

Medical Policy



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Title: Corneal Collagen Cross-Linking

Professional

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Populations	Interventions	Comparators	Outcomes
Individuals: • With progressive keratoconus	Interventions of interest are: • Corneal collagen cross-linking using riboflavin and ultraviolet A	Comparators of interest are: • Observation • Rigid or specialty contact lens • Intracorneal ring segments • Corneal transplant	Relevant outcomes include: • Change in disease status • Functional outcomes • Treatment-related morbidity
Individuals: • With corneal ectasia after refractive surgery	Interventions of interest are: • Corneal collagen cross-linking using riboflavin and ultraviolet A	Comparators of interest are: • Observation • Rigid or specialty contact lens • Intracorneal ring segments • Corneal transplant	Relevant outcomes include: • Change in disease status • Functional outcomes • Treatment-related morbidity

DESCRIPTION

Corneal collagen cross-linking (CXL) is a photochemical procedure approved by the Food and Drug Administration for the treatment of progressive keratoconus and corneal ectasia. Keratoconus is a dystrophy of the cornea characterized by progressive deformation (steepening) of the cornea while corneal ectasia is keratoconus that occurs after refractive surgery. Both lead to functional loss of vision and need for corneal transplantation.

OBJECTIVE

The objective of this policy is to assess whether the use of epithelium-off corneal collagen cross-linking using riboflavin and ultraviolet A for treatment of patients with progressive keratoconus and corneal ectasia after refractive surgery improves the net health outcome.

BACKGROUND**Keratoconus and Ectasia**

Keratoconus is a bilateral dystrophy characterized by progressive ectasia (paracentral steepening and stromal thinning) that impairs visual acuity. While frequently diagnosed at a young age, the progression of keratoconus is variable. Results from a longitudinal study with 7 years of follow-up showed that, over the study period, there was a decrease of 2 high- and 4 low-contrast letters in best-corrected visual acuity.^{1,2} About 1 in 5 patients showed a decrease of 10 or more letters in high-contrast visual acuity and one-third of patients showed a decrease of 10 or more letters in low-contrast visual acuity. Over 8 years of follow-up, there was a mean increase of 1.44 diopters (D) in First Definite Apical Clearance Lens (a rigid contact lens to measure corneal curvature) and 1.6 D in flatter keratometric reading.

Ectasia (also known as keratectasia, iatrogenic keratoconus, or secondary keratoconus) is a serious long-term complication of laser in situ keratomileusis (LASIK) surgery and photorefractive keratectomy. It is similar to keratoconus, but occurs postoperatively and primarily affects older populations. It may result from unrecognized preoperative keratoconus or, less frequently, from the surgery itself. Similar to keratoconus, it is characterized by progressive thinning and steepening of the cornea, resulting in corneal optical irregularities and loss of visual acuity.

Treatment

The initial treatment for keratoconus often consists of hard contact lenses. A variety of keratorefractive procedures have also been attempted, broadly divided into subtractive and additive techniques. Subtractive techniques include photorefractive keratectomy or laser in situ keratomileusis (LASIK), although generally, results of these techniques have been poor. Implantation of intrastromal corneal ring segments is an additive technique in which the implants are intended to reinforce the cornea, prevent further deterioration, and potentially obviate the need for penetrating keratoplasty. Penetrating keratoplasty (ie, corneal grafting) is the last line of treatment. About 20% of patients

with keratoconus will require corneal transplantation. All of these treatments attempt to improve the refractive errors, but are not disease-modifying.

Treatment options for ectasia include intraocular pressure-lowering drugs, and intracorneal ring segments. Frequently, a penetrating keratoplasty is required.

None of the currently available treatment options for keratoconus and corneal ectasia halt the progression of disease and corneal transplantation is the only option available when functional vision can no longer be achieved.

Corneal collagen cross-linking (CXL) has the potential to slow the progression of disease. It is performed with the photosensitizer riboflavin (vitamin B₂) and ultraviolet A (UVA) irradiation. There are 2 protocols for CXL.

1. Epithelium-off CXL (also known as "epi-off"): In this method, about 8 mm of the central corneal epithelium is removed under topical anesthesia to allow better diffusion of the photosensitizer riboflavin into the stroma. Following de-epithelialization, a solution with riboflavin is applied to the cornea (every 1-3 minutes for 30 minutes) until the stroma is completely penetrated. The cornea is then irradiated for 30 minutes with ultraviolet A 370 nm, a maximal wavelength for absorption by riboflavin, while the riboflavin continues to be applied. The interaction of riboflavin and UVA causes the formation of reactive oxygen species, leading to additional covalent bonds (cross-linking) between collagen molecules, resulting in stiffening of the cornea. Theoretically, by using a homogeneous light source and absorption by riboflavin, the structures beyond a 400-micron thick stroma (endothelium, anterior chamber, iris, lens, retina) are not exposed to an ultraviolet dose that is above the cytotoxic threshold.
2. Epithelium-on CXL (also known as "epi-on" or transepithelial): In this method, the corneal epithelial surface is left intact (or may be partially disrupted) and a longer riboflavin loading time is needed.

