BOSTON KPro news
SEPTEMBER 2021 | NUMBER 16

Dear Friends and Colleagues,

James Chodosh, MD, MPH

Much has happened this past year, most of it well beyond the scope of this newsletter. Most relevant to Boston Keratoprosthesis, the COVID-19 pandemic continues to wreak havoc across much of the world, and there continue to be sporadic shutdowns of elective surgery with many local hospital systems simply overwhelmed by a torrent of critically ill patients. However, as you will see in this newsletter, our work at Boston Keratoprosthesis has continued to move forward.

In this newsletter, we highlight three of the many areas of investigation currently in progress at Boston Keratoprosthesis. Dr. "Miraz" Islam describes headway in the potential use of animal corneas and also laboratory-generated corneal substitutes as alternatives to human corneas as carriers for implantation of the Boston KPro. Dr. Sina Sharifi discusses work being done with E-beam irradiation to enable KPro and donor cornea preassembly and subsequent room-temperature storage of preassembled devices for off-the-shelf use. And, Dr. Eleftherios Paschalis describes a novel approach in which subconjunctival placement of a drug delivery device, simultaneously eluting two FDA-approved biologic agents, dramatically reduces corneal and retinal damage after severe alkali injury. Although at this time there is no known way to prevent corneal scarring after severe chemical injury, Dr. Paschalis's invention led to more rapid healing of the corneal epithelium, reduced corneal neovascularization, and less retinal damage. This may mean better surgical outcomes and less postoperative and delayed-onset glaucoma when corneal replacement in chemical-injured eyes is necessary, whether the eye receives a corneal allograft or a keratoprosthesis.

You will also see brief bios from three renowned and highly successful keratoprosthesis surgeons: Dr. Thomas Neuhann, from Munich, Dr. Jose Vargas from Riyadh, and Dr. Victor Perez from Durham. Each of these icons of ophthalmology has contributed significantly to progress in the use of the Boston KPro, and we are grateful to have them as colleagues and as friends.

Finally, all of us at Boston Keratoprosthesis wish everyone reading this newsletter a safe, healthy, happy, and peaceful next year. Thank you for your support as we work together toward our goal of eliminating corneal blindness.

All best,

James Chodosh MD MPH
Edith Ives Cogan Professor of Ophthalmology
Mass. Eye and Ear – Harvard Medical School
Boston Keratoprosthesis

Boston KPro *news*

In this issue:

Update Your Info or Go Paperless

To update your mailing address or request a digital copy of *KPro news*, email:
larisa_gelfand@meei.harvard.edu
or
kpro_service@meei.harvard.edu

Editors:

James Chodosh, MD, MPH
Director, Boston KPro Clinical and Research Programs

Larisa Gelfand
Director, Boston KPro Business Operations

Eleftherios I. Paschalis, Ph.D
Director of Innovation, Boston KPro

Dear KPro users,

You will have likely seen several memos regarding changes in the distribution structure and process for exporting the Boston KPro to facilities in the European Union, effective August 1, 2021. These changes were driven by the need to comply with updated EU distribution regulations, and they will impact our EU-based users in several ways.

While the procedure for the submission of your orders remains the same, through Boston KPro customer service, shipment and delivery of devices is now performed through MundoMed, which has become our official European distributor. As a result, users will see two new fees on all invoices: a flat shipping fee in US$, which will cover shipping costs within the EU, and a flat handling, customs duties, and taxes fee, also in US$, which will cover shipment of the device from the United States, and all taxes, fees, and customs duties related to the importation of the KPro device into the European Union.

Please note that these fees were previously paid by all users directly, but will now be paid by Boston KPro and charged back to the users at cost.

Warm regards,

Larisa Gelfand, MEd

Director, Boston Keratoprosthessis Business Operations

Complete cornea and retina protection after trauma; A new therapy and delivery method

Eleftherios I. Paschalis, Ph.D

Ocular surface injuries cause corneal damage and corneal neovascularization,1 but when severe can also cause severe intraocular complications,2-4 including proliferative vitreoretinopathy (PVR)5 and secondary glaucoma.3,6-9 Improving the therapy for such injuries is a longstanding unmet clinical need that could substantially improve clinical outcomes and prevent vision loss. To this end, our laboratory has been on the forefront of ocular trauma research, delineating major mechanisms of tissue injury after penetrating, surgical, and chemical trauma to the eye.3,4,10-15 Our studies have shown that tumor necrosis factor alpha (TNF-α) and vascular endothelial growth factor (VEGF) are key mediators of ocular tissue injury and that their blockade using monoclonal antibodies substantially improves corneal wound healing and prevents PVR and secondary glaucoma.16,17 Analysis of the outcomes of inhibition of either TNF-α or VEGF after corneal alkali burn showed the potential for a therapeutic overlap, prompting us to explore the possible synergy of combining the two therapeutic biologics in one treatment. Leveraging these findings, we generated a drug delivery system (DDS) suitable for sustained subconjunctival administration of TNF-α and VEGF inhibitors. Use of the DDS was intended to allow significant reduction of the administered therapeutic dose, in order to minimize the risk of local and systemic adverse events. The biologic-loaded DDS was generated from biodegradable triblock hydrophilic/hydrophobic PLGA-PEG-PLGA co-polymer, and contained both antibodies. Administration of the DDS in the subconjunctival space was performed in liquid form using a 30G needle. The DDS rapidly forms a semi-solid hydrogel by a process that does not generate toxic byproducts. In vivo assessment of antibody release for the DDS showed zero-order kinetics for 3 months with antibody bioavailability in all ocular tissues tested (cornea, uvea, and retina)18. By 3 months, the polymer had degraded naturally. In our rabbit model of corneal alkali burn, a single application of the DDS containing only 1.3 mg of anti-VEGF and 0.7 mg of anti-TNF-α antibodies achieved complete (100%) inhibition of corneal neovascularization for 3 months (duration of the study) (Fig. 1A-D), complete re-epithelialization of the cornea (Fig. 1E-F), and most importantly, complete protection of the neuroretina and optic nerve from secondary degeneration (Fig. 2A-K), the latter a known complication of severe corneal alkali injury in animals and patients.2-4,10,11,13,14,19 Our low dose biodegradable DDS appears to be of low risk to recipients and can be used even after an open globe injuries, without risking intraocular toxicity from overdose. We foresee that future application of this therapy may substantially improve clinical outcomes and contribute to the reduction of vision loss after severe ocular trauma *(Original work by Zhou et al).*

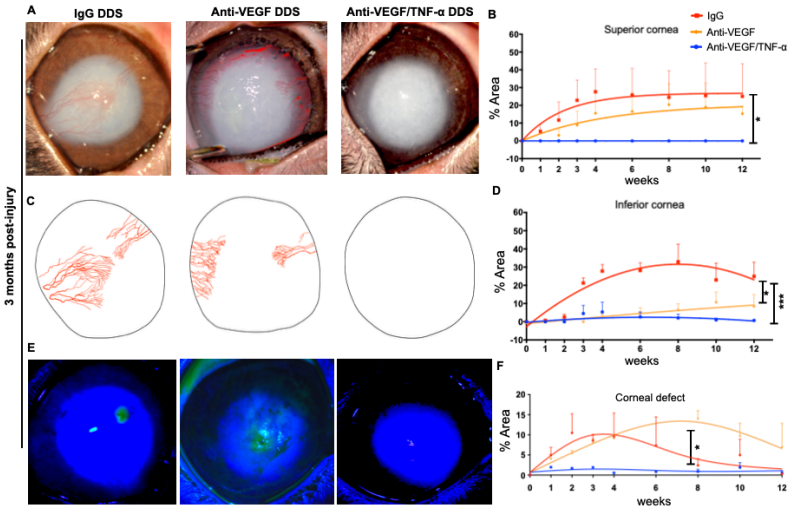


Figure 1. Anti-TNF-α/anti-VEGF DDS therapy for ocular burns. (A-D) Double therapy with anti-VEGF/anti-TNF-α triblock drug delivery system (DDS) after ocular alkali injury completely prevents corneal neovascularization for more than 3 months after a single application of the DDS in the subconjunctival space. (E-F) Moreover, DDS with double therapy leads to complete corneal re-epithelialization. In contrast, IgG DDS (isotope control), anti-VEGF, or from previous results,17 anti-TNF-α DDS monotherapy confers inferior outcomes as compared to double anti-VEGF/anti-TNF-α DDS therapy. *P<0.05, ***P<0.001 Generalized linear model.

