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Rigid Nylon Foil-Anchored Polytetrafluoroethylene (Gor-Tex) Sheet Stenting For Conjunctival Fornix Reconstruction

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Abstract

Purpose—To describe a surgical technique that deepens foreshortened conjunctival fornices by providing a scaffold for epithelialization that opposes contractile forces during wound healing.

Design—Retrospective interventional case series

Participants—Seventeen patients with anophthalmic sockets containing foreshortened conjunctival fornices

Methods—Conjunctival fornices was reconstructed with stents of expanded polytetrafluoroethylene (e-PTFE) sheet draped over rigid, 0.8 mm thick nylon strips that were anchored to the orbital rim. Preoperative and postoperative symptoms, prosthesis retention, fornix depth, and lagophthalmos were assessed.

Main Outcome Measure—Prosthesis retention, fornix depth, and lagophthalmos

Results—All 17 patients had preoperative inability to retain their prosthesis. After postoperative follow-up of 47 ± 43 months, retention was improved in all patients and was entirely satisfactory in 15 (88%) patients. After reconstruction, the repaired fornix was deep in 7 (41%) patients, adequate to retain a prosthesis in 9 (53%) patients, and shallow in 1 (6%) patient. Lagophthalmos improved in 15 (88%) patients and remained unchanged in 2 (12%) patients. Superior fornix was reconstructed concurrently with the inferior fornix in 6 patients. In these patients, the superior fornix improved to deep (3 patients; 50%) or adequate (2; 33%). In 1 (17%) patient, it remained shallow.

Conclusion—Rigid, nylon-foil anchored e-PTFE stenting opposes postoperative contracture, improving prosthesis retention, and lagophthalmos. It does not require an additional surgical site for graft harvesting.

Keywords

Orbit; Anophthalmic socket; Contracted socket; Foreshortened conjunctival fornix; Conjunctival fornix reconstruction; Polytetrafluoroethylene; Gor-Tex; Rigid nylon foil

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Foreshortened conjunctival fornices following enucleation or evisceration are observed in less than 5% of anophthalmic sockets, but cause considerable psychological and functional morbidity in affected patients.¹ In a study based on a survey of ophthalmic plastic surgeons,¹ fornix contracture is most common after dermis fat grafting (6.5%), but may complicate reconstruction performed with virtually any type of prosthetic implant. The foreshortened conjunctival fornix results in difficulty in retaining the prosthesis and poor cosmesis.

The management of the foreshortened conjunctival fornix is challenging. The shrinkage or loss of conjunctiva usually requires addition of ocular surface tissue or use of graft material. Several grafting materials have been used for the management of the contracted anophthalmic socket, including mucous membrane grafts,^{2,3} hard palate mucosal grafts,^{4,5} amniotic membrane,^{6,7} skin grafts or flaps,^{8–11} and custom-designed conformers.^{12,13} The main problem with grafting is contracture of the surgical bed, resulting in recurrent foreshortening of the conjunctival fornix. This requires repeated surgical intervention and additional grafting. Success in treating the foreshortened conjunctival fornix requires prevention of scarring that occurs postoperatively. In this study, we describe a new surgical technique that deepens the foreshortened conjunctival fornix by using a scaffold that promotes epithelialization while opposing contractile forces that initiate contracture. It also reduces the morbidity of a separate surgical site for harvesting of autogenous grafts.

Materials and methods

Clinical Evaluation

A retrospective review was performed on records of 17 patients who underwent the described foreshortened conjunctival fornix reconstruction at the Eye Plastic and Orbital Surgery Service of the University of Michigan Kellogg Eye Center. All patients had foreshortened inferior conjunctival fornices of their anophthalmic sockets. All repairs were performed using stents composed of 0.1 mm thick, expanded e-PTFE (Gortex; Gore Inc. Flagstaff, AZ) sheet anchored rigidly to the orbital rim with 0.8 mm thick nylon (Supramid, Alexandria, VA) strips maintained in place for an average of 5 weeks. The prostheses were made by the same ocularist at the University of Michigan Kellogg Eye Center. The Institutional Review Board at the University of Michigan approved this study.

