Pediatric Keratoprosthesis

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Objective: To describe the authors' experience using keratoprosthesis to treat pediatric corneal opacity.

Design: Nonrandomized, consecutive, retrospective interventional series.

Participants: Twenty-two eyes of 17 children with opaque corneas as a result of primary congenital disease and or previous failed keratoplasty.

Methods: A retrospective review of pediatric patients with a history of corneal opacification treated with keratoprosthesis surgery.

Main Outcome Measures: Intraocular pressure, inflammation, clarity of the visual axis, visual acuity, refraction, complications, and retention of the prosthesis.

Results: Twenty-two eyes of 17 patients 1.5 to 136 months of age underwent 23 keratoprosthesis procedures. The follow-up period was 220 patient months (range, 1–37 months; mean, 9.7 months). In both cases implanted with the AlphaCor (Argus Biomedical Pty. Ltd., Perth, Australia), the keratoprosthesis was not retained. In one instance, the prosthesis sustained traumatic dislocation and was replaced with a cadaver cornea. In the second instance, the intralamellar implant began to extrude and was replaced with a Boston keratoprosthesis. In all 21 Boston cases, the prosthesis was retained without dislocation or extrusion. The visual axis remained clear in 100% of cases, although retroprosthetic membranes were removed in 5 eyes. Reoperation was necessitated for management of concurrent glaucoma (n = 3) or retinopathy (n = 2). There were no instances of surface infection or endophthalmitis. In 7 instances where patient age was 4 years or more, visual acuity ranged from counting fingers to 20/30. In the remaining cases, all infants were able to follow light, fingers, and objects. Intraocular pressure was controlled in all cases.

Conclusions: Implantation of the Boston keratoprosthesis rapidly establishes and maintains a clear optical pathway and does not prejudice management of concurrent glaucoma or retinopathy. The device is retained without extrusion or rejection and is appropriate for the management of pediatric corneal opacity.
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Congenital corneal opacity may be related to infections or developmental factors or may be hereditary, whereas trauma is not an infrequent cause of opacity in older pediatric patients.[1] The treatment of pediatric corneal opacity by traditional corneal transplantation is associated with a high incidence of allograft rejection, reoperation, and complications.[2–5] The concurrence of glaucoma, retinopathy, anterior segment dysgenesis, and cataract often requires additional intraocular surgeries that increase the risk of corneal decompensation. The duration of initial opacity, in addition to potential graft rejection, corneal decompensation, and irregular astigmatism, renders this population at high risk for deprivation and refractive amblyopia. For these reasons, diverging opinions exist concerning the potential for amblyopia prevention and the advisability of any surgical intervention, particularly in monocular cases.[6] The authors have been encouraged by their results using the Boston (Dohlman-Doane) keratoprosthesis (Massachusetts Eye and Ear Infirmary, Boston, MA) in adults, particularly the rapid establishment of a clear visual axis, retention, and lack of postoperative complications.[7,8] A recent literature search uncovered only 2 previous instances in which a corneal prosthetic device was inserted in individuals younger than 8 years of age.[9] No other instances of pediatric use and no instances of infants implanted with a keratoprosthesis were uncovered until the recent report by one of the authors.[10] The authors extended their series to include pediatric cases and herein report their experiences in 23 consecutive cases of keratoprosthesis implantation in individuals from 1.5 to 136 months of age.

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Patients and Methods

A review of the charts of all patients younger than 16 years of age undergoing keratoprosthesis was performed. Attention was paid to the underlying cause of the corneal opacity, the number and types of prior surgeries, and assessment of preoperative vision. The operative technique, type of keratoprosthesis, and operative complications were recorded. Finally, postoperative vision, prosthesis retention, visual axis clarity, refraction, and subsequent surgeries and complications were analyzed.