Currently, the only CXL treatment approved by the Food and Drug Administration (FDA) is the epithelium-off method. There are no FDA-approved CXL treatments using the epithelium-on method. CXL is being evaluated primarily for corneal stabilization in patients with progressive corneal thinning, such as keratoconus and corneal ectasia following refractive surgery. CXL may also have anti-edematous and antimicrobial properties.

REGULATORY STATUS

In 2016, riboflavin 5'-phosphate in 20% dextran ophthalmic solution (Photrex Viscous®; Avedro) and riboflavin 5'-phosphate ophthalmic solution (Photrex®; Avedro) were approved by the U.S. Food and Drug Administration for use with KXL System in corneal collagen cross-linking for the treatment of progressive keratoconus and corneal ectasia after refractive surgery.³

Please refer to the member's contract benefits in effect at the time of service to determine coverage or non-coverage of these services as it applies to an individual member.

POLICY

- A. Corneal collagen cross-linking using riboflavin and ultraviolet A may be considered **medically necessary** as a treatment of progressive keratoconus or corneal ectasia resulting from refractive surgery in patients who have failed conservative treatment (eg, spectacle correction, rigid contact lens) (see Policy Guidelines).
- B. Corneal collagen cross-linking using riboflavin and ultraviolet A is considered **experimental / investigational** for all other indications.

Policy Guidelines

- 1. Progressive keratoconus or corneal ectasia is defined as 1 or more of the following:
 - a. An increase of 1 D in the steepest keratometry value
 - b. An increase of 1 D in regular astigmatism evaluated by subjective manifest refraction
 - c. A myopic shift (spherical equivalent) of 0.50 D on subjective manifest refraction
 - d. A decrease ≥ 0.1 mm in the back optical zone radius in rigid contact lens wearers where other information was not available.
- 2. Some contracts do not cover refractive surgery. When refractive surgery is not covered, any service or supply provided or obtained relative to an excluded service is considered a general exclusion based on member contract.

RATIONALE

The most recent literature review was performed through January 9, 2019.

Evidence reviews assess the clinical evidence to determine whether the use of a technology improves the net health outcome. Broadly defined, health outcomes are length of life, quality of life, and ability to function - including benefits and harms. Every clinical condition has specific outcomes that are important to patients and to managing the course of that condition. Validated outcome measures are necessary to ascertain whether a condition improves or worsens; and whether the magnitude of that change is clinically significant. The net health outcome is a balance of benefits and harms.

To assess whether the evidence is sufficient to draw conclusions about the net health outcome of a technology, 2 domains are examined: the relevance and the quality and credibility. To be relevant, studies must represent one or more intended clinical use of the technology in the intended population and compare an effective and appropriate alternative at a comparable intensity. For some conditions, the alternative will be supportive care or surveillance. The quality and credibility of the evidence depend on study design and conduct, minimizing bias and confounding that can generate incorrect findings. The randomized controlled trial (RCT) is preferred to assess efficacy; however, in some circumstances, nonrandomized studies may be

adequate. RCTs are rarely large enough or long enough to capture less common adverse events and long-term effects. Other types of studies can be used for these purposes and to assess generalizability to broader clinical populations and settings of clinical practice.

Corneal Collagen Cross-Linking for Keratoconus and Ectasia

The evidence base for Food and Drug Administration (FDA) approval of epi-off corneal collagen cross-linking (CXL) for the treatment of progressive keratoconus and corneal ectasia after refractive surgery consists of 3 randomized, parallel-group, open-label, sham-controlled trials that are summarized below. Also, there are systematic reviews, 2 RCTs, multiple prospective controlled studies, and uncontrolled trials reporting on longer term outcomes of the procedure.^{4,5} These RCTs are summarized in a section below.