Data included patient age, gender, laterality of involvement, and reasons for enucleation or evisceration. The presence and severity of symptoms, including inability to maintain the prosthesis were recorded from pre- and post-operative examinations. Also recorded were preoperative and postoperative signs, including lower eyelid position, lagophthalmos, and conjunctival fornix depth. Lower eyelid laxity, ectropion, or entropion were also documented as present or absent. The position of the lower eyelid was measured by the senior author (VME) in millimeters (mm) from the inferior corneoscleral limbus of the prosthesis to the lower eyelid margin with the contralateral eye in primary gaze and with the coronal plane of the patient's head perpendicular to the floor. Lagophthalmos, measured during gentle eyelid closure, was measured in millimeters (mm). The depth of inferior conjunctival fornix was assessed as deep, adequate, or shallow. A shallow fornix was defined as fornix depth inadequate to maintain an average-sized prosthesis in place while an adequate fornix was deemed to be of a depth capable of reliably maintaining an average-size prosthesis. A deep fornix was more than adequate.

Surgical Method

After obtaining informed consent, surgery was performed with intravenous sedation and local anesthetic consisting of bupivacaine 0.25%, lidocaine 0.5%, and sodium bicarbonate

0.84%, supplemented with epinephrine 1:50,000.¹⁴ A 3 mm wide, rigid strip of 0.8 mm thick nylon (Supramid) was cut to lengths varying between 22 and 27 mm, depending on the socket configuration. A 0.1 mm thick sheet of flexible e-PTFE (Gortex) was draped over the nylon strip which had three pairs of perforations fashioned with high temperature cautery to permit the passage of mattress sutures centrally and at each end of the nylon strip. Three 5-0 polypropylene (Prolene; Ethicon, Sommerville, NJ) sutures were then passed through the nylon strip and e-PTFE sheet. (Figures 1A and 2A) The conjunctival fornix was incised along its entire horizontal extent to expose the periosteum of the orbital rim. (Figure 1B) The sutures of the stenting were passed through the edges of inferior conjunctival fornix incision, with posterior arm of each suture passing through the posterior margin and anterior arm through the anterior conjunctival margin of the wound. The sutures were then advanced through the periosteum of the orbital rim, emerging on the cutaneous surface over the orbital rim. (Figures 1C and 2B) The sutures were passed through extruded polystyrene foam (Styrofoam, Dow Chemical, Midland, MI) bolsters and tied on their surfaces. (Figure 2C) Two rigid clear plastic conformers were placed between the leaves of the e-PTFE sheet extending from its rigid fixation in the fornix. (Figures 1D, E, F and 2D) After an average of 5 weeks, the nylon strip, e-PTFE sheet, polypropylene sutures, and bolsters were removed during a clinic visit. The patients tolerated the stenting well after being consulted as to need for prolonged placement. None of them required stent removal because of discomfort. The proliferative phase of wound healing, during which fibroblasts and myofibroblasts rapidly proliferate, begins 4 to 12 days following injury.^{15,16} Accumulating fibroblasts begin to synthesize and secrete collagen by 8 days after injury and continue to do so for 3 to 4 weeks, after which the collagen becomes crosslinked and organized.^{15,16} Because of the timing of active wound healing, the stents were maintained an average of 5 weeks to allow for the majority of fibroblast proliferation and collagen synthesis to be completed before stent removal.

During superior fornix reconstruction, the forniceal incision divided the levator aponeurosis/muscle and Muller's muscle as full thickness division of cicatrix was necessary to reform the fornix and lower the retracted upper eyelid which exhibited virtually no levator excursion in all cases. The surgery lowered the retracted upper eyelid, but did not cause clinically significant ptosis in any of the cases.

Results

Conjunctival fornix reconstruction was performed in 17 patients with an average follow-up time of 47 ± 43 months (median: 31 months; range: 5 to 164 months). The average patient age was 50 ± 21 years (range: 14 to 88 years); there were 7 (41%) women and 10 (59%) men. Right and left fornices were involved in 7 (41%) and 10 (59%) patients, respectively. Fourteen (82%) patients had a history of enucleation and three (21%) patients had a history of evisceration. Enucleation were performed for blind, painful eyes due to trauma in 8 (47%) patients, corneal perforation due to neurotropic keratopathy in 3 (18%) patients, malignancy (retinoblastoma and conjunctival squamous carcinoma with intraocular invasion) in 2 (12%) patients, and endophthalmitis in 1 (6%) patient. Eviscerations were for blind, painful eyes in 2 (12%) patients and corneal perforation due to neurotropic keratopathy in 1 (6%) patient. Eighteen or 20 mm spherical silicone implants (Jardón) were used in all patients except one who received a 16 mm implant. The average time interval between enucleation or evisceration and conjunctival fornix reconstruction was 67 ± 143 months (median: 23 months; range: 3 to 550 months). Four patients (24%) had histories of prior fornix repair with buccal mucosal grafts.