A detailed history was obtained in all cases. Examination under anesthesia (EUA) was conducted in all infants. In 1 case (case 18), the age and level of cooperation and the authors' ability to perform the necessary preoperative evaluation was such as to preclude the necessity for an EUA. In others, the axial length data obtained during EUA performed elsewhere was used. Axial length estimation was necessary to determine the optical power of aphakic prosthesis. The authors attempted to obtain an estimate of visual potential in all cases before surgery. A and B scan ultrasonography was performed. Retina and glaucoma consultations were obtained as indicated. Intraocular pressure was recorded by Tono-Pen (Medtronic, Minneapolis, MN) as well as by digital palpation of the globe. The operative techniques for the AlphaCor (Argus Biomedical Pty. Ltd., Perth, Australia) have been reported elsewhere.[11] Our standard technique (Videos 1–5 [available at http://aaojournal.org]) for the Boston keratoprosthesis in adults was used.[7,8] A donor cornea was trephined to create an 8.75-mm button with a central 3-mm opening. This tissue then was inserted between the front plate of the keratoprosthesis (with optical cylinder passing through the center 3-mm opening) and the fenestrated back plate (Fig 1). The back plate was tightened in nut-and-bolt fashion and a locking titanium ring was applied. The assembled device was inserted in an 8.0-mm recipient bed and sutured in standard fashion. The retinal repair was carried out before keratoprosthesis implantation, as a concurrent procedure, or after implantation, as indicated. An Eckhart temporary prosthesis (DORC, Kingston, NH) often was implanted to facilitate vitreoretinal procedures and subsequently was exchanged for the permanent keratoprosthesis after completion of the retinal surgery. Aqueous shunts were implanted as a prior procedure, concurrently, or secondarily as needed. A hydrophilic bandage lens was applied (Kontur Kontact Lens, San Pablo, CA) immediately after the conclusion of the procedure and was maintained in all cases. Informed consent was obtained in all cases, and Health Insurance Portability and Accountability Act regulations were observed in the transmittal of all information associated with the instant report. The review was conducted with University of Rochester or Johns Hopkins University Institutional Review Board approval as necessary. All keratoprosthesis surgery was performed by 2 of the authors (EKA or JVA), whereas glaucoma, vitreoretinal, and lens procedures were performed by the appropriate specialists. The Boston keratoprosthesis that was used is approved by the Food and Drug Administration for manufacture and sale according to the 1976 device legislation, and as such may be implanted freely without distinction as to patient age or disease entity. The Food and Drug Administration has made no further comment.

Patients were evaluated 1 day, 1 week, and 1 month after the procedure and every 3 months thereafter. When necessary, an EUA was used. Funduscopy, retinoscopy, and intraocular pressure determination were performed.[7,12] Estimates of visual acuity and function were recorded at each visit. The bandage lens was removed when necessary for cleaning.[7] Vancomycin 14 mg/ml and levofloxacin 0.5 % drops were instilled twice daily. One percent prednisolone drops were instilled 4 to 8 times daily and were reduced over time as necessary. The prophylactic antibiotic regimen was maintained indefinitely. Protective goggles or spectacles were worn during the day and a plastic shield for protection was worn during sleep. Amblyopia prevention measures were instituted (patching or atropine cycloplegia of the fellow eye) as indicated.

Results

Twenty-two eyes of 17 patients received a keratoprosthesis implant. In 1 eye, the original AlphaCor device was exchanged for a Boston keratoprosthesis so the total number of implants was 23. There were 12 males and 10 females. The mean age was 36.5 months (range, 1.5–136 months [standard deviation]; Table 1). These 17 patients had undergone a total of 100 previous surgical interventions (mean, 7 per eye). Twelve eyes had received a total

