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Innovative approaches to glaucoma management of Boston keratoprosthesis type 1

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Abstract

Glaucoma remains a prevalent disorder and visual limiting factor after Boston keratoprosthesis type 1 implantation. Patients with glaucoma have worse initial and late visual acuity outcomes after otherwise successful keratoprosthesis implantation. Management of glaucoma in the setting of a keratoprosthesis is challenging because of relatively rapid progression and an inability to accurately measure intraocular pressure (IOP). In addition, there are no standard guidelines for glaucoma surveillance and monitoring after keratoprosthesis surgery. This report provides a review of the current literature and offers innovative strategies that will overcome the challenges in managing glaucoma in the setting of a Boston keratoprosthesis type 1 implant. The topics that will be discussed in this section include alternative methods for IOP measurement, rationales and surgical techniques for a pars plana tube placement for glaucoma drainage device, effective medical and laser treatment, the risk for IOP elevations after YAG laser, and practical guides to glaucoma surveillance and monitoring.

Keywords

Glaucoma; intraocular pressure; keratoprosthesis; glaucoma drainage device; glaucoma surgery; glaucoma therapy

Introduction

Glaucoma remains a prevalent disorder and visual limiting factor after Boston keratoprosthesis type 1 implantation. The majority of eyes with Boston type 1 keratoprosthesis suffer from glaucoma, with the overall prevalence ranging from 64% to 84%.^{1–4} Among this population, the prevalence of pre-existing glaucoma ranges from 36% to 78%, while the incidence of postoperative IOP elevation and/or glaucoma ranges from 8% to 35% per year.^{2–14} Importantly, glaucoma negatively impacts both initial and late visual

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Conflict of Interest

Thasarat Vajaranant, Jacob Wilensky, Jessica Liu, Ahmad Aref and Soledad Cortina declare no conflict of interest.

Compliance with Ethics Guidelines

Human and Animal Rights and Informed Consent

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outcomes after otherwise successful keratoprosthesis implantation. Specifically, a recent report by Kamyar et al. showed that eyes with pre-existing glaucoma have worse initial best-corrected visual acuity, compared to those without glaucoma after Boston keratoprosthesis type 1 (3/200 vs. 20/563).⁸ Furthermore, Talajic et al. reported that 13% of eyes post keratoprosthesis implantation lost fixation from glaucoma after experiencing an initial dramatic improvement in visual acuity, and 21% had documented visual field progression and/or needed glaucoma surgery during a 16-month follow-up period.¹⁵ Consistently, Crnej et al. reported a similar rate of glaucoma progression of 21% annually based on data from a large series with relatively long follow-up (106 eyes during a 3.3 years follow-up period).⁵

Management of glaucoma in the setting of a keratoprosthesis is challenging because of relatively rapid progression and an inability to accurately measure intraocular pressure (IOP). In addition, there are no standard guidelines for glaucoma surveillance and monitoring in keratoprosthesis. This report provides a review of current literature, clinical pearls, and innovative strategies to assist in overcoming the challenges in monitoring and treating glaucoma in the setting of a Boston keratoprosthesis type 1 implant.

I) Alternative methods for IOP measurement in Boston type 1 keratoprosthesis

The main treatment goal of glaucoma is to control IOP; therefore an accurate measurement of IOP is vital. However, as most tonometers are designed to measure IOP through the central cornea, it is impossible to measure IOP through the prosthetic cornea. As a result, most surgeons rely on tactile IOP, which was reported to be useful for identifying an IOP of 30 mmHg or greater.¹⁶ In addition to tactile IOP, alternative methods for measurement include scleral pneumatonometry (Mentor Inc, Norwell, Massachusetts, USA)¹⁷ and transpalpebral (Diaton, BiCOM, Inc., Long Beach, NY, USA) tonometry. Based on our study comparing central corneal and scleral pneumatonometry in 97 healthy eyes,¹⁷ we found three important observations; 1) corneal and scleral pneumatonometry positively correlate; 2) a scleral IOP consistently reads higher than a corneal IOP; and 3) the scleral IOP reading is more accurate at the lower level of IOP. Practically, scleral pneumatonometry can be used in eyes with keratoprosthesis, and it is confirmative if the scleral IOP reading is within a normal range. Furthermore, we reported agreement among transpalpebral, transcleral and tactile IOP measurements in 23 eyes with Boston type 1 keratoprosthesis.¹⁸ Our data suggest that transcleral measurements by pneumatonometer yield higher readings compared to tactile and transpalpebral IOP measurements. The percentage agreement, defined as readings within 2 mmHg, was highest between tactile and transpalpebral methods (95%), compared to the percentage agreement between tactile range and transcleral IOP (85%) and transpalpebral and transcleral IOP (48%).¹⁸