Preoperatively, all patients complained of difficulty in retaining their prostheses. The inferior conjunctival fornix depth was also assessed as too shallow to retain a prosthesis in

all patients. Associated lower eyelid malpositions included entropion in 9 (53%) patients, and ectropion in 4 (24%) patients. Following reconstruction, prosthesis retention improved in all patients and was entirely satisfactory in 15 (88%) patients. The forniceal depth after reconstruction is shown in Table 1. The associated eyelid malpositions also responded to the procedure; entropion resolved in 8 (89%) and ectropion in 3 (75%) of the patients in whom it was present preoperatively.

Preoperative lagophthalmos was also present in all patients (Table 1). Lagophthalmos improved in 15 (88%) patients, resolving completely in 5 (33%) and remaining unchanged in 2 (12%) patients. The amount of preoperative lagophthalmos also significantly improved following reconstruction. ($p < 0.05$) (Table 1). (Figures 3A to D and Figures 4A to C). The distance between the inferior corneal limbus of the prosthesis to the lower eyelid margin significantly improved in all patients following reconstruction ($p < 0.01$)

Seven (41%) patients had preoperative superior conjunctival fornix foreshortening that contributed to difficulty in prosthesis retention. In these cases, the superior conjunctival fornices were repaired using the same surgical technique, either at the same session or subsequently. In these 7 patients, superior conjunctival fornix improved to deep in 3 patients (43%) or adequate fornix in 3 patients (43%). In 1 (14%) patient, it remained shallow.

The composite stent including nylon strip, e-PTFE sheet, polypropylene sutures, and bolsters was removed after a mean of 5.0 ± 2.1 weeks (range: 2 to 8 weeks). Complications included subacute, localized infections of the lower eyelid in 2 (12%) patients, both of whom responded to stent removal and systemic oral antibiotic treatment, and pyogenic granulomas in 3 (18%) patients, all treated successfully by simple excision. Four (24%) patients with severe and extensive involvement of their entire inferior fornix required staged, segmental reconstruction of their fornices. These patients underwent a second procedure 6.0 ± 3.0 months (range: 4 to 10 months) after their initial reconstruction. Lateral canthal sling using a tarsal strip was performed adjunctively in one patient during postoperative follow-up. All had successful outcomes with satisfactory prosthesis retention and deep or adequate fornices.

Discussion

Several pathophysiologic mechanisms have been proposed in the pathogenesis of the foreshortened conjunctival fornix. In a thermographic study, Soll¹⁷ reported that anophthalmic orbital sockets are cooler than normal orbits, and proposed that circulation of the anophthalmic socket is reduced. He suggested that changes in the orbital blood flow and metabolic activity of the socket tissues, and eventual fat atrophy following enucleation, leads to complications of the anophthalmic socket, including foreshortening of the conjunctival fornix. However, Kronish et al¹⁸ used ophthalmic artery angiography to show that caliber and filling characteristics of major orbital vessels in normal and anophthalmic orbits are similar. They used radioactive microsphere analysis to demonstrate that capillary blood flow per weight in orbital tissue compartments was also comparable in anophthalmic sockets and normal orbits. In an experimental primate study, Kronish et al.¹⁹ also compared orbital fat mass of normal and anophthalmic sockets and found the fat and connective tissue content of anophthalmic orbits to be greater than that of normal orbits. Additionally, there was no significant difference in mean cell diameters of adipocytes between normal and anophthalmic orbits. In another experimental primate study, Kaltreider et al.²⁰ reported that contracture of foreshortened conjunctival fornices involved anterior orbital tissues of anophthalmic sockets while orbital apical tissues retained normal tissue structure. There was no difference in the position of extraocular muscles between normal and contracted sockets.

However, myofibroblasts were present in healing and contracting sockets but not in non-contracting sockets.