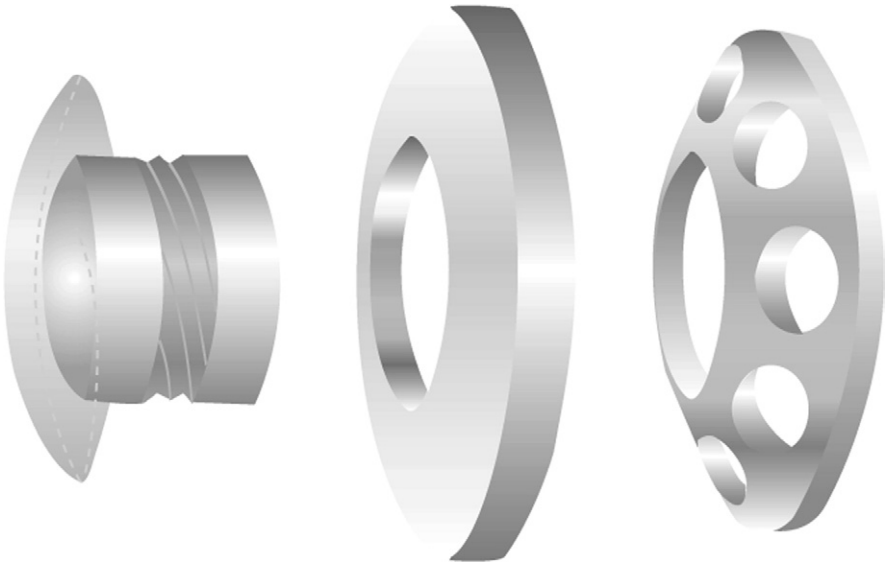

Figure 1. Illustration of the Boston keratoprosthesis assembly. Note that the donor tissue sits between the front plate optical cylinder and the fenestrated back plate. After assembly, the corneal tissue can be sutured in place in standard keratoplasty fashion.

Table 1. Summary of Individual Cases

Case No.	Eye	Gender	Age at Surgery (mos)	Initial Diagnosis	Observation after Surgery (mos)	Post operative Acuity
1	Right	Male	1.5	Peters anomaly	2.5	NA
2	Right	Female	4.75	Peters anomaly	2.25	NA
3	Left	Male	22.75	Peters anomaly/glaucoma	31	NA
4	Right	Male	5.75	Congenital glaucoma	28	NA
5	Right	Male	72	Peters anomaly/glaucoma	22	20/30
6	Right	Male	3.5	Peters anomaly/glaucoma	36.75	NA
7	Right	Female	15.25	Peters anomaly/glaucoma	7	NA
8	Left	Female	20.5	Peters anomaly/glaucoma	2.5	NA
9	Right	Male	96	Peters anomaly/glaucoma	6.5	12/400
10	Right	Male	110.5	Peters anomaly/glaucoma	12.75	20/400
11	Left	Female	10.25	Congenital perforation	5.5	NA
12	Right	Female	12.5	Congenital perforation	2.25	NA
13	Left	Female	27.5	Congenital glaucoma	3.75	NA
14	Right	Female	28.5	Congenital glaucoma	2.75	NA
15	Left*	Female	13.25	Peters anomaly/cleft palate	8	NA
16	Left	Female	27.5	Peters anomaly/cleft palate	7.75	NA
17	Right	Male	66	Congenital glaucoma	19.75	3/30
18	Right	Female	136	Congenital glaucoma	11.5	20/400
19	Right	Male	7	Congenital dermoid	20.5	NA
20	Left	Male	68.5	Peters anomaly	13.5	5/100
21	Left	Male	54	Congenital glaucoma	0.5	CF
22	Left	Male	2	Peters anomaly	1.5	NA

CF = counting fingers; NA = not applicable.
*Case 15 received initial AlphaCor, which extruded and was replaced with the Boston. Thus, the total number of prosthesis implanted was 23.