Pivotal Trials

The 3 open-label RCTs are summarized in Table 1. The primary end point was a 1-diopter (D) reduction in the maximum corneal curvature (Kmax) at month 3. Because corneal stromal remodeling associated with healing response after CXL requires 6 to 12 months to stabilize, the time point for primary end point was changed from 3 to 12 months. This end point was better suited for evaluating the long-term clinical benefits of the CXL treatment. In all 3 trials, only 1 eye per patient was designated as the experimental eye. Patients with corneal ectasia diagnosed after laser in situ keratomileusis or photorefractive keratectomy or those with progressive keratoconus were included in these trials. Progressive keratoconus was defined as one or more of the following over a period of 24 months or less before randomization:

- An increase of 1 diopter (D) in the steepest keratometry value
- An increase of 1 D in regular astigmatism evaluated by subjective manifest refraction
- A myopic shift (decrease in the spherical equivalent) of 0.50 D on subjective manifest refraction
- A decrease ≥ 0.1 mm in the back optical zone radius in rigid contact lens wearers where other information was not available.

Sham-control eyes were treated with a topical anesthetic and riboflavin solution (1 drop every 2 minutes for 30 minutes) but did not undergo epithelial débridement or have the ultraviolet A light source turned on. For sham subjects who received CXL treatment at month 3 or month 6, the last Kmax measurement recorded before CXL treatment was carried forward in the analysis for later time points. This is a conservative method of analysis in this situation because it reduces the expected worsening over time in untreated patients. Almost all patients in the sham group received CXL treatment at month 3 or 6, and therefore the analysis compared the Kmax at month 12 in the CXL group with the Kmax at month 3 or 6 in the sham group. In each study, Kmax was assessed at baseline and months 1, 3, and 12.

Table 1. Summary of Pivotal Trial Characteristics and Results

Study	Study	Design	Dates	Patients (N or n)	Difference in Mean Change in Kmax From Baseline to 12 Months (95% CI) ^b
Unpublished	UVX-001	RCT	2008-2010	• Keratoconus (58) • Ectasia (49)	• -1.9 D (-3.4 to -0.3) • -2.0 D (-3.0 to -1.1)
Hersh et al (2011) ^{6,a}	UVX-002	RCT	2008-2010	Keratoconus only (147)	-2.3 D (-3.5 to -1.0)
Hersh et al (2011) ^{6,a,b}	UVX-003	RCT	2008-2011	Ectasia only (130)	-1.1 D (-1.9 to -0.3)

CI: confidence interval; D: diopter; Kmax: maximum corneal curvature; RCT: randomized controlled trial.

^a Hersh et al (2011)⁶ reported early trial results that included data from 49 of 147 patients in the UVX-002 trial and 22 of 130 patients in the UVX-003 trial. These results are not discussed.

^bIn UVX-003, 4 patients in the collagen cross-linking group had missing baseline Kmax values and were excluded from the analysis.

Maximum Corneal Curvature

The CXL-treated eyes showed increasing improvement in Kmax from months 3 through 12 (data not shown). The difference of the change in Kmax from baseline to month 12 between CXL-treated eyes and sham-treated eyes is summarized in Table 1 and was statistically significant from 6 months onward in favor of CXL treatment.

Best Spectacle-Corrected Visual Acuity

The visual acuity outcomes as assessed by mean improvement in best spectacle-corrected visual acuity (BSCVA) and responder analysis (gain of ≥ 15 letters on Early Treatment Diabetic Retinopathy Study is considered clinically meaningful) are summarized in Tables 2 and 3, respectively. Statistical procedures to control for type I error for multiple comparisons were not described in either the sponsor⁷, or FDA documents.^{8,9} Therefore, these results should not be used for statistical inference. The results summarized in Tables 2 and 3 are based on last observation carried forward (LOCF) analysis. In the pooled analysis of the observed data, the mean change in sham-control patients for progressive keratoconus at 6 months was +1.1 letter (n=38) compared with +5.8 (n=96) for CXL-treated patients, yielding a difference of 4.7 letters in favor of CXL treatment. Respective numbers for patients with ectasia were -0.4 letters (n=88) vs +4 letters (n=91), yielding a difference of 4.4 letters in favor of CXL treatment. Notably, FDA-approved labels for Photrexa and Photrexa Viscous do not include any visual acuity outcomes.³

Table 2. Summary of BSCVA Outcomes in the Pivotal Trials

Study	Patients (n or N)	Mean Change in BSCVA From Baseline to 12 Months		Difference ^a
		CXL-Treated Eyes	Sham-Controlled Eyes	
UVX-001	· Keratoconus (58)	· + 7.2	· +3.4	· +3.8 letters
	· Ectasia (49)	· +5.0	· -0.9	· +5.9 letters
UVX-002	Keratoconus only (147)	+5.0	+1.4	+3.6 letters
UVX-003	Ectasia only (130)	+5.0	-0.1	+5.1 letters
Pooled	· Keratoconus (205)	· +5.6	· +2.0	· +3.6 letters
	· Ectasia (179)	· +5.0	· -0.3	· +5.3 letters

Adapted from Avedro (2015).⁷

BSCVA: best spectacle-corrected visual acuity; CXL: corneal collagen cross-linking.