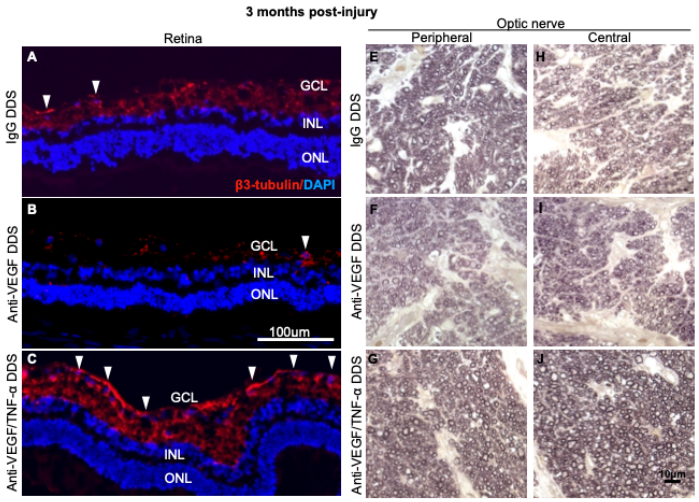


Figure 2. Anti-TNF-α/anti-VEGF DDS therapy results in complete retinal and optic nerve protection. Three months after corneal alkali burn, rabbit retinas were examined using β-3 tubulin (A-D), a marker for retinal nerve fiber layer and ganglion cells, while the optic nerves were examined using p-Phenylenediamine) staining (E-K). Double DDS therapy conferred almost complete protection against secondary damage to the retina and optic nerve, as opposed to IgG, or anti-VEGF DDS mono therapy, which failed to completely block degeneration. *P<0.05, **P<0.01, ***P<0.001, ****P<0.0001, Multiple group comparison with alpha level correction.

Carriers for the Boston Keratoprosthesis

Mohammad Mirazul Islam, Ph.D

Corneal diseases are among the leading causes of blindness throughout the world. The most commonly applied remedy for corneal blindness is transplantation of a cornea from a deceased human donor. However, in certain disease conditions, for example, recurrent corneal graft rejection, limbal stem cell deficiency, ocular burn, and aniridia, corneal transplantation is likely to fail. For patients with these disorders, implantation of a Boston keratoprosthesis (KPro) can restore vision and be a life-changing event. Claes H. Dohlman, MD, PhD created the first Boston KPro at Mass. Eye and Ear in the 1960s, and obtained approval for its marketing by the US Food and Drug Administration in 1992. Since then, substantial progress has been made in device design, identification of appropriate diagnostic categories, and postoperative management, and together these advances have significantly improved the safety and long-term success of implantation. The Boston KPro is by far the most frequently used keratoprosthesis in the world, with more than 15,000 implantations to date.

All Boston KPro designs require a corneal carrier. In select cases, the patient's own (diseased) cornea can be used,(Ament et al. Arch Ophthalmol 2010;128:795) but this lengthens the time that the eye is open and susceptible to intraocular hemorrhage or microbial contamination, lengthens the overall surgical and anesthesia time, and is contraindicated if there is corneal thinning. Therefore, for the great majority of cases, a donor cornea is needed as a carrier. Because the PMMA front plate bestows vision, the carrier cornea does not need to be of high quality or clarity, i.e., corneas that would not normally be considered for transplantation due to low endothelial cell counts or advanced age of the donor, can be utilized as carriers in Boston KPro surgery. However, even with these allowances, the need for a human donor cornea remains a limitation of Boston KPro surgery because of a scarcity of human corneas in much of the world. As illustration, it has been estimated that only 1 donor cornea is available for every in 70 patients awaiting corneal transplantation.

There is increasing interest in exploring alternatives to fresh human donor corneas as carriers for the Boston KPro. A frozen (cryopreserved) cornea is an alternative and may offer similar clinical outcomes compared with a fresh cornea.(Muzychuk AK, et al. Ophthalmology 2017:124:20.) As discussed by Dr. Sina Sharifi elsewhere in this newsletter, gamma or E-beam irradiated corneal tissue can also be used as an alternative for fresh tissue. In a limited case series, the visual acuity outcomes, complications, and KPro retention using gamma-irradiated carrier corneas were comparable with the outcomes using fresh corneas as carriers.(Fadlallah A, et al. Cornea 2014:235.) Glycerol preserved corneas can also be used for KPro implantation, and if planned properly, the time needed to rehydrate the glycerol-preserved cornea need not be a hindrance. However, this approach also requires a human corneal donor.

Corneas procured from non-human animal species (xenografts) present another potential alternative for use as KPro carriers. In one study, acellular porcine corneas were transplanted in lamellar keratoplasties in humans with tectonically stable outcomes.(Zhang M-C, et al. Am J Transplant 2015;15:1068) We have shown that porcine corneas can be decellularized by chemical treatment, then sterilized by gamma irradiation without damaging their physicochemical properties, and finally can be recellularized with human corneal cells.(Islam MM, et al. Acta Biomater 2019;96:330.) These data suggest promise in using the porcine cornea as KPro carrier for human implantation.

Many research groups including ours, are working toward the development of an artificial cornea using synthetic, semi-synthetic, or natural polymers or peptides, and success would provide another alternative to human corneal tissue for KPro implantation. Different polymers and crosslinking strategies can be employed to form an artificial cornea (Fig. 1). A natural polymer, collagen-based, artificial cornea showed promise as a lamellar implant in human clinical trials.(Islam MM, et al. NPJ Regen Med 2018;3:2) However, however collagen implants are by their nature mechanically weak and susceptible to enzymatic degradation. Recently, we showed improved physical properties by a specific crosslinking process,(Islam MM, et al. Pharmaceutics 2021;13:832) and propose that these implants could be used as carrier for the Boston KPro. An additional potential in using artificial corneas is these implants may be customizable based on the patient's condition and severity of the disease.

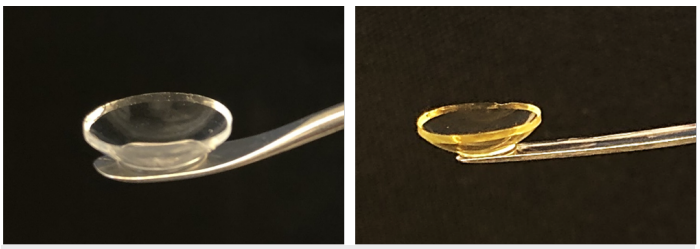


Figure 1. Artificial corneas made with natural polymer and different crosslinkers.

New Keratoprosthesis Sterilization Methods to Enable Boston KPro Preassembly

Sina Sharifi, Ph.D

Presently, implantation of a Boston keratoprosthesis (KPro) requires (i) an ethylene oxide (ETO) sterilized device, shipped from Boston Keratoprosthesis (Mass. Eye and Ear), with its power chosen for one particular patient (ii) a fresh, frozen, or irradiated corneal donor graft, shipped from an eye bank (the latter two may be kept in long term storage), and (iii) assembly by the surgeon in the operating room at the time of surgery, with the patient under anesthesia. ETO sterilization of the Boston KPro requires lengthy cycle times and is costly. Because ETO is a carcinogen and presents other significant health risks to those working at sterilization facilities, regulatory agencies may soon require that ETO sterilization be replaced by other methods. At the same time, a global scarcity of donor corneas suitable for transplantation, the lack of infrastructure required for transportation and storage, and the necessity for short donor-to-recipient time frames constrains the availability of the fresh corneas for keratoplasty surgery. These problems along with the need for surgical training in the assembly of the Boston KPro device for surgeons inexperienced in KPro implantation, suggest new approaches are needed to deliver ready-to-use KPro devices to surgeons and their patients. Preassembly of a standard device with refractive power suitable for most patients, with sterilization by ionizing irradiation, e.g., gamma or E-beam, would bypass many of the these obstacles, and enable transportation and long-term storage of devices at room temperature. In the Boston Keratoprosthesis Laboratory, we have been working with both gamma and E-beam irradiation to sterilize human donor corneas, Boston KPro device components individually, and KPro devices after assembly into human donor corneas (preassembled).

Our study of the effects of gamma irradiation of poly (methyl methacrylate) (PMMA) discs and Boston KPro front plates showed that a minimal effect on the mechanical properties (nanoindentation, flexural strength) and cell biocompatibility. Gamma-treated samples did show yellowing, although this faded away over time, and transparency was unaffected. In contrast, E-beam irradiation did not cause yellowing, and 25 kGY of irradiation did not alter the chemical, mechanical, optical, or biological properties of the PMMA. PMMA samples treated with either gamma or E-beam irradiation were equally biocompatible to untreated samples.

We then performed E-beam irradiation of whole human corneas from deceased donors and of corneas pre-assembled in a Boston KPro, immersed in recombinant human serum albumin, and showed that E-beam irradiation enhanced the tensile/compression moduli of corneas, with no impact on their tensile strength. E-beam also caused a minor degree of crosslinking between collagen fibrils, increasing the corneas resistance to collagenase-induced degradation. However, E-beam did not alter permeability, optical, or ultrastructural properties of treated corneas. Moreover, while there was no alterations to the interface between the PMMA stem and the donor corneas. Preassembled KPros withstood more than 200 mm Hg pressure before and after irradiation. Furthermore, E-beam induced chemical bonding between the PMMA stem and corneal tissue, theoretically reducing the likelihood of transmission of microorganisms from the ocular surface to inside the eye. E-beam irradiated devices, pre-assembled in human corneas, were stable for 6 months at room-temperature.

E-beam irradiation is relatively more rapid than gamma irradiation, less prone to cause yellowing of the PMMA component, and relatively inexpensive. Our data suggest that E-beam irradiation has no detrimental effects on the corneal tissues or Boston KPro device components, even when preassembled, and may improve the native properties of the corneal tissue, enabling prolonged preservation at room temperature. Thus, pre-assembly of the Boston KPro in a donor cornea, followed by E-beam irradiation, offers the potential for an off-the-shelf, ready to implant keratoprosthesis device.

