

Boston KPro: Past Successes and Future Challenges

With a history that dates back at least 230 years, the artificial cornea has long been considered a possible treatment option for patients with severe corneal disease. However, the greatest progress in designing and developing such an artificial cornea has occurred in the last half century. To date, over 11,000 Boston Keratoprotheses have been implanted worldwide in 66 countries by 598 surgeons.

Since the 1960s, changes to the Boston KPro design and its postoperative management have led to marked clinical improvements. In particular:

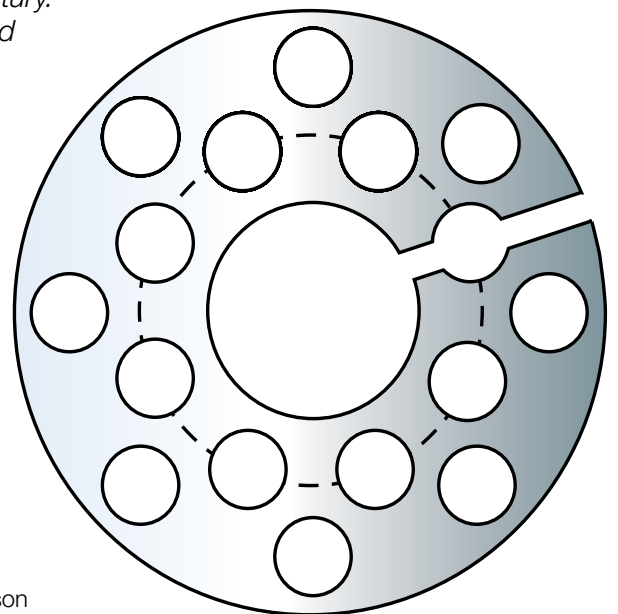
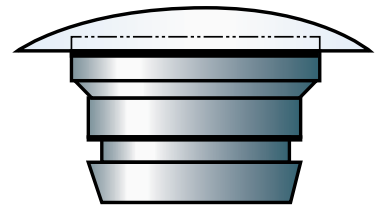
- The rate of postoperative endophthalmitis has decreased about 10-fold over 2 decades in patients with Boston KPro implants because of low-dose prophylactic antibiotics.
- The corneal surface has been found to be well protected from evaporative damage by a soft contact lens or a conjunctival flap.
- Corneal melt around the device has likewise decreased to about 3% over the first 17 postoperative months by improving nutrition from the aqueous (perforated back plates) and applying better anti-inflammatory strategies.
- The retroprosthetic membrane is diminishing in frequency. Titanium alloys are used for non-transparent parts to reduce inflammation and increase biointegration.

Nevertheless, post-operative glaucoma is still an obstinate problem that causes long-term reduction of vision.

In patients with corneal blindness due to autoimmune diseases (i.e. Stevens-Johnson syndrome and mucous membrane pemphigoid) and severe chemical burns, the Boston KPro can be a life-changing intervention. But these individuals still have a high rate of complications, and should only be seen at experienced KPro centers.

While the Boston KPro of 2015 has achieved remarkable success, additional refinements are necessary to make this artificial cornea a truly effective, inexpensive, and long-term safe treatment option. This means lower rates of postoperative inflammation, glaucoma, and retinal detachment—even for the most severe cases and in resource-poor countries. To meet these challenges head on, researchers and clinicians continue to seek ways to improve the Boston KPro, especially for the developing world.

—Andrea Cruzat, MD



*A Boston Keratoprosthesis update from
Harvard Medical School Department of Ophthalmology / Massachusetts Eye and Ear*



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Eye and Ear**

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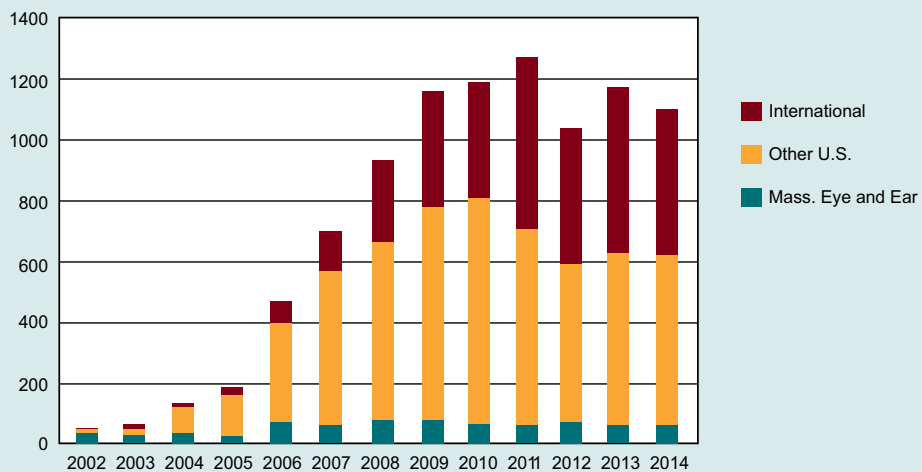
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Boston KPro Usage (approximately 11,000 implanted to date)