^aResults should be considered exploratory.

Table 3. Summary of ETDRS Chart Outcomes in the Pivotal Trials

Study	Patients (n or N)	Difference From Baseline to 12 Months in Percent Patients Who Gained ≥ 15 Letters on ETDRS		Difference ^a
		CXL-Treated Eyes	Sham-Controlled Eyes	
UVX-001	· Keratoconus (58)	· +24.1%	· +21.4%	· +2.7%
	· Ectasia (49)	· +21.7%	· +4.2%	· +17.5%
UVX-002	Keratoconus only (147)	+17.4%	+2.8%	+14.6%
UVX-003	Ectasia only (130)	+9.2%	+4.8%	+4.4%
Pooled	· Keratoconus (58)	· 19.4%	· 8.1%	· +11.3%
	· Ectasia (49)	· 12.5%	· 4.7%	· +7.8%

Adapted from Avedro (2015).⁷

CXL: corneal collagen cross-linking; ETDRS: Early Treatment Diabetic Retinopathy Study.

^aResults should be considered exploratory.

Other Randomized Controlled Trials

Keratoconus

Hersh et al (2017) analyzed 205 patients who had keratoconus treated with CXL (n=102) or a sham procedure (n=103) in a phase 3, prospective, randomized, controlled trial.¹⁰ At 1 year, those in the treatment group had a significant decrease in Kmax score (1.6) compared with baseline, while the control group saw an increase in Kmax (1.0); the between-group difference in Kmax change was 2.6 D (p<0.001). Mean corrected distance visual acuity (CDVA) improved significantly more in the treatment group (5.7 logMAR) than in the control group (2.2 log MAR; between-group difference, 3.5 logMAR; p<0.01). A similar finding, though statistically insignificant, was observed for mean uncorrected distance visual acuity, with the treatment group improving by 4.4 logMAR, compared with the control group (2.6 logMAR; between-group difference, 1.8 logMAR). Endothelial cell count did not change significantly from baseline to 1 year in either group. The trial was limited in that patients in the control group were allowed to switch to CXL treatment after 3 months; thus, their data were imputed based on the LOCF method. Also, in the control group, patients did not undergo removal of their epithelium.

Renesto et al (2010) reported on 2-year results of a randomized trial that compared CXL with 1 month of riboflavin eye drops in 39 eyes of 31 patients with keratoconus.¹¹ After 3 months, all patients received intrastromal corneal ring segments. Patients were evaluated at 1 and 3 months after treatment with CXL or riboflavin, and then at 1, 3, 6, 12, and 24 months after intrastromal corneal ring segments insertion. There were no significant differences between the 2 groups for UCVA, BCVA, or in 3 topographic parameters (flattest K, steepest K, and average keratometry) throughout the 24-month follow-up.

Corneal Ectasia

Hersh et al (2017) compared topographical with visual outcomes of 179 patients treated for corneal ectasia following laser in situ keratomileusis or photorefractive keratectomy surgery.¹² The prospective, multicenter controlled trial randomized 91 patients to treatment with standard CXL and 88 patients to a sham procedure which administered riboflavin alone and did not require the removal of the epithelium. The primary end point was a 1-year change in Kmax, which was a mean 0.7-D decrease in the CXL group and a 0.6-D increase in the control group (between-group difference, 1.3 D; p<0.001). A significantly greater improvement in CDVA was observed for the CXL group (5.0 logMAR gained) than for the control group (0.3 logMAR lost; p<0.001), as was the case with uncorrected distance visual acuity, for which the between-group difference was 4.6 letters (p<0.001). There was no significant difference between treatment and control groups for either manifest refraction spherical equivalent myopia or endothelial cell density, and fewer than 5% of eyes had adverse events. Over half of patients (68%) reported corneal stromal haze or demarcation line. The trial was limited by the LOCF analysis required for the control patients who elected to receive treatment after 3 months; also, because only 4 patients received photorefractive keratectomy surgery, comparison between types of surgery and effects of postsurgery CXL were precluded.