Clinical pearls—Alternative IOP measurements through the sclera and an eyelid should be considered as a confirmatory method in addition to routine tactile IOP in eyes with Boston type 1 keratoprosthesis.

II) Why consider a combined glaucoma drainage device at the time of keratoprosthesis implantation?

As mentioned previously, the overall prevalence of glaucoma is high in eyes with Boston type 1 keratoprosthesis.^{2–14} An overall rate of prior and/or combined glaucoma surgery at the time of keratoprosthesis ranges from 10% to 81%.^{2–4,6,8,15} Combined glaucoma surgery is performed more frequently in eyes with pre-existing glaucoma (17% to 45%).^{3,4} Notably, a series reporting a higher rate of prior and/or combined glaucoma surgery at the time of keratoprosthesis implantation had a lower rate of subsequent glaucoma surgery compared to the other.^{3,4} In our early series of 70 eyes between 2006–2010, with a follow-up time on average of 14.7 ± 11.4 months, the prevalence of pre-existing glaucoma is 70%.¹⁹ Figure 1 shows a diagram of glaucoma prevalence and incidence of IOP elevation that required treatment in eyes with or without pre-existing glaucoma and with or without prior or combined glaucoma surgery. One third of patients without pre-existing glaucoma developed an IOP elevation that required treatment (29%).¹⁹ Eyes with pre-existing glaucoma had a twice higher rate of post-operative IOP elevations that required treatment (58% vs. 29%).¹⁹ In eyes with pre-existing glaucoma, the rate of IOP elevation that required treatment was higher in eyes without prior/combined shunt compared to eyes with prior/combined shunt (66% vs. 45%).¹⁹ Accordingly, glaucoma surgery prior or at the time of keratoprosthesis should be strongly considered.^{1,5,20,21}

Clinical pearls—These data suggest that performing a combined glaucoma shunt procedure at the time of keratoprosthesis lowers the rate of subsequent IOP elevation and/or glaucoma surgery in eyes with pre-existing glaucoma regardless of pre-operative IOP. However, there is not enough evidence to support combined glaucoma surgery at the time of keratoprosthesis implantation in eyes without pre-existing glaucoma. Further analysis with longer-term follow up is needed to address this issue.

III) The art of glaucoma surgery in eyes with Boston type 1 keratoprosthesis

For a successful glaucoma drainage device implantation in eyes with Boston type 1 keratoprosthesis, there are two important considerations: 1) the position of tube placement and 2) the necessity for optimal postoperative contact lens fitting to maintain corneal hydration and post-operative best-corrected visual acuity.^{20,21}

With regards to optimal tube position, pars plana insertion is preferred for a number of reasons.^{20,22} First, there is limited space in the anterior chamber after keratoprosthesis surgery, and a functional anterior chamber depth is on average less than 1 mm in both pseudophakic and phakic eyes (Figure 2). Specifically, averaged anatomical anterior chamber depth is 2 mm whereas averaged functional anterior chamber depth is 0.21 mm.²³ Second, angle closure is prevalent, extensive, and progressive in eyes with keratoprosthesis.²³ For instance, the majority of eyes with keratoprostheses have extensive angle closure. In our series of 52 eyes at 19 months post Boston type 1 keratoprosthesis surgery, 86.5% demonstrated peripheral anterior synechia on anterior segment optical

coherence imaging, and on average approximately one third of the angle was closed (8.7 clock hours).²³ In addition, anterior chamber depth and anterior chamber angle dimensions are dynamic in eyes with a keratoprosthesis.^{24,25} In eyes with no pre-operative angle closure, post-operative angle closure has been documented with serial anterior segment optical coherence imaging.²⁴ Lastly, previous reports have documented an occurrence of tube occlusion in the anterior chamber.^{2,26} Robert et al. also reported that 22% of eyes with keratoprosthesis and glaucoma drainage device had tube occlusion, which was mainly caused by vitreous incarceration. For these reasons, pars plana tube insertion with a complete vitrectomy is preferred.^{1,20,21}