Update on Antifungal Prophylaxis in KPro Patients

Silvia Odorcic, MD, FRCSC

Infectious endophthalmitis remains the most serious and vision threatening complication in patients with KPro implants. While antibiotic prophylaxis has virtually eliminated bacterial cases of endophthalmitis, it has ushered in an increased rate of fungal colonization and infection. In reviewing the literature on patients with KPro implants, fungal infection rates vary from 0.009 to 0.190 infections per patient year, while reported colonization rates range from 0 to 11% and fluctuate over time.

We recently collected a series of surveillance cultures in our cohort of patients with KPro implants and found that serial cultures in eyes without visible signs of fungal colonization or infection are not justified. Colonization rates fluctuate and do not predict future fungal infection. Fungal colonization often presents as mulberry shaped deposits on the soft contact lens, while fungal infiltrates start around the optic stem, resulting in a “white sheen.” (See Figures). *Candida* species, and *C. parapsilosis* in particular, are the predominant causative organisms reported in KPro infections in northern North America.

There is no standard antifungal prophylaxis regime for KPro patients. However, we are working on elucidating the optimal antifungal agent, dosing and indications for prophylaxis. Various centers around the world employ a 5% povidone-iodine rinse in combination with contact lens exchange or a short course of a topical antifungal. At Massachusetts Eye and Ear, we recommend short periodic bursts of antifungal treatment: amphotericin B 0.15% or natamycin 5% twice daily for a week at a time. However, these agents are costly, toxic with longer duration of use, and often unavailable in developing countries.

A candidate antifungal agent is hypochlorous acid, 0.01%, commercially available as Avenova™ (NovaBay Pharmaceuticals) and marketed as an adjunct treatment for blepharitis. Our own *in vitro* testing has shown that this agent has broad spectrum antifungal activity and is rapidly fungicidal, often in as little as 15 seconds. Formal clinical testing will help determine whether hypochlorous acid is non-toxic and well tolerated by our patients. A global antifungal prophylaxis agent, especially for the developing world, is a pressing need, and hypochlorous acid holds great promise.



Figure 1: Fungal colonization presents as white, mulberry shaped deposits on the soft contact lens.



Figure 2: Early fungal keratitis presents as a white sheen around the optic stem.

Glaucoma Drainage Device Conjunctival Erosion Associated with Boston KPro

Elise V. Taniguchi, MD and Lucy Q. Shen, MD

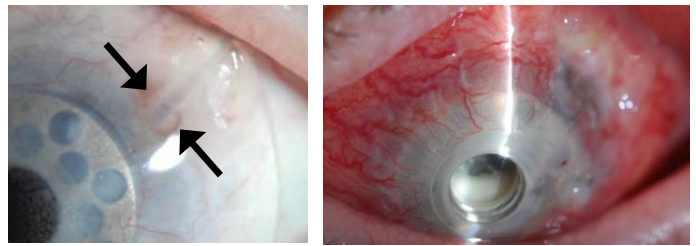
Glaucoma poses a challenge in the long-term follow up of patients with Boston Keratoprosthesis (KPro) implants, and glaucoma drainage devices play an important role in controlling intraocular pressure. Although continuous modifications have improved clinical outcomes and reduced postoperative complications, patients with glaucoma drainage devices are still at risk for conjunctival tissue erosion, particularly those with KPro implants.

In this patient population, tissue erosion has been reported as high as 58.8%.¹ Associated complications include hypotony, choroidal detachment, and rare cases of endophthalmitis in the presence of routine antibiotic prophylaxis. In cases of infection, the eroded conjunctiva probably serves as a pathway for normal flora from the ocular surface to enter the eye.

Reasons for conjunctival erosions are not clearly understood and may be multifactorial. While the type of aqueous shunt and its location on the eye do not seem to play an important role,² concomitant intraocular surgery and postoperative contact lens use increases the risk of tube erosion in this patient population.