Wittig-Silva et al (2008) reported the first RCT of corneal CXL.¹³ Three-year results were published in 2014.¹⁴ Recruitment for the trial was completed in 2009 with 50 eyes randomized to CXL treatment and 50 eyes to the untreated control. To be eligible for enrollment, clear evidence of progression of ectasia over the preceding 6 to 12 months was required. Progression was confirmed if at least one of the following criteria was met: an increase of at least 1 D in the steepest simulated keratometry reading (Kmax); an increase in astigmatism determined by

manifest subjective refraction of at least 1 D; an increase of 0.50 D in manifest refraction spherical equivalent; or a 0.1-mm or more decrease in back optic zone radius of the best-fitting contact lens. At the time of analysis for the 2008 report, 20 eyes had reached 1-year follow-up. The 3-year results included 46 CXL-treated and 48 control eyes. LOCF was used for 26 eyes, including 17 eyes from the control group with a progressive disease that underwent compassionate-use CXL or corneal transplantation. In the CXL group, there was a flattening of Kmax by -1.03 D, compared with a 1.75 increase in Kmax in the control group. One eye in the CXL group progressed by more than 2 D, compared with 19 eyes in the control group. Uncorrected visual acuity (UCVA) and best-corrected visual acuity (BCVA) improved in the CXL-treated eyes at 1, 2, and 3 years.

Systematic Reviews

Keratoconus

A Cochrane review (2015) evaluated the use of corneal CXL for the treatment of keratoconus.¹⁵ The literature search was conducted in August 2014 and did not include all of the phase 3 trials submitted to FDA (described previously). Reviewers included 3 small RCTs conducted in Australia, the United Kingdom, and the United States, which enrolled a total of 225 eyes and analyzed 219 eyes. All 3 trials were at high risk for performance bias (lack of masking), detection bias (only 1 trial attempted to mask outcome assessment), and attrition bias (incomplete follow-up). Reviewers did not conduct a meta-analysis due to differences in measuring and reporting outcomes. The overall quality of the evidence was judged to be very low, primarily due to downgrading the evidence due to the risk of bias in the included studies, imprecision, indirectness, and publication bias.

Meri et al (2016) reported on the results of a systematic review and meta-analysis of ocular functional and structural outcomes in patients with keratoconus who underwent CXL treatment.¹⁶ Reviewers reported a modest but statistically nonsignificant improvement in visual acuity of 1 to 2 Snellen lines at 3 months or more after undergoing CXL. Reviewers concluded that, although CXL appeared to be effective at halting the deterioration of keratoconus, it was only slightly effective at improving visual acuity.

McAnena et al (2017) reported on the results of a systematic review and a meta-analysis assessing the efficacy of CXL treatment for keratoconus in pediatric patients.¹⁷ A total of 13 articles, published between May 2011 and December 2014, examining 490 eyes of 401 patients (mean age, 15.25 years), were included in the meta-analysis. Bias assessment of individual studies was not included. Reviewers reported a significant improvement in BCVA at 6 months (standardized mean difference, -0.66; 95% confidence interval [CI], -1.22 to -0.11; p=0.02), which was maintained at 1 year (standardized mean difference, -0.69; 95% CI, -1.15 to -0.22; p<0.01). Two-year data were available for 3 studies (n=131 eyes) and the improvement in BCVA remained significant (standardized mean difference, -1.03; 95% CI, -2 to -0.06; p=0.04).

Uncontrolled Studies

Keratoconus

Longer term follow-up is being reported from Europe, where corneal CXL has been performed for a greater number of years. Indications for treatment typically include progression of steepening (increase in Kmax by at least 1 D in 1 year), deteriorating visual acuity, or the need to be fitted for new contact lenses more than once in 2 years. The largest and longest series to date are described next.

Toprak et al (2017) retrospectively analyzed 29 eyes from pediatric patients (age range, 10-17 years) whose progressive keratoconus was treated with unilateral CXL treatment.¹⁸ From baseline to 2-year follow-up, there was a significant decrease in mean CDVA (0.34 logMAR to 0.13 logMAR; $p < 0.001$). Maximum keratometry (Kmax) measures decreased from baseline 54.65 to 53.25 at 2 years ($p = 0.034$), while anterior chamber parameters, corneal thickness, and corneal volume were not significantly affected by CXL after 2 years ($p > 0.05$). Several parameters of the Scheimpflug imaging system were improved following CXL treatment: index of surface variance decreased from 69.75 at baseline to 62.95 at 2 years ($p = 0.004$); keratoconus index decreased from 1.16 ($p = 0.001$); center keratoconus index decreased from 1.05 to 1.04 ($p = 0.004$); and index of height decentration decreased from 0.056 to 0.042 ($p = 0.001$). The radius of minimum curvature (Rmin) increased significantly from baseline to 2 years (6.21 to 6.36; $p = 0.007$), although 2 other indices (indices of height and vertical asymmetry) did not change significantly. The authors noted that follow-up beyond 2 years is required to make long-term assessments of CXL as a treatment for keratoconus, but concluded that their results seemed favorable for postoperative outcomes.