What is the Present Status (2021) of the Boston Keratoprosthesis – And What is Next? Questions and Answers

Claes H. Dohlman, MD, PhD; Thomas H. Dohlman, MD; Sarah Kim, BA; Larisa Gelfand, MEd; James Chodosh, MD, MPH; Eleftherios Paschalis, PhD

Q. Since many keratoprostheses have been suggested (and abandoned) in the past, what is the background and history of the Boston KPro? Why has it received a degree of sustained acceptance?

A. The background of the B-KPro has been covered in two reviews from Boston.[1,2] The effort behind the B-KPro has been quite focused and sustained for more than half a century. Much evidence stems from long-term laboratory experiments.

Q. When was research on B-KPro and its management initiated and when did it become FDA approved?

A. Early experimentation started in the 1960ies,[3] originally based on designs published elsewhere. The designs and, particularly, the postoperative management gradually changed substantially and improved in outcome, and the process became distinctly original.[2] FDA approved the device in 1992.

Q. When did outcomes become correlated with corneal diagnoses?

A. Very early, the outcomes became clearly related to the patient's history and degree of ocular inflammation, as well as the recipient's age.[4] In general:

Low inflammation—good prognosis
Advanced age of patient—favorable prognosis[5]
In children—difficult, guarded prognosis[6,7]
Chemical burns, trauma—vulnerable to secondary glaucoma[8]
Autoimmune diseases—guarded prognosis[9]

Q. How many papers have been published on the B-KPro?

A. About 500 publications (of them about 200 from Boston, many focused on cellular mechanisms. In publications from outside Boston, the subject has been primarily clinical outcomes.)[2]

Q. After failure with a standard PK (one or more), which has now the best visual prognosis: a B-KPro or one more PK?

A. Definitely a B-KPro.[10-13] No study has shown the opposite. In addition, astigmatism-free visual improvement is very rapid after a B-KPro.

Q. However, when a B-KPro fails, can it result in a more severe, irreversible situation (such as NLP) than after a standard PK failure?

A. Possibly—but the severity of ocular disease that end up with a B-KPro has (so far) been much worse than in eyes selected for PK—which makes it difficult to compare.[14]

Q. At present time, how many B-KPro are being implanted worldwide per year, compared to standard PKs?

A. Only about 800 B-KPros are presently being implanted per year, divided about equally between the US and the rest of the world. (This should be compared with about 200,000 standard PKs worldwide per year—180,000 identified in 2013[15]). In total, about 16,000 B-KPros have been implanted into patients.

Q. Why is demand still small compared to PK, especially when visual acuity and retention by comparison are favorable for B-KPro?

A. B-KPro is a much newer procedure. Long-term outcomes are not yet fully defined.
In addition, B-KPro is still more expensive and requires more management attention. These discrepancies are gradually being diminished, however.

Q. Is a B-KPro procedure more surgically complex for an experienced surgeon than a PK?

A. Not really, but postoperative management is, and the necessity for patient compliance with postoperative treatment is—still more complex for the B-KPro patient than after PK.

Q. Which is the most severe complication after a B-KPro?

A. Long-term glaucoma is, by far, the most consequential complication for B-KPro patients, in our opinion. Endophthalmitis and retinal detachment are also difficult to rehabilitate but are much less common. Retroprosthetic membranes are frequent but often manageable (anti-inflammatories, lasers, surgery).

Q. Is research ongoing on complications after B-KPro?

A. Yes, intensive research is being conducted at least a dozen centers around the world. Secondary glaucoma is being studied particularly in Boston.[16-19] Substantial attention is also directed at endophthalmitis and its main risk factor: tissue melt around the device stem. - The massive clinical outcome research also helps to fine-tune clinical practices.[2]

Q. How are questions about prophylactic treatment of the secondary glaucoma being addressed?

A. Research and insight into the molecular mechanisms of retinal ganglion cell death ("hallmark of glaucoma") and optic

nerve degeneration have led to the opening of great prophylactic possibilities.[16-19]

Q. In what way?

A. First, it has been found that any trauma to the eye such as surgery, laceration, chemical burn, infection, etc., triggers inflammation. Inflammatory cytokines, among them TNF-α, are rapidly (within hours) upregulated and diffuse back to damage retinal cells and the optic nerve—the likely pathway to secondary glaucoma. Antibodies against TNF-α (infliximab, adalimumab) have been found to dramatically prevent such damage in animals.[17,20]

Q. Is this a fast process?

A. This initial phase is very fast, inflammatory and IOP-independent—in fact it is a newly identified pathway to glaucomatous damage.[19] It has recently been corroborated from outside Boston.[21] It does not eliminate the classical IOP-triggered mechanism in any way, just adds to it.

Q. How can these findings protect against devastating secondary glaucoma?

A. Antibodies against TNF-α have been used for years as effective anti-inflammatory medications in rheumatoid arthritis, ulcerative colitis, etc. For the eye, 25 years ago we found such antibodies (administered IV) can dramatically prevent tissue melt around B-KPro in autoimmune patients.[22] This led us to suspect more widespread protection.

Q. Are such antibodies sufficiently effective also against the secondary glaucoma?

A. Yes, antibodies like infliximab (Remicade™) or adalimumab (Humira™) have been extremely effective in animal models (almost 100%) against events that are known to result in glaucoma.[20] Such ganglion cell apoptosis and optic nerve degeneration have yet to be demonstrated in humans, however.

Q. If such antibodies against TNF-α are effective prophylaxis against secondary glaucoma also in humans, how would that change the clinical scene?

A. It would mean that any significant trauma to the eye, from ocular surgery to war trauma, accidents, chemical burns, inflammatory diseases, etc., would benefit from injection of antibody. Most likely, such administration would be done subconjunctivally, which is feasible in possibly millions of patients per year, worldwide.[23] It would be expected to be effective also against other B-KPro complications where inflammation is a risk factor (corneal melt, retroprosthetic membrane, uveitis, sterile vitritis, retinal detachment, etc.). These biologics will probably change ophthalmology as dramatically as they have changed rheumatology and gastrointestinal medicine.

Q. What initiatives, changes are required to accomplish these clinical goals?

A. More translational research to show efficacy also in humans, drastic reduction of price of the biologics (of original antibody drug or biosimilar), improved prophylactic antibiotic delivery systems, streamlining of management (e.g. in-house device graft assembly with irradiated carrier tissue, etc.[24]), improved biointegration between carrier cornea and KPro stem[25-27]—all achievable but time consuming to work out.

Q. Which company is benefitting from selling the B-KPro?

A. No commercial company—the devices are machined locally and marketed under the auspices of Massachusetts Eye and Ear. After expenses, the proceeds have mostly been used for further B-KPro research. We (MDs, PhDs, investigative staff and fellows) have received only standard salaries for our academic work and no additional benefits or royalties.

Q. What about the future of the B-KPro?

A. Of course, the present B-KPro is expected to have been only a step in the long-term development of artificial corneas. New designs, materials, new management principles, and new insights of ocular biology, will hopefully lead to continuously improving results, safety, practicality and affordability. We already know that spectacular vision is possible if the rest of the eye allows. The future of artificial corneas should be great!

---

1. Dohlman CH, Cruzat A, and White M. **The Boston Keratoprosthesis 2014: a step in the evolution of artificial corneas.** Spektrum der Augenheilkunde. 2014; 28:226-233.

2. Dohlman CH. T**he Boston Keratoprosthesis—the first 50 years.** Annu Rev Vis Sci. 2022; in press.

3. Dohlman CH, Webster RG, Biswas SK, and Refojo MF. **Prosthèses cornéenees à double plaque maintenues à l'aide d'adhésifs chirurgicaux.** Arch Ophtalmol (Paris). 1969; 29:169-174.

4. Yaghouti F, Nouri M, Abad JC, Power WJ, Doane MG, and Dohlman CH. **Keratoprosthesis: preoperative prognostic categories.** Cornea. 2001; 20:19-23.

5. Homayounfar G, Grassi CM, Al-Moujahed A, Colby KA, Dohlman CH, and Chodosh J. **Boston Keratoprosthesis Type I in the elderly.** Br J Ophthalmol. 2017; 101:514-518.

6. Aquavella JV and Wozniak RA. **Benefits of Multidisciplinary Team Approach to Infant Keratoprosthesis.** Int J Ophthal Vision Res. 2018; 2:008-010.

7. Fung SSM, Jabbour S, Harissi-Dagher M, Tan RRG, Hamel P, Baig K, and Ali A. **Visual Outcomes and Complications of Type I Boston Keratoprosthesis in Children: A Retrospective Multicenter Study and Literature Review.** Ophthalmology. 2018; 125:153-160.

8. Crnej A, Paschalis EI, Salvador-Culla B, Tauber A, Drnovsek-Olup B, Shen LQ, and Dohlman CH. **Glaucoma progression and role of glaucoma surgery in patients with Boston Keratoprosthesis.** Cornea. 2014; 33:349-54.

9. Papakostas TD, Le HG, Chodosh J, and Jacobs DS. **Prosthetic replacement of the ocular surface ecosystem as treatment for ocular surface disease in patients with a history of Stevens-Johnson syndrome/toxic epidermal necrolysis.** Ophthalmology. 2015; 122:248-253.