Mechanical rubbing of the edge of the contact lens against the conjunctiva over the tube is the major concern. In some cases, the erosion will resolve with adjustments to the contact lens.³

Glaucoma drainage devices placed posteriorly in the pars plana can reduce the risk of tube erosion³ and improve contact lens fitting, although tube visualization inside the eye is limited and a full pars plana vitrectomy is needed. Anterior chamber placement of the glaucoma aqueous shunt is still preferred when the surgery is performed concomitantly with KPro implantation and when pars plana vitrectomy is not required for other indications.



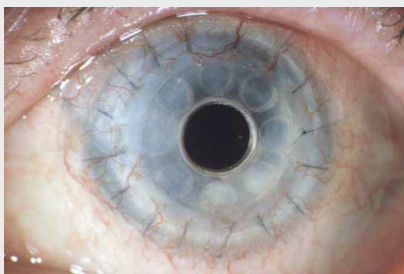
CASE STUDY

In our 19 cases of tube erosions seemingly from contact lens edge rubbing, 1 patient developed endophthalmitis. A 69-year-old woman with Boston KPro implanted due to Salzmann's nodular degeneration presented with a glaucoma drainage device eroding through the conjunctiva in her left eye in May 2014. In August 2014, there was mucous overlying the eroded tube (photograph on the left with arrow indicating the eroded area of 3-4 mm). An urgent tube revision was recommended. The visual acuity was 20/50 at this time, and the patient refused the surgery. In October 2014, the patient presented with severe endophthalmitis, likely secondary to tube exposure, and could not perceive light. The patient underwent pars plana vitrectomy combined with removal of the glaucoma drainage device. A significant amount of pus was found in the bleb of the glaucoma drainage device. Photograph on the right shows the eye four days after surgery.

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Primary Implantation of Type I Boston KPro

Han-Ying Peggy Chang, MD



After decades of research and development, the Boston KPro is capable of successfully restoring vision to patients with devastating cases of corneal blindness. As complications have been reduced, indications for the Boston KPro have expanded. Increasingly, more surgeons are considering the Type I Boston KPro as the primary corneal procedure in patients expected to have a poor prognosis from traditional keratoplasty.

At Mass. Eye and Ear, we performed a large retrospective case series of 43 eyes followed for an average of 3.5 years after primary Boston KPro implantation. The most common indication for primary Boston KPro was a vascularized host cornea, often secondary to aniridia or herpetic infection. Prior studies have demonstrated that rates of graft rejection and failure are high in

this patient population. KPro implantation successfully and rapidly improved visual acuity in these patients. More importantly, visual improvement was sustained, with 72% of eyes demonstrating improvement from pre-operative vision at the last follow-up. Thus, we believe that primary Boston KPro can be an effective option for certain patients, though close follow-up and appropriate management of complications, especially glaucoma, are critical for long-term preservation of vision.

Profiles of Distinguished Boston KPro Surgeons

Natalie Afshari, MD, FACS



Dr. Afshari is Professor of Ophthalmology and Stuart I. Brown MD Chair in Ophthalmology in Memory of Donald P. Shiley, Chief, Division of Cornea and Refractive Surgery, and Director of Education at the Shiley Eye Center, University of California, San Diego.

In her clinical practice, Dr. Afshari specializes in corneal transplantation, keratoprosthesis, cataract, and refractive surgery. She has received the inaugural

Top Ten Women in Medicine Award by Triangle News and was named in the *U.S. News & World Report's* "Top Doctors List." Her research on Fuchs' dystrophy is supported by a National Institutes of Health grant, and she investigates the intricacies of endothelial keratoplasty and regeneration of the cornea.

After receiving her medical degree from Stanford University, Dr. Afshari completed her residency training at Harvard Medical School and then a two-year fellowship in cornea and refractive surgery at Mass. Eye and Ear.

Dr. Afshari is the co-editor of a new, two-volume cornea book called *Principles and Practice of Cornea*. She has published articles in the American Academy of Ophthalmology's (AAO) *EyeNet* magazine on the "Nuts and Bolts of Keratoprosthesis" as well as AAO's monthly publication, *Focal Points*, on keratoprosthesis. Additionally, she received AAO's Senior Achievement Award and the Secretariat Award.

She serves on the editorial boards of *Investigative Ophthalmology and Visual Science* and *American Journal of Ophthalmology*, and previously served on the *EyeNet* editorial board, BCSC Cornea text book committee, and the AAO council representing the American Society of Cataract and Refractive Surgery. Dr. Afshari also was Co-chair of the cornea program committee for the Association for Research in Vision and Ophthalmology and Co-director of Cornea Subspecialty Day for the AAO.