Eyes that require keratoprosthesis often have compromised or scared conjunctiva secondary to poor ocular surface and/or previous surgery.²⁰ As a result, these eyes are prone to glaucoma drainage device related complications such as implant exposure. The incidence of glaucoma implant exposure after Boston type 1 keratoprosthesis varies and ranges from none in 18 eyes during 21.5 months to 9 in 25 eyes during 33.6 months based on previous reports (0% to 12% annually).^{26,27} In comparison, the incidence of tube exposure in the Tube vs. Trab Study is 6% in 5 years (1.2% annually).²⁸ Based on the higher incidence of tube exposure in keratoprosthesis, careful conjunctival closure, selection of patch graft and position of the tube are essential steps that will influence the outcomes.²⁰

Our preferred surgical techniques and pearls are as followed.^{1,20,21}

1. Pars plana tube insertion: The most posterior placement from the limbus (approximately 4–5 mm) is preferred. To identify pars plana and a proper position, intraoperative scleral indentation and/or transillumination is often required. The pars plana vitrectomy can be performed through Boston type 1 keratoprosthesis or temporary keratoprosthesis depending on retinal surgeon's experiences and preferences.
2. Patch graft: In eyes with Boston type 1 keratoprosthesis, it is essential to use patch graft reinforcement of the tube to prevent exposure. The preferred choice of patch graft in a combined case is a corneal or corneoscleral patch graft. The corneal patch graft can be obtained from the recipient or preserved donor graft whereas the corneoscleral patch graft can be prepared from a rim of the same donor tissue used for the keratoprosthesis. The key to optimal contact lens fitting is to use a thin patch graft with a corneal side covering the tube entry. In some cases, a careful preparation of the patch graft is necessary. For example, if the patch is too thick or bulky, one might consider to perform a lamellar dissection of the patch graft and/or to create a slope on an anterior edge of the patch graft.
3. Conjunctival closure: The least tension is preferred to promote optimal conjunctival closure and proper healing. Blunt dissection of the conjunctival flap might be necessary in some cases. In eyes with inadequate conjunctival closure, it is much preferred to use a corneal patch graft and bring the edge of the conjunctiva to cover all edges of the patch graft. This will allowed conjunctival epithelization over the corneal patch graft. In addition, it is important to consider a complete ligation of the tube in this case to allow maximal time to conjunctival

healing to ensure a watertight closure. Lastly, consider using an amniotic membrane and fibrin glue in difficult conjunctival closure.

In our series of eyes with pars plana tube insertion,²² 1 in 20 eyes experienced exposure during 31.6 months follow-up time on average. In this case, the exposure was thought to be due to a bulky scleral patch graft and pars plana clip. After we adopted the above techniques there was no reported tube exposure in our series. In addition, during follow-up, the majority of eyes had normal tactile IOP (85%) and optimal contact lens fitting (75%). Twenty percent required subsequent glaucoma procedures to further control IOP and 2 eyes required explantation due to endophthalmitis that was not related to glaucoma implants.

Clinical pearls—Pars plana tube insertion, careful preparation of patch graft, and meticulous conjunctival closure in eyes with Boston type 1 keratoprosthesis is essential to ensure the optimal IOP control with decreased risk of device-related complications.