10. Akpek EK, Cassard SD, Dunlap K, Hahn S, and Ramulu PY. **Donor Corneal Transplantation vs Boston Type 1 Keratoprosthesis in Patients with Previous Graft Failures: A Retrospective Single Center Study (An American Ophthalmological Society Thesis).** Trans Am Ophthalmol Soc. 2015; 113:T3.

11. Ahmad S, Mathews PM, Lindsley K, Alkharashi M, Hwang FS, Ng SM, Aldave AJ, and Akpek EK. **Boston Type 1 Keratoprosthesis versus Repeat Donor Keratoplasty for Corneal Graft Failure: A**

Systematic Review and Meta-analysis. Ophthalmology. 2016; 123:165-77.

12. Kang KB, Karas FI, Rai R, Hallak JA, Kang JJ, de la Cruz J, and Cortina MS. **Five year outcomes of Boston Type I Keratoprosthesis as primary versus secondary penetrating corneal procedure in a matched case control study.** PLoS One. 2018; 13:e0192381.

13. Ono T, Mori Y, Nejima R, Iwasaki T, Fukuda M, Minami K, and Miyata K. **Short-term interim results of clinical outcomes and complications after implantation of Boston Keratoprosthesis in Japanese patients.** Cornea. 2020; 39 Suppl 1:S28-S33.

14. Muzychuk AK, Durr GM, Shine JJ, Robert MC, and Harissi-Dagher M. **No Light Perception Outcomes Following Boston Keratoprosthesis Type 1 Surgery.** Am J Ophthalmol. 2017; 181:46-54.

15. Gain P, Jullienne R, He Z, Aldossary M, Acquart S, Cognasse F, and Thuret G. **Global survey of corneal transplantation and eye banking.** JAMA Ophthalmol. 2016; 134:167-73.

16. Cade F, Paschalis EI, Regatieri CV, Vavvas DG, Dana R, and Dohlman CH. **Alkali burn to the eye: protection using TNF-α inhibition. Cornea.** 2014; 33:382-9.

17. Paschalis EI, Zhou C, Lei F, Scott N, Kapoulea V, Robert MC, Vavvas D, Dana R, Chodosh J, and Dohlman CH. **Mechanisms of Retinal Damage after Ocular Alkali Burns.** Am J Pathol. 2017; 187:1327-1342.

18. Dohlman CH, Cade F, Regatieri CV, Zhou C, Lei F, Crnej A, Harissi-Dagher M, Robert MC, Papaliodis GN, Chen D, Aquavella JV, Akpek EK, Aldave AJ, Sippel KC, D'Amico DJ, Dohlman JG, Fagerholm P, Wang L, Shen LQ, González-Andrades M, Chodosh J, Kenyon KR, Foster CS, Pineda R, Melki S, Colby KA, Ciolino JB, Vavvas DG, Kinoshita S, Dana R, and Paschalis EI. **Chemical Burns of the Eye: The Role of Retinal Injury and New Therapeutic Possibilities.** Cornea. 2018; 37(2):248-251.

19. Dohlman CH, Zhou C, Lei F, Cade F, Regatieri CV, Črnej A, Dohlman JG, Shen LQ, and Paschalis EI. **Glaucoma After Corneal Trauma or Surgery-A Rapid, Inflammatory, IOP-Independent Pathway.** Cornea. 2019; 38:1589-1594.

20. Zhou C, Hui PC, Wolkow N, Dohlman CH, Vavvas DG, and Paschalis EI. **Corneal and retinal protection using a novel slow-release injectable anti-TNF-α/anti-VEGF drug delivery system.** Invest Ophthalmol Vis Sci. 2021; ARVO Abstract 3546816.

21. Huang Y, Lin L, Yang Y, Cheng Z, Duan F, Jiang Z, Lou B, and Lin X. **Endoplasmic Reticulum Stress and Neuroinflammation Participate in Retinal Ganglion Cells Injury in Ocular Alkali Burn Model of Mice.** J Mol Histol. 2021; submitted.

22. Dohlman CH and Doane MG. **Keratoprosthesis in end-stage dry eye. in Lacrimal gland, tear film, and dry eye syndromes: Basic Science and Clinical Relevance.** S DA, Editor. 1994; Springer. p. 561-564.

23. Paschalis EI, Zhou C, Lei F, Kim S, Vavvas DG, Chodosh J, Urtti A, Papaliodis GN, and Dohlman CH. **The effect of subconjunctival TNF-α inhibitors on retinal ganglion cell apoptosis and optic nerve degeneration after corneal surgery or trauma.** 2021; in progress.

24. Gonzalez-Andrades M, Sharifi R, Islam MM, Divoux T, Haist M, Paschalis EI, Gelfand L, Mamodaly S, Di Cecilia L, Cruzat A, Ulm FJ, Chodosh J, Delori F, and Dohlman CH. **Improving the practicality and safety of artificial corneas: Pre-assembly and gamma-rays sterilization of the Boston Keratoprosthesis.** Ocul Surf. 2018; 16:322-330.

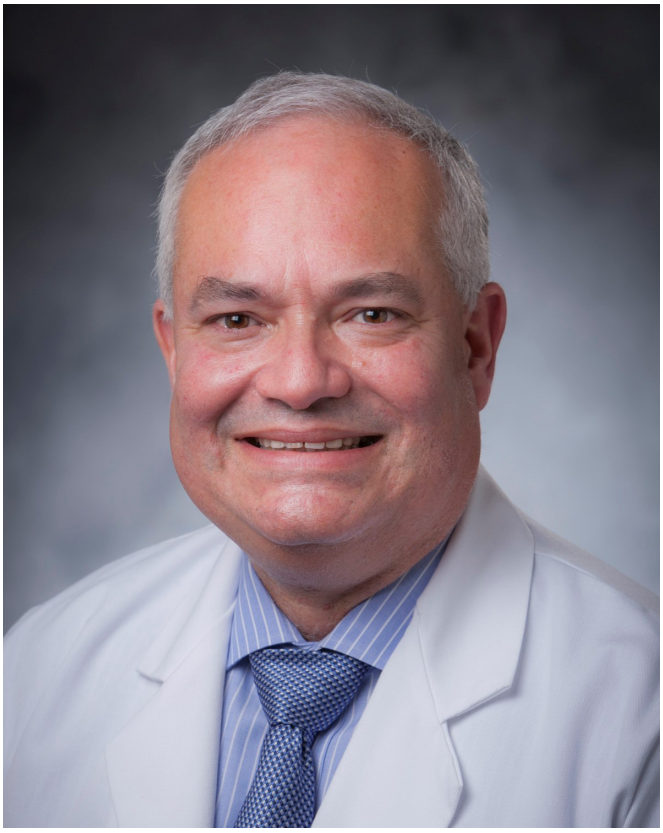
25. Salvador-Culla B, Jeong KJ, Kolovou PE, Chiang HH, Chodosh J, Dohlman CH, and Kohane DS. **Titanium Coating of the Boston Keratoprosthesis.** Transl Vis Sci Technol. 2016; 5:17.

26. Bakshi SK, Paschalis EI, Graney J, and Chodosh J. **Lucia and Beyond: Development of an Affordable Keratoprosthesis.** Cornea. 2019; 38:492-497.

27. Bakshi SK, Graney J, Paschalis EI, Agarwal S, Basu S, Iyer G, Liu C, Srinivasan B, and Chodosh J. **Design and Outcomes of a Novel Keratoprosthesis: Addressing Unmet Needs in End-Stage Cicatricial Corneal Blindness.** Cornea. 2020; 39:484-490.

Profiles of Distinguished Boston KPro Surgeons

These distinguished surgeons were selected based on their exceptional contributions to Boston KPro research, demonstrated excellence in clinical practice, and commitment to teaching the future leaders in the field.



Victor L. Perez, MD

Victor L. Perez, MD received his bachelor's degree in biology from the Washington University in St. Louis and his MD from the University of Puerto Rico School of Medicine. He performed his residency training at the Massachusetts Eye and Ear Infirmary at Harvard Medical School. Dr. Perez then completed clinical fellowships in Cornea and External Diseases with Dr. Dimitri Azar and Dr. Claes Dohlman, and then in Uveitis with Dr. Stephen Foster, both at the Massachusetts Eye and Ear Infirmary. In addition, he trained as an Immunologist Scientist Research Fellow in Ocular Immunology at Schepens Eye Research Institute at Harvard Medical School with Dr. JW Streilein and performed a Research Fellowship in Immunology at the Department of Pathology, Brigham & Women's Hospital in Boston with Dr. Abul K Abbas. He was Professor of Ophthalmology and the Director of the Ocular Surface Center at the Bascom Palmer Eye Institute and is now Professor of Ophthalmology at Duke University School of Medicine, where he is the Stephen and Frances Foster Professor of Ocular Immunology and Inflammation. He is also Director of the Foster Center for Ocular Immunology at the Duke Eye Center. His areas of expertise include immune-mediated diseases of the ocular surface, dry eye, high risk corneal transplantation, uveitis and keratoprosthesis (KPro).