Badawi et al (2017) published a prospective nonrandomized observational study of accelerated CXL to treat pediatric patients with keratoconus.¹⁹ Of the 25 patients (33 eyes) enrolled, 80% were male, and most patients ($n = 17$) received unilateral CXL, administered with VibeX Rapid solution and Vega CBM X-Linker. The group's mean unaided and aided visual acuity were significantly improved at all time points (3, 6, and 12 months): at 12-month follow-up, the mean unaided visual acuity score was 0.34, which was a significant decrease compared with preoperative mean score (0.54; $p < 0.001$). For aided visual acuity, there was a similar decrease from preoperative (0.36) to 12-month (0.17) time points ($p < 0.001$). Mean corneal astigmatism values also decreased significantly (preoperative 2.4 D decreased to 2.01 D at 12 months; $p < 0.001$). The mean Kmax showed an average flattening of 1.2 D in 1 year (49.12 D decreasing to 47.9 D; $p < 0.001$); the authors reported significant improvements in other measures such as central pachymetry, maximum anterior elevation, average progression indices, and Q values. A limitation of the study was the slight increase observed in posterior surface elevation, which, contrary to other study measures, showed no significant positive effect 12 months after accelerated CXL ($p = 0.9$). Advising further study of the procedure, the authors noted that the unusual result might be accounted for by the choice of Pentacam as a corneal analysis tool because there might have been corneal artifacts present during evaluation.

Knutsson et al (2018) published a prospective cohort study of 43 patients (52 eyes) between the ages of 12 and 17 who underwent CXL as a treatment for keratoconus in 1 or both eyes.²⁰ Two-year outcomes were reported for all patients, although longer-term (up to 7 years) follow-up was available for 21 eyes. At 2 years, overall mean Kmax decreased from 59.30 ± 7.08 to 57.07 ± 6.46 ($p < 0.001$), and overall mean UCVA and BSCVA decreased, although not significantly. Additional analyses were conducted of patients whose eyes had Kmax values of 60 D or greater ($n = 25$), compared with those whose keratometry was less severe (< 60 D). As with the overall findings, mean Kmax for both cohorts were significantly decreased for both cohorts, while neither UCVA nor BSCVA measures changed significantly at 1 or 2 years. In patients with advanced keratoconus, mean Kmax decreased from 64.94 (95% CI, 62.94 to 66.94) to 62.25 (95% CI, 60.55 to 63.95) at 2 years ($p < 0.001$); for the less-advanced cohort, mean Kmax decreased from 53.88 (95% CI, 52.48 to 55.28) at baseline to 52.08 (95% CI, 50.68 to 53.48) at 2 years ($p < 0.001$). While most findings were favorable for the efficacy of CXL in treating even severe keratometry, the authors noted that the study was limited by the use of 2 pachymetric

measurement techniques (optical coherence tomography and ultrasound) rather than a single technique across the study. Further, the lack of full long-term data for all patients limited the study to reporting only 2-year outcomes.

Padmanabhan et al (2016) retrospectively analyzed 377 eyes of 336 patients (mean age, 15 years) who underwent CXL for progressive keratoconus.⁵ There was a significant improvement in mean BSCVA from 0.33 to 0.27 logMAR ($p < 0.05$). The authors found that the benefits of CXL in stabilizing keratoconus were maintained for more than 2 years in most pediatric eyes.

Padmanabhan et al (2017) also published follow-up results from the retrospective study previously mentioned of 377 eyes in 336 pediatric patients.²¹ Of 59 eyes for which investigators had longer term follow-up data (4 to 6.7 years), 30.9% showed worsening CDVA, and 24% showed corneal steepening of greater than 1 D (Kmax). These results showed the majority of patients still experienced improvements or stabilization of keratoconus-related outcomes after CXL, but suggested that long-term, there may be less efficacy.

Raiskup-Wolf et al (2008) reported on outcomes of 241 eyes (272 patients) treated with CXL, with a minimum of 6 months of follow-up.²² Follow-up examinations were performed at 1, 6, and 12 months, and then annually. Mean follow-up was 26 months, with a range of 12 months ($n=142$) to 6 years ($n=5$). In the first year ($n=142$), steepening (Kmax) improved or remained stable in 86% of eyes, and BCVA improved by at least 1 line in 53% of the eyes. Three years after treatment ($n=33$), Kmax improved by a mean of 2.57 D in 67% of eyes while BCVA improved by at least 1 line in 58% of eyes. In 2015, the same group published 10-year follow-up of CXL treatment in 34 eyes (24 patients) with progressive keratoconus.²³ Mean patient age at the time of treatment was 28 years (range, 14-42 years). Corneal steepening improved slightly between baseline and 10-year follow-up ($p < 0.001$), while corrected distance visual acuity improved by 0.14 logMAR ($p=0.002$). Two eyes had repeat CXL, one after 5 years and one after 10 years, without adverse sequelae. One of the 34 eyes treated developed a permanent corneal scar. These studies are limited by their retrospective designs and the small number of cases with extended follow-up.