of 39 previous failed grafts (mean, 3.25). In 10 instances, the keratoprosthesis was the initial corneal procedure. Thirteen of the 22 eyes had an original diagnosis of Peters anomaly at presentation, 6 with congenital glaucoma, 1 with a dermoid tumor, and 2 with spontaneous congenital perforations (Table 1). There were no intraoperative complications. The 2 eyes that received AlphaCor keratoprostheses extruded the prosthesis (1 traumatically, 1 spontaneously). In the 1 case in whom traumatic extrusion of the AlphaCor keratoprosthesis resulted, a penetrating keratoplasty that opacified was performed elsewhere and no further efforts were made to improve the visual status. In the second case involving the intralamellar AlphaCor, the prosthesis extruded and was replaced with a Boston keratoprosthesis that has remained stable with a clear visual axis, and normal intraocular pressure has been maintained. There have been no infections or complications directly related to the Boston keratoprosthesis except retroprosthetic membrane formation. One case was returned to surgery for placement of an aqueous shunt that later required revision. A retinal detachment occurred after hypotony and was repaired with ultimate hand movements visual acuity. A second case with an aqueous shunt became hypotonic and experienced choroidal effusion and ultimately a funnel retinal detachment. The Boston prosthesis was retained in all instances (n = 22) throughout the period of observation (220 patient months; range, 1–30 months; mean, 9.7 months; Fig 2). The 5 instances of retroprosthetic membrane were treated successfully.

Postoperative visual acuity was measured in 7 eyes of children older than 4 years of age and ranged from light perception and counting fingers (n = 2) to 20/30 (Table 1). All of the remaining

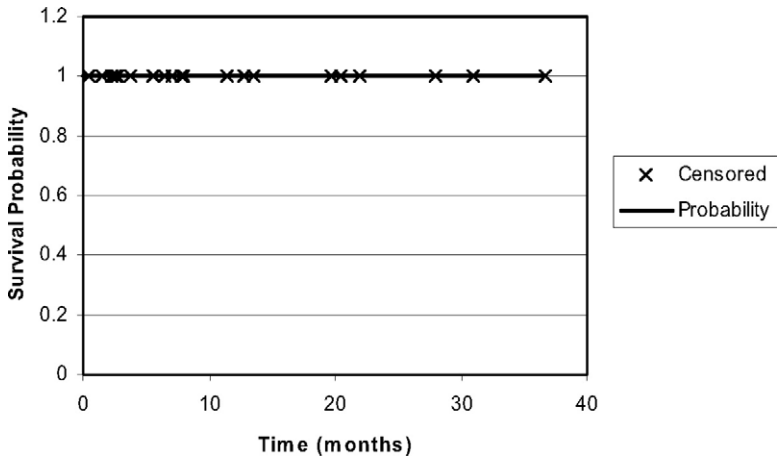

Figure 2. Graph showing survival probability over time of Boston keratoprosthesis.

15 infant eyes demonstrated the ability to follow light, fingers, and objects.

Discussion

The historical perspective of keratoprosthesis is an infrequently performed risky procedure used as a last resort.[8] This environment has been altered dramatically as a result of a number of design, surgical technique, and postoperative routine changes. The back plate of the keratoprosthesis has been fenestrated to allow free passage of metabolites; the device is mounted on donor tissue and fixed firmly, enabling easy implanting in corneal graft fashion. A hydrophilic badge lens is placed over the keratoprosthesis and is worn indefinitely, protecting the underling surface tissue from erosion, and a prophylactic antibiotic regime using vancomycin has been instituted. The combination of these and other modifications and their specific effects are thought to be responsible for the improved progress.[8] A complete discussion of this subject is beyond the scope of the present communication.