Several classifications for contracted sockets have been proposed. Baylis et al.²¹ separated contracted sockets into two groups: those with moist conjunctival surfaces and those with dry surfaces. Molgat² and later Guyuron²² described a classification with 3 groups: primary volume deficits, mucosal deficits, and both volume and mucosal deficits. Bonavolonta²³ classified contracted sockets into 6 categories: contraction of the conjunctival fornix, contraction of conjunctival fornix and lid, contraction of conjunctival fornix and orbital fat, absence of conjunctival fornix and severe contraction of orbital fat, and any of the above plus developmental bone abnormalities.

Surgical options for the rehabilitation of the contracted socket include mucous membrane grafts, skin grafts, hard palate grafts, dermis-fat grafts, amniotic membrane grafts, microvascular flaps, free flaps, alloplastic orbital implants, and tissue expanders.^{24–27} Mucous membrane grafting, particularly full or partial thickness buccal mucosa grafting, is the most common method because the grafts are abundant and easily accessible. Full thickness grafts are less prone to migration, extrusion, and contraction than partial thickness grafts. However, contracture occurs frequently following placement of either type of mucous membrane graft, leading to recurrent contracture. Molgat et al.² described some improved success using a modified grafting technique in which substantia propria and fat were harvested with full thickness mucous membrane, increasing the mucosal surface and partially replacing orbital volume. Hard palate mucosal grafts have a dense connective tissue component that imparts increased rigidity. They are abundant in size, easily accessible, and can be reharvested. However, they are also prone to complications of contracture, presumably because they are not firmly anchored in the fornix and permit contracture to occur beneath them. Holck et al.⁴ reviewed their experiences in 10 patients with contracted anophthalmic sockets who underwent reconstruction with hard palate mucosal grafts and reported that 8 of them (80%) were able to wear an ocular prosthesis comfortably with acceptable cosmesis. Two patients (20%) had recurrent socket contracture. Recently, amniotic membrane has been used in the reconstruction of contracted socket.^{7,28, 29} Bajaj et al.⁶ compared the use of amniotic membrane to mucous membrane grafting in the treatment of mild to moderately contracted sockets. They reported that improvements in the depths of inferior and superior fornices were similar for both groups. After brief follow-up of 6 months, they observed recurrent contracture in 2 (20%) patients with amniotic membranes and 1 (10%) patient with mucous membranes.

None of the aforementioned techniques directly address the propensity for postoperative contracture that is due to myofibroblastic proliferation and collagenization. To address this, tissue expanders have been used with variable success in studies with short term follow-up.²² Expanders are expensive and cumbersome. They also do not maximally oppose the forces of contracture directly within the fornix where the prosthesis rests.

In this study, we used a method that directly opposes the forces that occur postoperatively. e-PTFE is a porous, synthetic teflon-related material.³⁰ It is non-antigenic and well tolerated by tissue, inciting little inflammatory response while promoting epithelialization or endothelialization.³⁰ e-PTFE is often used in vascular surgery as a vascular by-pass graft or in the repair of intracardiac or vascular wall defects or cardiac valve problems.^{31,32} In ophthalmology e-PTFE has been used for ptosis surgery, repair of the lower eyelid retraction, wrapping socket implants, and in glaucoma implants.^{33–36} Levin and Dutton³⁷ used e-PTFE for the reconstruction of contracted sockets, cicatricial conjunctival shortening, and severe symblepharon. After incision of the foreshortened conjunctiva, they apposed edges of conjunctiva to the e-PTFE sheet. They removed the e-PTFE usually 2–3 weeks

later. Eight of nine patients had satisfactory reconstruction of their sockets and one case developed recurrent contracture. In contrast, we anchored e-PTFE sheet to the orbital rim with a rigid nylon strip. The e-PTFE sheet provided a scaffold for cellular growth and matrix deposition, promoting conjunctival epithelialization along the e-PTFE sheet. The rigid nylon strip anchoring the sheet to the orbital rim meanwhile opposed the contractile forces created by myofibroblasts in the submucosal fibrous tissue during the proliferative phase of wound healing characterized by fibroblast and myofibroblast proliferation followed by collagen depositin during the first postoperative month.^{15,16} The connective tissue that did grow beneath the nylon anchor simulated the ligamentous attachments between the orbital rim and conjunctival fornix. (Figure 1C)