A publication from the Siena Eye Cross Study (2010) reported on 52-month mean follow-up (range, 48-60 months) for 44 keratoconic eyes treated with CXL.²⁴ Follow-up evaluations were performed at 1, 2, 3, 6, 12, 24, 36, 48, and 60 months after CXL. Topographic analysis showed the following mean K reading reductions: -1.96 D after 1 year, -2.12 D after 2 years, -2.24 D after 3 years, and -2.26 D after 4 years of follow-up. By comparison, in fellow eyes untreated for the first 24 months, the mean K value increased by 1.2 D at 1 year and 2.2 D at 2 years. In treated eyes, UCVA improved by a mean of 2.41 lines after 12 months, 2.75 lines after 24 months, 2.80 lines after 36 months, and 2.85 lines after 48 months. There was no significant decrease in endothelial cell density, central corneal thickness, or intraocular pressure over follow-up. Temporary adverse events included stromal edema in the first 30 days (70% of patients) and temporary haze (9.8% of patients). No persistent adverse events were observed.

A publication from the Siena CXL Pediatrics trial (2012) reported on 12- to 36-month follow-up after CXL in 152 patients ages 18 years or younger with keratoconus progression.²⁵ Visual acuity increased by an average of 0.15 Snellen lines (a clinically relevant change is generally considered to be 2 Snellen lines).

The French National Reference Center for Keratoconus published their findings in 2011.²⁶ Of 142 eyes enrolled in the study, 6-month follow-up was available for 104 (73%), and 12-month follow-up was available for 64 (45%). At 12 months after treatment, the BCVA had stabilized in 48% of eyes, improved in 40%, and decreased in 12%. Keratoconus progression had stopped in 69%, and Kmax had decreased by more than 2 D in 21% of eyes. There was a 7% complication rate in the total sample, with 5 eyes (3.5% of 142 or 7.8% of 64) losing 2 or more Snellen lines of visual acuity. This retrospective study had a low proportion of patients available at the 12-month follow-up.

Adverse Events

The safety analysis conducted by FDA included 512 eyes (293 eyes with keratoconus, 219 eyes with corneal ectasia) in 364 patients who received CXL treatment.^{3,8} As described earlier, the procedure involves removing the corneal epithelium to enhance the riboflavin solution's penetration. As a result, patients may develop a range of ocular adverse reactions, including corneal opacity (haze), corneal epithelial defects, punctate keratitis, corneal striae, eye pain, reduced visual acuity, blurred vision, dry eye, and photophobia among others. Most adverse events resolved in the first month, while others took up to 12 months to resolve. However, in 1% to 6% of patients, these adverse events could continue beyond 12 months.

SUMMARY OF EVIDENCE

For individuals who have progressive keratoconus who receive CXL using riboflavin and ultraviolet A, the evidence includes multiple RCTs, systematic reviews, and nonrandomized studies. Relevant outcomes are change in disease status, functional outcomes, and treatment-related morbidity. In both pivotal RCTs, the primary end point (an intermediate outcome) of reducing maximum corneal curvature (Kmax) by 1 D was achieved at month 3 and maintained at months 6 and 12 in CXL-treated patients compared with sham controls. In both RCTs, the difference in mean change in Kmax from baseline to 12 months was 1.9 D and 2.3 D, respectively, favoring the CXL-treated patients. Long-term follow-up for visual acuity outcomes are needed. The adverse events associated with CXL include corneal opacity (haze), corneal epithelial defects, and other ocular findings. Most adverse events resolved in the first month but continued in a few (1%-6%) patients for 6 to 12 months. The evidence is sufficient to determine that the technology results in a meaningful improvement in the net health outcome.