It was the mentorship from Dr. Dohlman during Dr. Perez's early stages as a resident and cornea fellow in the use of keratoprosthesis, that led to his goal of developing a comprehensive program of using artificial corneas as part of the armamentarium to treat corneal blindness in high-risk patients. As such, Dr. Perez has performed more than 100 Boston Type I KPro surgeries, and has also implanted the Boston Type 2 KPro in patients with severe immune-mediated diseases. His group has published how performing pars plana vitrectomy decreases anterior segment complications after Boston Type 1 KPro surgery, and has shown that corneal buttons suffering keratolysis after KPro implantation contain a population of inflammatory cells consisting of T cells and macrophages, which may be responsible for keratolysis. Following his passion to treat high risk, end-stage cases with immunological diseases of the cornea, Dr. Perez was the first KPro surgeon in the United States to perform Modified-Osteodonto-Kerato-

Prosthesis (MOOKP) surgery to treat such patients, in collaboration with Dr. Giancarlo Falcinelli and Dr. Johnny Falcinelli from Italy. He is also a site Principal Investigator in a multi-center clinical trial, led by Dr. Joseph Ciolino at the Massachusetts Eye and Ear, studying the use of riboflavin cross-linking technology in Boston Type I Kpro corneal donors to prevent keratolysis in patients with immunological mediated diseases. Presently, as Director of the Foster Center, Dr. Perez continues to organize translational research projects directed to identified immunological signals after KPro surgery in order to develop novel immune-modulatory therapies to regulate these, and to improve the survival of high-risk KPro recipients.

Jose M Vargas, MD

Dr. Jose M Vargas is Chairman of the Surgery Department and also the Head of the Ophthalmology Division at King Abdullah Bin Abdulaziz University Hospital in Riyadh, Saudi Arabia. He earned his MD from the University of Zulia in Maracaibo, Venezuela in 1990, and completed his residency training program at the Hospital Risquez in Caracas in 1993. Dr. Vargas was trained in Cornea, External Diseases, Cataract and Refractive Surgery at the UT Southwestern Medical Center in Dallas, Texas under the mentorship of James P. McCulley, MD, from July 2000 to July 2002. He implanted his first Boston KPro in 2008, and since that time has been deeply involved in the use of the Boston KPro. Dr Vargas also participated in the development of Keraklear, a foldable artificial cornea and has one of the largest case series in the world. He joined King Khaled Eye Specialist Hospital (KKESH) as an Anterior segment Consultant in 2014, where he established the first KPro Clinic in the Middle East on March 2019. Dr. Vargas was appointed Head of the Anterior Segment Department at KKESH from February 2019 through February 2021, and then joined King Abdullah Bin Abdulaziz University Hospital in March 2021. He has been a guest speaker in many international symposiums and lectured about the Boston KPro surgery around the world.

Thomas Neuhann, M.D

Thomas Neuhann, M.D., has been an ophthalmologist in private practice and head of the ophthalmology department of the Red Cross Hospital in Munich since 1982. He trained at the University Eye Clinic of Heidelberg from 1973-1977, and was on staff at the University Eye Clinic of Mainz from 1977 to 1982, where he also obtained his PhD (Habilitation). He is an Associate Professor of Ophthalmology at the medical faculty of the Technical University of Munich. He had a major role in introducing modern cataract surgical procedures in his country, specifically phacoemulsification and PC IOL implantation. His contributions to this field include capsulorrhexis and individual aberration correcting lenses. He has been on the forefront of excimer laser corneal applications, intracorneal ring segments, and modern phakic implants, endothelial keratoplasty, and femtosecond laser-assisted keratoplasty. He founded the first publicly accessible cornea bank in Germany. While earlier versions of the Boston KPro had been only used in isolated cases previously, in 2009 Dr. Neuhann introduced the modern Boston KPro into Germany, remaining the only user in the country for many years and until very recently. His clinical experience of more than 70 cases to date has been published in the German medical literature. He was initiator and principal investigator of the first and only study of an intraocular pressure sensor in KPro cases, published in the journal Ophthalmology. Richard Kratz and Claes Dohlman are his admired heroes and role models.

THE BOSTON KPRO TEAM

Claes H. Dohlman, MD, PhD
Translational Research

James Chodosh, MD, MPH
Surgery, Translational Research

Roberto Pineda II, MD
Surgery, Clinical Research

Samir Melki, MD, PhD
Surgery, IOP Transducers

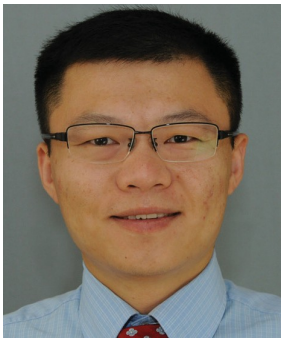
Joseph Ciolino, MD
Surgery, Clinical Research

Eleftherios I. Paschalis, MSc, PhD
Bioengineering

Lucy Shen, MD
Glaucoma

Reza Dana, MD, MSc, MPH
Translational Research

Pablo Argüeso, PhD
Enzymology, Glycobiology



Dylan Lei, MD, PhD
Translational Research

Mohammad Mirazul Islam, PhD
Translational Research

Jyoti Sharma, PhD
Translational Research

Sina Sharifi, PhD
Translational Research

Jie Liu, PhD
Translational Research

Saini, Chhavi
Translational Research

Sarah Kim, MS
KPro Research Assistant

Swati Sangwan
Manager, KPro
Regulatory Affairs

Rhonda Walcott-Harris
Administrative Assistant

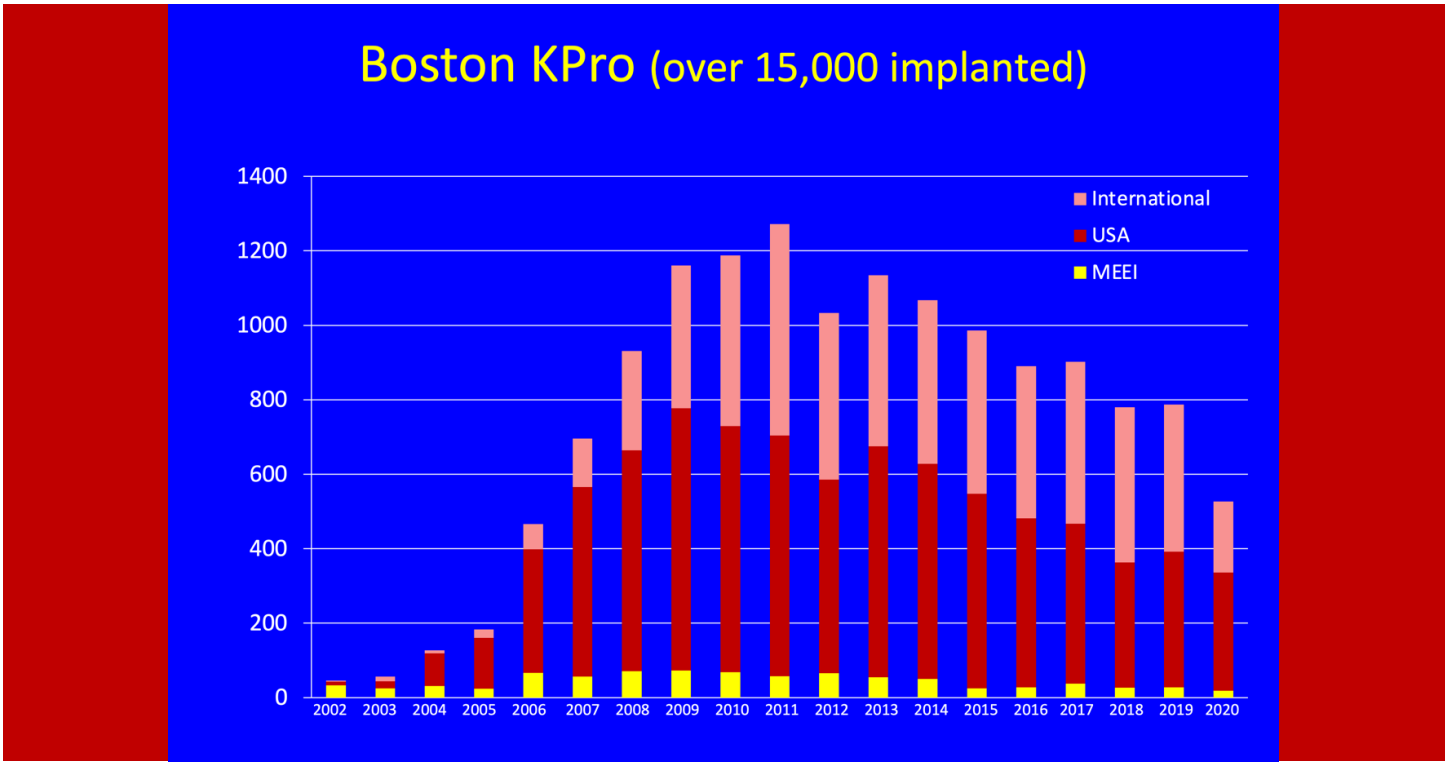
Sandra Vizcarra
KPro Laboratory
Technician

Alexandra Martinez
KPro Project
Coordinator

Mary Lou Moar
Consulting KPro
Coordinator

Larisa Gelfand
Director, Boston KPro
Business Operations

Boston KPro usage (2002-2020)



Boston KPro Bibliography

2017

Kaufman AR, Cruzat A, Colby KA. **Clinical outcomes using oversized back plates in type I Boston keratoprosthesis.** *Eye Contact Lens.* 2017 Dec 5. doi: 10.1097/ICL.0000000000000446.