Although the purpose of this report is limited to a description of the authors' experiences with this specific technique and no control group is included, comparison with pediatric corneal transplantation is unavoidable.[2–5] The ability to achieve a quiet and comfortable eye with a clear visual axis and stable refraction within days after surgery is an enormous benefit in any ophthalmic procedure, but assumes greater importance when treating amblyopia. These Boston keratoprosthesis eyes are uninflamed and quiet, enabling facile examination including retinoscopy and funduscopy without the necessity of frequent EUA (Fig 3). On occasion, the bandage contact lens is lost, creating an uncomfortable ocular surface. Replacement usually can take place in the office with a few drops of topical anesthetic. In 1 instance, a partial lateral tarsorrhaphy was necessary to insure retention of the bandage lens in a previously buphthalmic eye. The absence of photophobia, epiphora, and blepharospasm contrasts sharply with the authors' experience after penetrating keratoplasty in pediatric populations. The absence of regular and irregular astigmatism enabled them to achieve a best correctable refraction in the early postoperative period. The incorporation of refractive power in the bandage contact lens is an important advantage. The authors plan for an initial 4 diopters of hyperopia in the infants, changing the power of the contact lens to maintain optimum acuity as the eye grows. The availability of aphakic powered keratoprostheses manufactured to conform with the axial length or desired refractive power avoids the added complexity and potential for complication associated with intraocular lens implantation in this age group. The authors always have available both aphakic- and pseudophakic-powered Boston keratoprostheses at surgery. Thus, they are prepared for intraoperative surprises such as the discovery of a well-placed intraocular lens, or the advisability of implant removal if it has the potential to cause future complication. Their routine involves lens extraction even without signs of cataract. They perform anterior and posterior capsulotomy with limited vitrectomy to avoid any subsequent opacification of the visual axis. They are careful to leave an intact capsular shell still attached to the zonules while open anteriorly and posteriorly in the event that an implant is indicated in the distant future.

The elimination of allograft rejection and its consequences for inflammation, infection, discomfort, and interference with amblyopia therapy is a major benefit of pediatric keratoprosthesis surgery, the importance of which cannot be overestimated. All of the present cases have retained their Boston keratoprostheses (2 reimplantations were necessary to accommodate manipulation of aqueous shunts). The number of surgical procedures that had been performed before keratoprosthesis in this series totaled 100, and the number of previous keratoplasties totaled 39, all of which failed. Although the observation period in this report is brief, no repeat keratoprosthesis or corneal transplant has been necessary in the Boston group. Removal of the keratoprosthesis and replacement with a traditional graft, or even with a replacement keratoprosthesis at some future point, has not been prejudiced by the keratoprosthesis procedure. There is no indication, however, that this will be necessary or even desirable in the absence of a complication.

Although the authors' experience in these pediatric cases is relatively limited and the follow-up period brief, they no longer advocate corneal transplantation for their pediatric patients with corneal opacity and elect to perform keratoprosthesis surgery as early as possible as the treatment of choice. In view of the past history of keratoprosthesis surgery, which has been replete with complications,[8] a longer follow-up will be necessary before definitive judgments can be made. Indeed, any potential benefits for amblyopia prevention or therapy will be unknown for years. Many advocate surgery in monocular cases as early as possible and before 2 months of age, whereas others believe that improvement can occur later, particularly if appropriate occlusion is instituted. There is no agreement among pediatric ophthalmologists on these issues. Indeed, some believe that monocular cases should not be candidates for surgical correction because of poor prognosis.[6] The authors' position continues to be that in view of the anatomic and optical success now associated with this procedure, these children should be afforded the opportunity for visual improvement. The advantages of this technique in this population are compelling. One of the oldest children in this series improved from hand motions to 20/400 visual acuity (Fig 4). At this level of acuity, her teachers were able to discontinue Braille-based educational techniques and reported improved learning capacity. Although the AlphaCor devices were not retained, it should be noted that these devices were specifically not intended by the manufacturer for infant implantation.

All of the Boston keratoprostheses have been retained without infection. A number of factors most likely contribute to this favorable situation. The bandage contact lens is instrumental in achieving a quiet and comfortable ocular surface. A spare lens is supplied to the parents so that in the event of loss, reinsertion can be accomplished locally. Further, the authors do not bury the knots of the interrupted 10-0 nylon sutures and yet have been surprised to observe

