual  $\Delta$ MRD1 ( $P < .05$ ) with an average of 1 mm more than what would be expected by the 4:1 rule. This disagreement was demonstrated in our prior study of sutured CSM<sup>30</sup> and in other studies as well.<sup>65,67,68</sup> Although the mechanism of the procedure is not completely understood, posterior ptosis repair is undoubtedly effective in a subset of ptosis patients. Many algorithms have been used in different patient populations and have afforded similar results,<sup>8,19,20,24,44,45,54,63-66</sup> suggesting that there is more than a simple mechanical explanation.

Another potential benefit of external ptosis repair is intraoperative titratability as opposed to relying on preoperative algorithms and calculations. Theoretically, intraoperative feedback and adjustment should allow for precise fine-tuning of eyelid contour, symmetry, and height. In practice, however, intraoperative measurements during external ptosis repair are less than perfect predictions of final postoperative results. Although healing is much more predictable in posterior ptosis repair, because of the preplaced nature of the suture, there is historically no role for intraoperative adjustment or titration. However, with the use of a bipolar forceps to create the adhesion, treatments can be enhanced by intraoperative measurements and observations. Eyelids may be either gently stretched for overcorrection, carefully re-everted and retreated in cases of undercorrection, or a combination for poor contour. Anecdotally, we believe that this intraoperative modification provides superior symmetry with excellent predictability. A future study designed to investigate this question is already underway.

There are limitations to the study, including its retrospective nature and smaller number of patients with extended follow-up beyond 1 year. Further study is needed to assess more accurately the longevity of the procedure.

Overall, sutureless CSM has been shown to be a promising alternative to MMCR based on the long-term outcomes of 100 patients. There was a significant improvement in both MRD1 and PFH, with good symmetry in almost all cases. It is important to note that the full effect of surgery may not be realized for several months, so appropriate patient counseling must take place. The procedure takes about

half as long as traditional MMCR because of the use of cauterization instead of suturing, and has a low complication and reoperation rate. We have also noticed anecdotally less tissue swelling and bruising overall, but this observation was not formally quantified. Given its efficacy, efficiency, and safety, sutureless CSM has become the senior author's default approach to posterior ptosis repair.

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