Sravani NG, Mohamed A, Sangwan VS. **Type 1 Boston keratoprosthesis for limbal stem cell deficiency in epidermolysis bullosa.** *Ocul Immunol Inflamm.* 2017 Nov 3:1-3. doi: 10.1080/09273948.2017.1390588.

Schaub F, Neuhann I, Enders P, Bachmann BO, Koller B, Neuhann T, Cursiefen C. **[Boston keratoprosthesis: 73 eyes from Germany: An overview of experiences from two centers].** *Ophthalmologe.* 2017 Oct 17. doi: 10.1007/s00347-017-0581-0.

Ono T, Iwasaki T, Miyata K. **Fungal keratitis after Boston keratoprosthesis.** *JAMA Ophthalmol.* 2017 Oct 12;135(10):e173272. doi: 10.1001/jamaophthalmol.2017.3272.

Perez VL, Leung EH, Berrocal AM, Albini TA, Parel JM, Amescua G, Alfonso EC, Ali TK, Gibbons A. **Impact of total pars plana vitrectomy on postoperative complications in aphakic, Snap-On, type 1 Boston keratoprosthesis.** *Ophthalmology.* 2017 Oct;124(10):1504-1509. doi: 10.1016/j.ophtha.2017.04.016.

Muzychuk AK, Durr GM, Shine JJ, Robert MC, Harissi-Dagher M. **No light perception outcomes following Boston keratoprosthesis type 1 surgery.** *Am J Ophthalmol.* 2017 Sep;181:46-54. doi: 10.1016/j.ajo.2017.06.012.

Lin M, Bhatt A, Haider A, Kim G, Farid M, Schmutz M, Mosaed S. **Vision retention in early versus delayed glaucoma surgical intervention in patients with Boston keratoprosthesis type 1.** *PLoS One.* 2017 Aug 4;12(8):e0182190. doi: 10.1371/journal. pone.0182190. eCollection 2017.

Saeed HN, Shanbhag S, Chodosh J. **The Boston keratoprosthesis.**

Curr Opin Ophthalmol. 2017 Jul;28(4):390-396.

Abdelaziz M, Dohlman CH, Sayegh RR. **Measuring forward light scatter by the Boston keratoprosthesis in various configurations.** *Cornea.* 2017 Jun;36(6):732-735.

Schaub F, Bachmann BO, Seyeddain O, Moussa S, Reitsamer HA, Cursiefen C. **[Mid- and longterm experiences with the Boston-keratoprosthesis. The Cologne and Salzburg perspective].** *Klin Monbl Augenheilkd.* 2017 Jun;234(6):770-775.

Robert MC, Crnej A, Shen LQ, Papaliodis GN, Dana R, Foster CS, Chodosh J, Dohlman CH. **Infliximab after Boston keratoprosthesis in Stevens-Johnson syndrome: an update.** *Ocul Immunol Inflamm.* 2017 Jun;25(3):413-417.

Petrou P, Banerjee PJ, Wilkins MR, Singh M, Eastlake K, Limb GA, Charteris DG. **Characteristics and vitreoretinal management of retinal detachment in eyes with Boston keratoprosthesis.** *Br J Ophthalmol.* 2017 May;101(5):629-633.

Gologorsky D, Williams BK Jr, Flynn HW Jr. **Posterior pole retinal detachment due to a macular hole in a patient with a Boston keratoprosthesis.** *Am J Ophthalmol Case Rep.* 2017 Apr;5:56-58.

Homayounfar G, Grassi CM, Al-Moujahed A, Colby KA, Dohlman CH, Chodosh J. **Boston keratoprosthesis type I in the elderly.**

Br J Ophthalmol. 2017 Apr;101(4):514-518.

Hussain Farooqui J, Sharifi E, Gomaa A. **Corneal surgery in the flying eye hospital: characteristics and visual outcome.** *Can J Ophthalmol.* 2017 Apr;52(2):161-165.

Poon LY, Chodosh J, Vavvas DG, Dohlman CH, Chen TC. **Endoscopic cyclophotocoagulation for the treatment of glaucoma in Boston keratoprosthesis type II patient.** *J Glaucoma.* 2017 Apr;26(4):e146-e149.

Miyata K. **Sustainability of anterior segment surgery.** *Nippon Ganka Gakkai Zasshi.* 2017 Mar;121(3):249-291.

Choi CJ, Stagner AM, Jakobiec FA, Chodosh J, Yoon MK. **Eyelid mass in Boston keratoprosthesis type 2.** *Ophthalmic Plast Reconstr Surg.* 2017 Mar/Apr;33(2):e39-e41.

Vaillancourt L, Papanagnu E, Elfekhfakh M, Fadous R, Harissi-Dagher

M. **Outcomes of bilateral sequential implantation of the Boston keratoprosthesis type 1.** *Can J Ophthalmol.* 2017 Feb;52(1):80-84.

Scotto R, Vagge A, Traverso CE. **Corneal graft dellen in a patient implanted with a Boston keratoprosthesis type 1.** *Int Ophthalmol.* 2017 Feb;37(1):263-266.

Baratz KH, Goins KM. **The Boston keratoprosthesis: highs and lows of intraocular pressure and outcomes.** *Ophthalmology.* 2017 Jan;124(1):9-11.

Muzychuk AK, Robert MC, Dao S, Harissi-Dagher M. **Boston keratoprosthesis type1: a randomized controlled trial of fresh versus frozen corneal donor carriers with long-term follow-up.** *Ophthalmology.* 2017 Jan;124(1):20-26.

Lee R, Khoueir Z, Tsikata E, Chodosh J, Dohlman CH, Chen TC. **Long-term visual outcomes and complications of Boston keratoprosthesis type II implantation.** *Ophthalmology.* 2017 Jan;124(1):27-35.

2018

Iyer G, Srinivasan B, Agarwal S, Pattanaik R, Rishi E, Rishi P, Shanmugasundaram S, Natarajan V. **Keratoprostheses in silicone oil-filled eyes: long-term outcomes.** *Br J Ophthalmol.* 2018 Jul 18. pii: bjophthalmol-2018-312426.

Ang M, Man R, Fenwick E, Lamoureux E, Wilkins M. **Impact of type I Boston keratoprosthesis implantation on vision-related quality of life.** *Br J Ophthalmol.* 2018 Jul;102(7):878-881.

Gonzalez-Andrades M, Sharifi R, Islam MM, Divoux T, Haist M, Paschalis EI, Gelfand L, Mamodaly S, Di Cecilia L, Cruzat A, Ulm FJ, Chodosh

J, Delori F, Dohlman CH. **Improving the practicality and safety of artificial corneas: Pre-assembly and gamma-rays sterilization of the Boston Keratoprosthesis.** *Ocul Surf.* 2018 Jul;16(3):322-330.

Shanbhag SS, Saeed HN, Paschalis EI, Chodosh J. **Boston keratoprosthesis type 1 for limbal stem cell deficiency after severe chemical corneal injury: A systematic review.** *Ocul Surf.* 2018 Jul;16(3):272-281.

Wang JC, Rudnisky CJ, Belin MW, Ciolino JB; Boston type 1 Keratoprosthesis Study Group. **Outcomes of Boston**

keratoprosthesis type 1 reimplantation: multicentre study results.

Can J Ophthalmol. 2018 Jun;53(3):284-290.

Helms RW, Zhao X, Sayegh RR. **Keratoprosthesis decentration and tilt results in degradation in image quality.** *Cornea.* 2018 Jun;37(6):772-777.

Samarawickrama C, Strouthidis N, Wilkins MR. **Boston keratoprosthesis type 1: outcomes of the first 38 cases performed at Moorfields Eye Hospital.** *Eye (Lond).* 2018 Jun;32(6):1087-1092.

Ali MH, Dikopf MS, Finder AG, Aref AA, Vajaranant T, de la Cruz J, Cortina MS. **Assessment of glaucomatous damage after Boston keratoprosthesis implantation based on digital planimetric quantification of visual fields and optic nerve head imaging.**

Cornea. 2018 May;37(5):602-608.

Iyer G, Srinivasan B, Agarwal S, Talele D, Rishi E, Rishi P, Krishnamurthy S, Vijaya L, Subramanian N, Somasundaram S. **Keratoprosthesis: Current global scenario and a broad Indian perspective.** *Indian J Ophthalmol.* 2018 May;66(5):620-629.

Geetha Sravani N, Mohamed A, Sangwan VS. **Response to Modabber and Harissi-Dagher's Letter: "Type 1 Boston Keratoprosthesis for Limbal Stem Cell Deficiency in Epidermolysis Bullosa."** *Ocul Immunol Inflamm.* 2018 Apr 12:1.