Edward Holland, MD



Dr. Holland is the Director of Cornea Services at Cincinnati Eye Institute (CEI) and Professor of Ophthalmology at the University of Cincinnati. As Director, he has attracted worldwide referrals for medical and surgical corneal problems, and specializes in the management of severe ocular surface disease and high risk keratoplasty.

Dr. Holland has performed over 250 Boston Type 1 Keratoprosthesis

surgeries—the majority in patients with severe ocular surface disease. He has used the Boston KPro as a primary procedure and as a secondary procedure in patients with successful ocular surface stem cell transplants, but failed keratoplasty. His research includes the evaluation of the safety and efficacy of the Boston KPro in severe ocular surface disease.

Dr. Holland trained in Ophthalmology at the University of Minnesota, and then completed a fellowship in Cornea and External Disease at the University of Iowa, followed by a second fellowship in ocular immunology at the National Eye Institute/ National Institutes of Health. Subsequently, he returned to the University of Minnesota and served as Director of the Cornea Service. He was then promoted to the position of Professor and was granted the Elias Potter Lyon Chair in Ophthalmology. He joined CEI and the University of Cincinnati in 2000.

Among his numerous leadership roles, Dr. Holland currently serves as the Program Chair for the American Society of Cataract and Refractive Surgery (ASCRS). Previously, he served as President of ASCRS, Chair of the Eye Bank Association, member of the Board of Trustees of the American Academy of Ophthalmology (AAO), and President of the Cornea Society, among other roles.

Dr. Holland was awarded the Castroviejo Award from the Cornea Society in 2013. He has also received both the Senior Achievement Award and The Honor Award from the AAO. He was awarded the Binkhorst Medal by the American Society of Cataract and Refractive Surgery in 2008. Additionally, he was a recipient of the 2002 Paton Society Award given by the Eye Bank Association of America. Dr. Holland is the author of over 200 articles in peer reviewed journals and has edited *Cornea*, the most widely read textbook on corneal disease and surgery.

Juan Alvarez de Toledo, MD



Dr. Alvarez de Toledo is a Senior Surgeon of Cornea and Refractive Surgery at the Centro de Oftalmología Barraquer of Barcelona, Spain. He is also responsible for the Corneal Preservation Department of the Eye Bank for Treating Blindness in Barcelona.

With clinical interests in medical and surgical corneal diseases, he performs around 200 corneal transplants a year, including deep anterior lamellar keratoplasty

(DALK), Descemet's stripping automated endothelial keratoplasty (DSAEK), Descemet's membrane endothelial keratoplasty (DMEK), penetrating keratoplasty (PK), and ocular surface reconstruction, including limbal allografts and keratoprotheses. Also, he is a cataract and refractive surgeon performing corneal and lens-based refractive procedures and cataract surgeries, iris reconstruction, and intraocular lens implantation.

Credited with first introducing the Boston KPro in Barcelona, Dr. Alvarez de Toledo and the Cornea Department of Barraquer Institute continue to conduct research in the field of keratoprotheses. In particular, they focus their studies on tibial and dental osteo-odonto-keratoprotheses, in which they have more than 50 years of experience.

After graduating from Barcelona Central University in Clinic Hospital of Barcelona, Dr. Alvarez de Toledo performed his Ophthalmology residency in the Centro de Oftalmología Barraquer, followed by a fellowship in Cornea with Prof. Joaquín Barraquer. He also was trained in eye-bank procedures at Amsterdam Netherlands Ophthalmic Institute with Prof. Lisbeth Pels and at Kiel University Eye-bank with Prof. Gernot Duncker.

He is member of several national and international Ophthalmology societies as well as a reviewer of some peer-reviewed journals. The author of more than 50 papers and book chapters, Dr. Alvarez de Toledo has delivered more than 400 presentations at ophthalmology meetings. He has received several awards including Best Paper of the Session in American Society of Cataract and Refractive Surgery for the description of the recurrence of keratoconus long time after penetrating keratoplasty (*Cornea*. 2003 May;22(4):317-23).

William Power, MD



Dr. Power is President of the Irish College of Ophthalmologists. He also leads the national keratoprosthesis program and has been implanting the Boston KPro since 2000.

His clinical interests include managing patients with Stevens-Johnson Syndrome, ocular cicatricial pemphigoid, chemical burns, and limbal stem cell transplantation. His research interests include limbal stem cell

transplantation and biosynthetic collagen membranes.

After graduating from Trinity College Medical School, Dr. Power completed an internal residency program and obtained his membership of the Royal College of Physicians in Ireland. He then commenced training in Ophthalmology, completing his residency and specialist registrar training at the Royal Victoria Eye and Ear Hospital. Next, he was awarded fellowships of the Royal College in Surgeons, Glasgow and the Royal College of Ophthalmologists in 1989. He then completed his postgraduate thesis and was awarded the degree of Masters in Surgery (TCD).