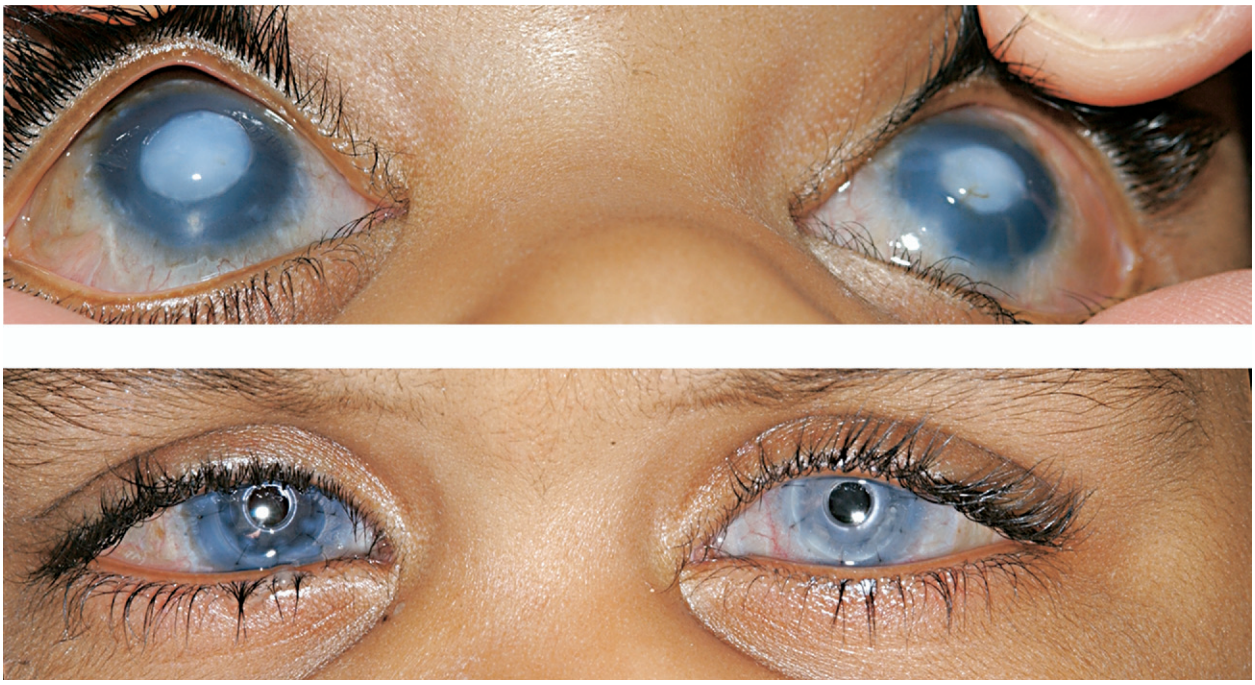

Figure 3. Top, Photograph showing the preoperative appearance of a patient with bilateral congenital glaucoma with symmetrical dense corneal opacity. **Bottom**, Photograph showing the postoperative appearance: left eye, 1 day; right eye, 1 month.

that the sutures do not loosen or require early removal. The reason for this remains obscure. This is in sharp contrast to the process of suture management in pediatric corneal transplantation, which often is associated with generalized surface inflammation and, on occasion, early allograft rejection. Because the crystalline lens was removed in all cases, the authors are not reluctant to use topical steroids aggressively as indicated, and these children are maintained on topical instillation indefinitely. Although the potential for steroid-related interocular pressure elevation exists, the population is closely monitored for glaucoma. Although a slow taper often occurs, a regimen of 1 or 2 drops daily has been maintained for the long term. The active immune system and propensity for inflammation in this age group is a factor that must be considered. The antibiotic prophylaxis of 14 mg/ml vancomycin combined with levofloxacin is a major factor in the absence of surface infection, as well as endophthalmitis. The authors do not intend to discontinue this regimen.

Despite concern that these infants and children would cause damage by rubbing, this has not been the case with the Boston keratoprosthesis. Rubbing may have been a factor in the dislocation of one of the early AlphaCor cases. Spectacles, goggles, and a nighttime shield have been the only special precautions necessary. This in part is the result of the low level of inflammation and irritation. Parents are advised to prohibit swimming because of the potential for contamination of the ocular surface. Routine bathing or showers have not been problematic.