Modabber M, Harissi-Dagher M. **Letter to the Editor: Type 1 Boston keratoprosthesis for limbal stem cell deficiency in epidermolysis bullosa.** *Ocul Immunol Inflamm.* 2018 Mar 15:1-2.

Gibbons A, Leung EH, Haddock LJ, Medina CA, Fernandez V, Parel JA, Durkee HA, Amescua G, Alfonso EC, Perez VL. **Long-term outcomes of the aphakic snap-on Boston type I keratoprosthesis at the Bascom Palmer Eye Institute.** *Clin Ophthalmol.* 2018 Feb 15;12:331- 337.

Talati RK, Hallak JA, Karas FI, de la Cruz J, Cortina MS. **Retroprosthetic membrane formation in Boston keratoprosthesis: a case-control-matched comparison of titanium versus PMMA backplate.** *Cornea.* 2018 Feb;37(2):145-150.

Fung SSM, Jabbour S, Harissi-Dagher M, Tan RRG, Hamel P, Baig K, Ali A. **Visual outcomes and complications of type I Boston keratoprosthesis in children: a retrospective multicenter study and literature review.** *Ophthalmology.* 2018 Feb;125(2):153-160.

Nowak M, Nowak L, Nowak J, Chaniecki P. **[Fixed and temporary keratoprosthesis].** *Pol Merkur Lekarski.* 2018 Jan 23;44(259):36-40. Review.

Lim JI, Machen L, Arteaga A, Karas FI, Hyde R, Cao D, Niec M, Vajaranant TS, Cortina MS. **Comparison of visual and anatomical outcomes of eyes undergoing type I Boston keratoprosthesis with combination pars plana vitrectomy with eyes without combination vitrectomy.** *Retina.* 2018 Jan 23.

Silva LD, Santos A, Sousa LB, Allemann N, Oliveira LA. **Anterior segment optical coherence tomography findings in type I Boston keratoprosthesis.** *Arq Bras Oftalmol.* 2018 Jan-Feb;81(1):42-46.

Sun YC, Kam JP, Shen TT. **Modified conjunctival flap as a primary procedure for nontraumatic acute corneal perforation.** *Ci Ji Yi Xue Za Zhi.* 2018 Jan-Mar;30(1):24-28.

Zarei-Ghanavati M, Shalaby Bardan A, Liu C. **'On the capability and nomenclature of the Boston Keratoprosthesis type II'.** *Eye (Lond).* 2018 Jan;32(1):9-10.

Bouhout S, Robert MC, Deli S, Harissi-Dagher M. **Corneal melt after Boston keratoprosthesis: clinical presentation, management, outcomes and risk factor analysis.** *Ocul Immunol Inflamm.*

2018;26(5):693-699.Mohamed A, Shah R, Sangwan VS. **Boston-keratoprosthesis for idiopathic limbal stem cell deficiency.** *Ocul Immunol Inflamm.* 2018;26(5):689-692.

Gu J, Zhai J, Liao G, Chen J. **Boston Type I Keratoprosthesis implantation following autologous submandibular gland transplantation for end stage ocular surface disorders.** *Ocul Immunol Inflamm.* 2018;26(3):452-455.

Malhotra C, Jain AK, Aggarwal N. **Fungal keratitis and endophthalmitis after implantation of type 1 keratoprosthesis.** *Oman J Ophthalmol.* 2018 Jan-Apr;11(1):62-64.

Baltaziak M, Chew HF, Podbielski DW, Ahmed IIK. **Glaucoma after corneal replacement.** *Surv Ophthalmol.* 2018 Mar - Apr;63(2):135-148

2019

Iyer G, Srinivasan B, Agarwal S, Ravindran R, Rishi E, Rishi P, Krishnamoorthy S. **Boston Type 2 keratoprosthesis- mid term outcomes from a tertiary eye care centre in India.** *Ocul Surf.* 2019 Jan;17(1):50-54.

Matthaei M, Bachmann B, Hos D, Siebelmann S, Schaub F, Cursiefen C. **[Boston type I keratoprosthesis implantation technique : Video article].** *Ophthalmologe.* 2019 Jan;116(1):67-72.

Paschalis EI, Taniguchi EV, Chodosh J, Pasquale LR, Colby K, Dohlman CH, Shen LQ. **Blood levels of tumor necrosis factor alpha and its type 2 receptor are elevated in patients with Boston type I keratoprosthesis.** *Curr Eye Res.* 2019 Jan 11:1-8.

Gao M, Chen Y, Wang J, Wang C. **Post-operative outcomes associated with Boston type 1 keratoprosthesis implantation in Northeast China.** *Exp Ther Med.* 2019 Jan;17(1):869-873.

Cortina MS, Karas FI, Bouchard C, Aref AA, Djalilian A, Vajaranant TS. **Staged ocular fornix reconstruction for glaucoma drainage device under neoconjunctiva at the time of Boston type 1 Keratoprosthesis implantation.** *Ocul Surf.* 2019 Feb 8. pii: S1542- 0124(18)30350-1.

Enders P, Hall J, Bornhauser M, Mansouri K, Altay L, Schrader S, Dietlein TS, Bachmann BO, Neuhann T, Cursiefen C. **Telemetric intraocular pressure monitoring after Boston keratoprosthesis surgery with the Eyemate-IO Sensor: Dynamics in the first year.** *Am J Ophthalmol.* 2019 Mar 5. pii: S0002-9394(19)30084-4.

Basu S, Serna-Ojeda JC, Senthil S, Pappuru RR, Bagga B, Sangwan V. **The auroKPro versus the Boston type I keratoprosthesis: 5-year clinical outcomes in 134 cases of bilateral corneal blindness.** *Am J Ophthalmol.* 2019 Mar 21. pii: S0002-9394(19)30122-9.

de la Paz MF, Salvador-Culla B, Charoenrook V, Temprano J, de Toledo JÁ, Grabner G, Michael R, Barraquer RI. **Osteo-odonto-, Tibial bone and Boston keratoprosthesis in clinically comparable cases of chemical injury and autoimmune disease.** *Ocul Surf.* 2019 Apr 12. pii: S1542-0124(18)30378-1.

2020

Szigiato A-A, Bostan C, Nayman T, Harissi-Dagher M. **Long-term visual outcomes of the Boston type I keratoprosthesis in Canada.** Br J Ophthalmol. 2020 Feb 17.bjophthalmol-2019-315345.

Jabbour S, Harissi-Dagher M, Agoumi Y, Singh H, Robert MC. **Cyclophotocoagulation in the control of glaucoma in patients with the Boston keratoprosthesis type 1.** Cornea 2020; 39(2):181-185.

Bostan C, Elfekhfakh M, Harissi-Dagher M. **Patient-reported vision-related quality of life after Bostontype I keratoprosthesis.** Cornea 2020; 39(2):222-228.

Jerez-Peña M, Salvador-Culla B, de la Paz MF, Barraquer RI. **Bilateral Boston keratoprosthesis type 1 in a case of severe Mooren's ulcer.** Eur J Ophthalmol. 2020 March 6. 6:1120672120909768.

Chen Y, Wang C, Liu Q, Wang Z, Gao M. **Comparison of the clinical efficacy of Boston keratoprosthesis type I and repetitive penetrating keratoplasty for refractory keratopathy .** J Craniofac Surg. 2020 Mar/Apr; 31(2):e194-e199.

Manachai Nonpassopon , Muanploy Niparugs , Maria Soledad Cortina. **Boston Type 1 Keratoprosthesis: Updated Perspectives.** Clin Ophthalmol. 2020 Apr; 29; 14:1189-1200.

Pui-Chuen Hui , Leonardo A Pereira , Renald Dore , Shengtong Chen , Elise Taniguchi , James Chodosh , Claes H Dohlman , Eleftherios I Paschalis . **Intrinsic Optical Properties of Boston Keratoprosthesis.** Transl Vis Sci Technol. 2020 Nov 3; 9(12):10.

Liqiang Wang , Zongyuan Li , Tengyun Wu , Anqi Liu , Xiezhou He , Shuo Zheng , Tao Ye , Liyuan Rong , Yifei Huang . **Modified Boston Type-II Keratoprosthesis Implantation with Autologous Auricular Cartilage Reinforcement.** Ocul Surf. 2020 Nov 25; S1542-0124(20)30179-8.

Luís Camacho , Anna Soldevila , María Fideliz de la Paz . **Transmucosal Boston Keratoprosthesis Type I in a Patient with Advanced Ocular Cicatricial Pemphigoid.** Cornea. 2020 Dec; 39(12):1563-1565.

Swapna S Shanbhag , Sirisha Senthil , Ashik Mohamed , Sayan Basu . **Outcomes of the Boston type 1 and the Aurolab keratoprosthesis in eyes with limbal stem cell deficiency.** Br J Ophthalmol. 2020 Jun 17; bjophthalmol-2020-316369.

Matias Camerati , Neal Jaque, Jose Lievano, Maria A Henriquez, Luis Izquierdo Jr. **Automated Keratopigmentation in Boston Type 1 Keratoprosthesis: An Aesthetic Alternative.** Cornea. 2020 Dec; 39(12):1578-1580.

Kevin K Ma 1, Stephan Ong Tone, James Chodosh, Hajirah N Saeed.