In 1993, he traveled to Boston and completed two fellowships at Mass. Eye and Ear – one in Uveitis and the other in Cornea. During his cornea fellowship, he worked closely with Dr. Claes Dohlman and gained tremendous experience in managing patients with the Boston KPro. He was appointed Assistant Professor of Ophthalmology at Harvard Medical School and consultant eye surgeon at Mass. Eye and Ear in 1995. The following year, he was appointed Chief of Ophthalmology at Brigham and Women's Hospital in Boston.

In 1998, he returned to Dublin and took up the post of consultant ophthalmologist in the Royal Victoria Eye and Ear Hospital, St. Vincent's University Hospital and the Blackrock Clinic. In 2012, he was awarded the Fellowship of the College of Physicians in Ireland.

THE BOSTON KPRO TEAM



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Translational Research



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Surgery, Translational
Research



Roberto Pineda II, MD
Surgery, Clinical Research



Samir Melki, MD, PhD
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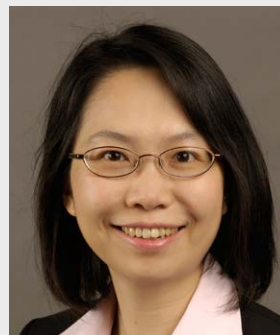
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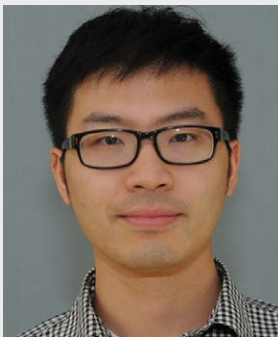
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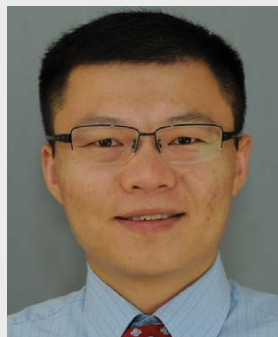
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2014

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You're invited... Please join us!



KPro Study Group Round Tables

September 3, 2015
Barcelona, Spain
Instituto de Microcirugía Ocular (IMO)
3:00-8:00pm
Registration: www.imo.es/kpro



American Academy of Ophthalmology Meeting

November 2015
Las Vegas, Nevada
Venetian Hotel

- **Boston Keratoprosthesis Users Breakfast**

November 16th | 7:00am- 8:30am
Place: Venetian Hotel in the Bassano Room (2601, 2605)
If you plan to attend please e-mail: mlmoar@verizon.net

- **Glaucoma Management in Patients with Boston Keratoprosthesis**

November 16th | 11:30am -12:30pm
Room Galileo 1001
Senior Instructor: Lucy Q. Shen, MD

- **AAO KPro Course**

The Boston Keratoprosthesis: Case-Based Presentations Highlighting the Essentials for Beginning and Experienced Surgeons

November 17th | 10:15am-12:30pm
Senior Instructor: Kathryn Colby, MD, PhD



6th EuCornea Congress

September 2015
Barcelona, Spain

- **Keratoprosthesis Free Paper Session**

September 5th | 8:00-9:00am

- **Keratoprosthesis Focus Session 5**

September 5th | 9:00-10:30am
Chairpersons: J. De La Cruz (USA) & C. Liu (UK)



ESCRS

September 2015
Barcelona, Spain

- **Boston Type 1 Keratoprosthesis: from indications to innovations**

Pre Requisite Course for Surgical Skills Training Course
September 5th | 5:00pm-6:00pm
Leader: M. Cortina

- **Boston KPro Surgical Skills Training Course**

September 6th
8:30-10:30am and 11:00am-1:00pm
Instructors: Alja Crnej, MD, Andrea Cruzat, MD, Kathryn Colby, MD, and Jose de la Cruz, MD



Harvard's Boston KPro Course at 18th University of São Paulo Ophthalmology Meeting

December 3, 2015 | 1:30pm-7:45pm
São Paulo city of São Paulo State, Brazil
Register at: www.jdeeventos.com.br/Evento.aspx?EV=108



29th Biennial Cornea Conference

October 16-17, 2015
Boston, MA
Harvard Medical School
Department of Ophthalmology
Cornea Center of Excellence



10th KPro Study Group Meeting

April 22-23, 2016
Kyoto Hotel Okura, Kyoto, Japan
For details contact: fukuda-m@med.kindai.ac.jp



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