The authors' usual procedure before advocating corneal transplantation in this age population has been to assess the parents for their ability to cope with the rigorous demands

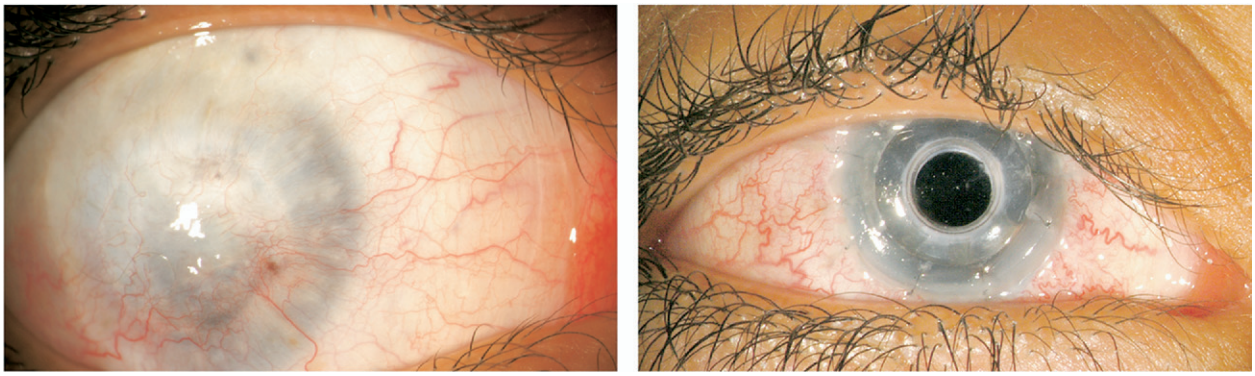

Figure 4. Left, Preoperative photograph of case 18 (age 11 years) after multiple graft failure. **Right**, Photograph of the same case at the 12-month follow-up.

associated with maintenance of the graft and with the high probability of allograft rejection with the potential for multiple grafts. Following keratoprosthesis maintenance routines are simplified, although amblyopia therapy and the rigors of glaucoma management continue to require diligence and dedication.

In those cases where close observation of the retina is mandatory, EUA may still be necessary in the very young, although the fundus view is unimpeded by the 3-mm optic. This good view of the optic nerve is also important for management of glaucoma. Usually a good impression of intraocular pressure can be obtained by tactile means or by direct applanation of the sclera.

Complications observed that in part may be related to concurrent glaucoma included choroidal effusion, hypotony, and elevated intraocular pressure. In one instance, a pannus developed after a hypotonic episode. Modifications of the shunts, including removal of the tube, were performed. In one case, a total funnel retinal detachment resulted after a prolonged period of hypotony with choroidal effusion. These instances were noted in the eyes where Baerveldt shunts (Advanced Medical Optics, Inc., Santa Clara, CA) had been implanted elsewhere. No cases of hypotony resulted when Ahmed shunts (New World Medical, Inc., Cucamonga, CA) were used. Retention of the device even in the face of such complications is probably related to the secure method of assembly (Fig 1). In one case of ptysis after a funnel retinal detachment, the prosthesis remained firmly in place without any sign of extrusion.

Although some form of adult keratoprosthesis surgery has been performed for decades,[7,8] dealing with the multiple associated pathologic features common in this young age group often requires additional expertise and resources. Thus, a team approach is used with close coordination between cornea, vitreoretinal, glaucoma, and pediatric services for preoperative evaluation, surgery, and postoperative care. Pediatric anesthesiologists and perioperative services are necessary and must be available and coordinated.

On the basis of the experiences described herein, the Boston keratoprosthesis is appropriate for implantation in pediatric cases and may be the procedure of choice to establish a clear optical pathway quickly, to reduce the potential for reoperation and complication, and to assist in the process of amblyopia prevention and therapy. The increased ocular morbidity associated with concurrent glaucoma, vitreoretinal disease, and multiple previous surgical interventions continues to render this population at high risk for visual restoration.

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