Ochrobactrum anthropi Keratitis in a Boston Type 1 Keratoprosthesis Recipient. Cornea 2020 Nov 19.

Levi N Kanu , Muanploy Niparugs , Manachai Nonpassopon, Faris I Karas, Jose M de la Cruz, Maria S Cortina. **Predictive factors of Boston Type I Keratoprosthesis outcomes: A long-term analysis.** Ocul Surf. 2020 Oct; 18(4):613-619.

Michael Marchand, Mona Harissi-Dagher. **Recurrent preseptal cellulitis in Boston keratoprosthesis type II implantation for ocular Stevens-Johnson syndrome.** Can J Ophthalmol. 2020 Apr; 55(2):e59-e61.

Soumaya Bouhout, Marie-Claude Robert, Mona Harissi-Dagher. **Mid-term prognosis of type I Boston keratoprosthesis reimplantation.** Br J Ophthalmol. 2020 Oct 14; bjophthalmol-2020-317598.

Rafaella Nascimento E Silva, Elise V Taniguchi, Andrea Cruzat, Eleftherios I Paschalis, Louis R Pasquale, Kathryn A Colby, Claes H Dohlman, James Chodosh , Lucy Q Shen. **Angle Anatomy and Glaucoma in Patients with Boston Keratoprosthesis.** Cornea. 2020 Jun; 39(6):713-719.

Andrei-Alexandru Szigiato, Cristina Bostan, Taylor Nayman, Mona Harissi-Dagher. **Long-term visual outcomes of the Boston type I keratoprosthesis in Canada.** Br J Ophthalmol 2020 Nov; 104(11):1601-1607.

Andressa Zanini Fantato Quercia, Luzia Diegues Silva, Filipe de Oliveira, Sergio Henrique Teixeira, Luciene Barbosa de Sousa, Lauro Augusto de Oliveira. **Visual Field Characteristics of Type I Boston Keratoprosthesis Patients without Glaucoma.** J Glaucoma. 2020 Dec 29.

Samir Touma, Mona Harissi-Dagher. **Outcomes and complications of Boston keratoprosthesis type I implantation in unilateral versus bilateral corneal blindness.** Can J Ophthalmol. 2020 Sep 28; S0008-4182(20)30741-9.

Clemence Bonnet, Ismael Chehaibou, Reza Ghaffari, Nicholas J Jackson, Cristina Bostan, Jean-Pierre Hubschman, Mona Harissi-Dagher, Anthony J Aldave. **Idiopathic Vitritis after Boston Type 1 Keratoprosthesis Implantation: Incidence, Risk Factors and Outcomes in a Multicentric Cohort.** Ocul Immunol Inflamm. 2020 Oct 15; 1-7.

Cristina Bostan, Taylor Nayman, Andrei-Alexandru Szigiato, Hussein Morfeq, Mona Harissi-Dagher. **Endophthalmitis in Eyes With the Boston Type I Keratoprosthesis: Incidence, Recurrence, Risk Factors, and Outcomes.** Cornea. 2020 Dec 31.

Roy Daoud, Saama Sabeti, Mona Harissi-Dagher. **Management of corneal melt in patients with Boston Keratoprosthesis Type 1: Repair versus repeat.** Ocul Surf. 2020 Oct; 18(4):713-717.

Takashi Ono, Yosai Mori, Ryohei Nejima, Takuya Iwasaki, Masahiko Fukuda, Keiichiro Minami, Kazunori Miyata. **Short-term Interim Results of Clinical Outcomes and Complications after Implantation of Boston Keratoprosthesis in Japanese Patients.** Cornea. 2020 Nov; 39 Suppl 1:S28-S33.

Samar K Basak, Soham Basak. **Recurrent cystoid macular edema following Boston keratoprosthesis type-II implantation: A treatment option.** Indian J Ophthalmol. 2020 Aug; 68(8):1691-1693.

Shaunak K Bakshi, John Graney, Eleftherios I Paschalis, Shweta Agarwal, Sayan Basu, Geetha Iyer, Christopher Liu, Bhaskar Srinivasan, James Chodosh. **Design and Outcomes of a Novel Keratoprosthesis: Addressing Unmet Needs in End-Stage Cicatricial Corneal Blindness.** Cornea. 2020 Apr; 39(4):484-490.

Yuying Zhang, Zhancong Ou, Jin Zhou, Jiajie Zhai, Jianjun Gu, Jiaqi Chen. **Treatment of Oculoplastic and Ocular Surface Disease in Eyes Implanted with a Type I Boston Keratoprosthesis in Southern China: A Retrospective Study.** Adv Ther. 2020 Jul; 37(7):3206-3222.

Luzia Diegues Silva, Albert Santos, Flavio Hirai, Norma Allemann, Adriana Berezovsky, Solange Rios Salomão, Paulo Ricardo Chaves de Oliveira, Gabriel Andrade, André Maia, Luciene Barbosa de Sousa, Lauro Augusto de Oliveira. **B-scan ultrasound, visual electrophysiology and perioperative videoendoscopy for predicting functional results in keratoprosthesis candidates.** Br J Ophthalmol. 2020 Oct 22; bjophthalmol-2020-316962.

Masako Chen, Sueko M Ng, Esen K Akpek, Sumayya Ahmad. **Artificial corneas versus donor corneas for repeat corneal transplants.** Cochrane Database Syst Rev. 2020 May 13; 5(5):CD009561.

Joani M Christensen, Swapna S Shanbhag, Grace C Shih, Jeremy Goverman, Bohdan Pomahac, James Chodosh, Richard J Ehrlichman. **Multidisciplinary Treatment to Restore Vision in Ocular Burns.** J Burn Care Res. 2020 Jul 3; 41(4):859-865.

Philip Enders, Claus Cursiefen. **Device profile of the EYEMATE-IO™ system for intraocular pressure monitoring: overview of its safety and efficacy.** Expert Rev Med Devices. 2020 Jun; 17(6):491-497.

Sophie X Deng, Friedrich Kruse, José A P Gomes, Clara C Chan, Sheraz Daya, Reza Dana, Francisco C Figueiredo, Shigeru Kinoshita, Paolo Rama, Virender Sangwan, Allan R Slomovic, Donald Tan, and the International Limbal Stem Cell Deficiency Working Group. **Global Consensus on the Management of Limbal Stem Cell Deficiency.** Cornea. 2020 Oct; 39(10):1291-1302.

Chengxin Zhou, Arushi Singh, Grace Qian, Natalie Wolkow, Claes H Dohlman, Demetrios G Vavvas, James Chodosh, Eleftherios I Paschalis. **Microporous Drug Delivery System for Sustained Anti-VEGF Delivery to the Eye.** Transl Vis Sci Technol. 2020 Jul 2; 9(8):5.

Sarah Kim, Paulo J M Bispo, Eden E L Tanner, Samir Mitragotri, Rafaella N E Silva, Ilene Gipson, James Chodosh, Irmgard Behlau, Eleftherios I Paschalis, Michael S Gilmore, Claes H Dohlman. **The Search for Antifungal Prophylaxis after Artificial Corneal Surgery-An In Vitro Study.** Cornea. 2020 Dec; 39(12):1547-1555.

Pui-Chuen Hui, Katia Shtyrkova, Chengxin Zhou, Xiaoniao Chen, James Chodosh, Claes H Dohlman, Eleftherios I Paschalis. **Implantable self-aligning fiber-optic optomechanical devices for in vivo intraocular pressure-sensing in artificial cornea.** J Biophotonics. 2020 Jul; 13(7):e202000031.

Andri K Riau, Nyein C Lwin, Larisa Gelfand, Huanlong Hu, Bo Liedberg, James Chodosh, Subbu S Venkatraman, Jodhbir S Mehta. **Surface modification of corneal prosthesis with nano-hydroxyapatite to enhance in vivo biointegration.** Acta Biomater. 2020 Apr 15; 107: 299-312.

2021

Dominique Geoffrion, Mona Harissi-Dagher. **Glaucoma Risk Factors and Outcomes Following Boston Keratoprosthesis Type 1 Surgery.** Am J Ophthalmol. 2021 Jan 22; S0002-9394(21)00026-X.

Canan Asli Utine, Merih Birlik, Denizcan Özizmirliler, Ali Karakaş, Betül Akbulut, Ismet Durak. **TNF-α Inhibitors for the Management of Intractable Corneal Melt: Report of Three Cases and Review of the Literature.** Eye Contact Lens. 2021 Jan 4.

HARVARD MEDICAL SCHOOL | DEPARTMENT OF Ophthalmology

MASSACHUSETTS EYE AND EAR

Join us at these upcoming events. . .

American Academy of Ophthalmology Annual Meeting

Boston Keratoprosthesis Users Breakfast
Sunday, November 14, 2021 6:30 AM - 8:00 AM
Hilton Riverside Magazine Banquet Rounds
Hilton New Orleans Riverside
2 Poydras Street,
New Orleans, LA 70130

407 - The Boston KPro: Case-Based Presentations Highlighting the Essentials for Beginning and Experienced Surgeons
Sunday, November 14, 2021, 8:00 am - 9:15 am
Room: 280-282, Morial Convention center, New Orleans
Course Number: 407