IV) Effective medical and laser treatment for glaucoma in eyes with Boston type 1 keratoprosthesis

For medical therapy, both topical and oral IOP-lowering agents can be used. In theory, topical medications could still be absorbed through the recipient/donor corneas as well as through the sclera. Clinical pearls for selecting IOP-lowering agents are as follow:

1. Based on the mechanism of action, an aqueous suppressant and medications that improve uveoscleral outflow are most likely superior to medications that target the trabecular meshwork as the majority of these eyes often have extensive angle closure.
2. As many of these eyes also suffer from chronic and/or chronic cystoid macular edema, prostaglandins should be avoided or stopped.²⁹
3. Steroid response may also be a cause of increased IOP in the eyes with an open angle.³⁰ However, in eyes with complete angle closure, steroid does not likely affect the IOP. In the case of steroid response, tapering steroid and/or changing a potent to a less potent steroid may reverse the steroid response.
4. To promote a healthy ocular surface and to ensure adequate hydration between a prosthesis and donor cornea junction, fixed-combination, benzalkonium chloride (BAK)-free and/or preservative-free agents should be considered.
5. Oral carbonic anhydrase inhibitors (CAI) such as acetazolamide and methazolamide may be used with caution after reviewing a history of kidney function and allergy. For a long-term use of oral CAI, a primary physician should be consulted and involved in a long-term care and monitoring of its side effects. Special caution should also be taken in patients who reported a history of Stevens-Johnson syndrome from a sulfa allergy. However, a previous report showed that when acetazolamide or furosemide was challenged in patients with idiopathic intracranial hypertension, who had a history of sulfa allergy, none of

34 patients demonstrated a true allergic reaction from a potential cross-reaction between sulfa and acetazolamide.³¹

For laser treatment for glaucoma in Boston keratoprosthesis type 1, a recent by Rivier et al suggested that transcleral cyclophotocoagulation could be performed as an adjunct therapy for IOP control in Boston type 1 keratoprosthesis. They found a significantly decreased IOP after laser without a significant change in final visual acuity, in 18 eyes during a mean follow-up of 26.6 months $\pm$ 19.6 months.³² Furthermore, 33.3% required additional laser and 11% required more than two sessions.³² In this series, complications included one case of conjunctival dehiscence and the other with fungal endophthalmitis.³²

Clinical pearls—Topical and oral anti-glaucoma medications and cyclophotocoagulation could be used in eyes with Boston type 1 keratoprosthesis with caution.

V) The risk for IOP elevations after YAG laser

The risk for an immediate post-operative IOP elevation after YAG capsulotomy is well recognized. However, the risk for a long-term effect of YAG laser on IOP is not widely known. Based on a retrospective review of 69 glaucoma patients who underwent YAG capsulotomy, 38.1% had disease progression, which was defined as increased IOP of greater than 5mmHg on two consecutive visits, addition of anti-glaucoma medications or subsequent glaucoma surgery at 12 months.^{33,34} In eyes with Boston type 1 keratoprosthesis, YAG capsulotomy for posterior capsule opacity and/or YAG membranectomy for a retroprosthetic membrane are often needed. In addition, repeated procedures and a high energy are often required. It is therefore conceivable that the YAG laser may lead to undetected IOP elevations and perhaps a long-term instability of IOP control in eyes with glaucoma. As IOP cannot be accurately measured in eyes with keratoprostheses, pre-treatment with topical and/or oral anti-glaucomatous medications for YAG laser in eyes with keratoprosthesis should be considered. In addition, careful monitoring of IOP and glaucoma progression after YAG laser treatment is recommended.

Clinical pearls—Pre-treatment for YAG laser to prevent IOP immediate post-operative IOP elevations and careful monitoring of IOP and glaucoma progression is recommended.

VI) Practical guides to glaucoma surveillance and monitoring in eyes with Boston type 1 keratoprosthesis

Glaucoma is the most common of irreversible visual loss in eyes with Boston type 1 keratoprosthesis. Hence, glaucoma surveillance in eyes without pre-existing glaucoma and glaucoma monitoring in eyes with pre-existing glaucoma after Boston type 1 keratoprosthesis is essential to prevent permanent blindness.