In conclusion, rigid nylon-foil anchored e-PTFE significantly improved prosthesis retention in all patients and reduced lagophthalmos. The stent successfully addressed the postoperative contractile forces and maintained fornices after long term follow-up of 47 months. Moreover, this method avoided the morbidity of an additional surgical site required for autogenous grafting. The distance between the inferior corneal limbus of the prosthesis to the lower eyelid margin, which we found to be significantly improve, is dependent on several factors such as size of orbital implant volume, which did not change in our patients, as well as the size and fit of the prosthesis. The prostheses are custom fit to optimize symmetry and cosmesis, often requiring extensions to promote horizontal stability, provide for symmetrical palpebral fissure measurements, and reduce upper eyelid ptosis. This requires each prosthetic to have different amounts of superior and inferior scleral extensions in order to center the prosthesis. The extent of prosthesis inferior to its limbus was at least 3 mm in all our patients, and it improved to “0” mm at final follow-up.

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Figure 1.

Detailed illustration of surgical technique. A. A 0.1 mm thick sheet of flexible expanded polytetrafluoroethylene (e-PTFE) draped over a 3 mm wide, rigid strip of 0.8 mm thick nylon strip through which three 4-0 polypropylene mattress sutures are passed. B. The conjunctival fornix incised to expose the periosteum of the orbital rim. C. One arm of each mattress suture is passed through the posterior edge of the fornix incision, advanced through the periosteum of the orbital rim, to emerge through the skin outside orbital rim. The other arm of the suture is passed through the anterior edge of the incision and periosteum of the orbital rim to emerge through the skin. D. The sutures are tied over the polystyrene foam bolsters and one or two rigid clear plastic conformers are placed between the leaves of the e-PTFE sheet extending from its rigid fixation in the fornix. E. Conformer(s) fully seated between leaves of e-PTFE deep in fornix. F. The outside appearance of the eye after e-PTFE/rigid nylon stent and conformers are placed, showing lids fully closed.

Figure 2.

Surgical use of expanded polytetrafluoroethylene (e-PTFE)/rigid nylon stent. A. A 0.1 mm thick sheet of flexible e-PTFE draped over a 3 mm wide, rigid strip of 0.8 mm thick nylon. Three 5-0 polypropylene sutures are passed through three pairs of perforations on the nylon strip and e-PTFE sheet. B. The sutures are passed through the margins of the conjunctival fornix incision, the periosteum of the orbital rim, and the skin overlying the orbital rim. C. The sutures are passed through extruded polystyrene foam bolsters and tied on their surfaces. D. Rigid nylon foil-anchored e-PTFE stent deepens the fornix and provides attachment between the superior orbital rim and conjunctival fornix by opposing the contractile forces of myofibroblasts.

Figure 3.

A 35-year-old woman who underwent left enucleation for complications of neurotrophic keratopathy developed difficulty in retaining any prosthesis. A and C. Preoperative and postoperative appearances. B and D. Preoperative and postoperative lagophthalmos.

Figure 4.

A 64-year-old woman with right anophthalmic socket due to severe trauma and longstanding difficulty in retaining any prosthesis. A. Preoperative appearance. B. Swelling and redness of right lower eyelid while the rigid nylon foil-anchored expanded polytetrafluoroethylene (e-PTFE) stent is present in inferior fornix. (C). Appearance 2 years after surgery showing improved cosmesis and ability to reliably retain prosthesis. She has residual lateral lower eyelid retraction compared to the left side.

Table 1

Results of rigid, nylon foil-anchored expanded polytetrafluoroethylene (e-PTFE) sheet stent for conjunctival fornix reconstruction in 17 patients with contracted sockets

	Preoperative	Postoperative
Inferior conjunctival fornix depth		
Unable to retain any prosthesis	17 (100%)	0 (0%)
Shallow	0 (0%)	1 (6%)
Adequate	0 (0%)	9 (53%)
Deep	0 (0%)	7 (41%)
Lagophthalmos		
Mean $\pm$ standard deviation (mm)	5.1 $\pm$ 3.2	2.4 $\pm$ 2.5**
Range (mm)	0 to 10	0 to 7
Inferior scleral show		
Mean $\pm$ standard deviation (mm)	1.5 $\pm$ 1.4*	0.3 $\pm$ 0.3**
Range (mm)	0.5 to 2	0 to 1

* Lower eyelid lower level was lower than limbus

** Lower eyelid lower was higher than limbus and significantly improved when compared to preoperative inferior scleral show ($p < 0.01$)

*** Significantly improved when compared to preoperative lagophthalmos ($p < 0.05$)