Surveillance for de novo glaucoma

As the incidence of IOP elevation and glaucoma is high among eyes without pre-existing glaucoma (8% to 35% annually).^{2–14} Surveillance of glaucoma is necessary. Practically,

these eyes should be considered glaucoma suspects and/or high risk, and it is therefore recommended to establish a baseline for IOP measurement, visual field and imaging of the optic nerve and optical coherence tomography of the anterior segment and optic nerve. Figure 3 shows visual field, optic nerve photographs and imaging. Notably, a previous report demonstrated that reliable visual field tests could be obtained in only 59%; therefore it is advised to use structural measures the main outcome measure.⁵ The causes of de novo IOP elevations and glaucoma are multifactorial, and the main causes are likely progressive angle closure, steroid response or a combination. As previously documented, progressive angle closure can occur within 6 months post-operatively in eyes without pre-operative angle closure.²⁴ Chronic angle closure that progresses slowly may potentially lead to progressive glaucomatous damage without accompanying acute pain or symptoms. In addition, as topical steroid is commonly used after a corneal transplantation, these eyes are at risk for IOP elevation. In the normal population the incidence of IOP elevation after a topical steroid use is approximately 30%.³⁰ Depending on the baseline IOP, the steroid response may lead to a significant IOP elevation with subsequent optic nerve damage and permanent visual loss. In practice, IOP measurement should be documented on each visit while visual field testing and optic nerve imaging should be alternately performed every 6 months.

Monitoring for glaucoma progression

In eyes with glaucoma, careful monitoring for IOP elevation and glaucoma progression is extremely important to prevent permanent visual loss for two main reasons. First, the incidence of progression is high (21% annually). Furthermore, the incidence of IOP elevations required treatment is twice higher in eyes with glaucoma compared to those without (58% vs. 29%).¹⁹ Second, rapid progression and losses of fixation may occur in the eyes with pre-existing glaucoma as many of them often have limited outflow facility from extensive angle closure and underlying advanced optic nerve damage. Accordingly, frequent follow-up is often required to detect any glaucoma progression. It is advised to perform IOP measurements at each visit (every 3–4 months) while visual fields and optic nerve photographs and imaging may be alternately every 6 months. Given the potentially aggressive nature of glaucomatous progression in eyes with keratoprosthesis, prompt treatment is needed in eyes with IOP elevations and/or suspicious glaucoma progression.

Clinical pearls—Early detection for IOP elevations and/or glaucoma progression requires regular surveillance and frequent follow-up. Low-threshold and prompt treatment is necessary to prevent permanent visual loss from glaucoma in eyes with Boston type 1 keratoprosthesis.

In conclusion, management of glaucoma in Boston type 1 keratoprosthesis remains a challenge because of the high prevalence of glaucoma, fast progression and an inability to measure IOP. In eyes with pre-existing glaucoma, glaucoma drainage device before or at the time of keratoprosthesis should be performed. Most importantly, early detection and prompt treatment of IOP elevations and glaucoma progression is required to prevent poor visual outcomes.

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Figure 1.

A diagram showing the incidence of intraocular pressure elevations that required treatment in 70 eyes with Boston type 1 keratoprosthesis with an averaged follow-up of 14.7 months. The incidence is 29%, 45% and 66% in patients without pre-existing glaucoma, with pre-existing glaucoma and glaucoma drainage device, and with pre-existing glaucoma without drainage device.

Figure 2.

Anterior segment optical coherence tomography of an implanted Boston type 1 keratoprosthesis. Top left image shows anatomical anterior chamber depth of 1.69mm but functional chamber depth of 0.91mm at 180°. The iris is touching the backplate with a very narrow angle and an almost flat anterior chamber at 0°. Varied degrees of functional anterior chamber shallowing, angle closure and peripheral anterior synechiae is seen in the four quadrants imaged.

A. Visual field testing

B. Optic nerve imaging

Figure 3.

Glaucoma surveillance and monitoring in Boston type 1 keratoprosthesis. 3A: Visual field results (automated and static visual fields) from the same patient with Boston type 1 keratoprosthesis. 3B: an optic nerve photograph on the left and optical coherence tomography of the optic nerve on the right from an eye with Boston type 1 keratoprosthesis.