For individuals who have corneal ectasia after refractive surgery who receive CXL using riboflavin and ultraviolet A, the evidence includes multiple RCTs, systematic reviews, and nonrandomized studies. Relevant outcomes are change in disease status, functional outcomes, and treatment-related morbidity. In both pivotal RCTs, the primary end point (an intermediate outcome) of reducing Kmax by 1 D was achieved at month 3 and maintained at months 6 and 12 in the CXL-treated patients compared with sham controls. In both RCTs, the difference in mean change in Kmax from baseline to 12 months was 2.0 D and 1.1 D, respectively, favoring CXL-treated patients. Long-term follow-up for visual acuity outcomes are needed. The adverse events associated with CXL include corneal opacity (haze), corneal epithelial defects, and other ocular findings. Most adverse events resolved in the first month but continued in a few (1%-6%) patients for 6 to 12 months. The evidence is sufficient to determine that the technology results in a meaningful improvement in the net health outcome.

CLINICAL INPUT FROM PHYSICIAN SPECIALTY SOCIETIES AND ACADEMIC MEDICAL CENTERS

While the various physician specialty societies and academic medical centers may collaborate with and make recommendations during this process, through the provision of appropriate reviewers, input received does not represent an endorsement or position statement by the physician specialty societies or academic medical centers, unless otherwise noted.

In response to requests, input was received from 1 physician specialty society and 1 academic medical center (2 reviewers) while this policy was under review in 2012. The input was mixed, noting the limited literature and lack of U.S. Food and Drug Administration (FDA) approval for this procedure, although there are ongoing FDA-regulated clinical trials. Reviewers also commented on the lack of alternatives to slow disease progression and that data indicated the procedure is safe and effective enough to offer to patients with adequate informed consent under an investigational protocol.

PRACTICE GUIDELINES AND POSITION STATEMENTS

National Institute for Health and Care Excellence

In 2013 the National Institute for Health and Care Excellence (NICE) issued guidance on corneal collagen cross-linking (CXL) using riboflavin and ultraviolet A updated and replaced its 2009 guidance.²⁷ The 2013 guidance stratified NICE recommendations for corneal CXL as follows:

“Most of the published evidence on photochemical corneal collagen cross-linkage (CXL) using riboflavin and ultraviolet A (UVA) for keratoconus and keratectasia relates to the technique known as 'epithelium-off' CXL'. 'Epithelium-on (transepithelial) CXL' is a more recent technique and less evidence is available on its safety and efficacy. Either procedure (epithelium-off or epithelium-on CXL) can be combined with other interventions, and the evidence base for these combination procedures (known as 'CXL-plus') is also limited. Therefore, different recommendations apply to the variants of this procedure, as follows.

- 1.1 Current evidence on the safety and efficacy of epithelium-off CXL for keratoconus and keratectasia is adequate in quality and quantity. Therefore, this procedure can be used provided that normal arrangements are in place for clinical governance, consent and audit.
- 1.2 Current evidence on the safety and efficacy of epithelium-on (transepithelial) CXL, and the combination (CXL-plus) procedures for keratoconus and keratectasia is inadequate in quantity and quality. Therefore, these procedures should only be used with special arrangements for clinical governance, consent and audit or research.”

U.S. PREVENTIVE SERVICES TASK FORCE RECOMMENDATIONS

Not applicable.

ONGOING AND UNPUBLISHED CLINICAL TRIALS

Some currently unpublished trials that might influence this review are listed in Table 4.

Table 4. Summary of Key Trials

NCT No.	Trial Name	Planned Enrollment	Completion Date
Ongoing			
NCT00560651	German Corneal Cross-Linking Registry	7500	Nov 2017 (ongoing)

NCT No.	Trial Name	Planned Enrollment	Completion Date
NCT01708538 ^a	Phase III Study of Corneal Collagen Cross-linking Using Two Different Techniques	30	Oct 2020
NCT01604135	Collagen Crosslinking for Keratoconus - a Randomized Controlled Clinical Trial	200	May 2019
NCT03319082 ^a	A Phase IV Observational Registry to Assess the Durability of Effect of Corneal Collagen Cross-linking With Photrexa Viscous, Photrexa, and the KXL System in Patients With Corneal Ectasia Following Refractive Surgery	200	Jul 2023
Unpublished			
NCT01459679	A Multi-Center, Randomized, Controlled Evaluation of the Safety and Efficacy of the KXL System With VibeX (Riboflavin Ophthalmic Solution) for Corneal Collagen Cross-Linking in Eyes With Keratoconus or Corneal Ectasia After Refractive Surgery	4000	Jan 2016 (terminated)
NCT01344187 ^a	A Multi-Center, Randomized, Placebo-Controlled Evaluation of the Safety and Efficacy of the KXL System With VibeX (Riboflavin Ophthalmic Solution) for Corneal Collagen Cross-Linking in Eyes With Keratoconus	236	Jun 2016 (completed)
NCT01972854 ^a	A Multi-Center, Randomized, Placebo-Controlled Evaluation of the Safety and Efficacy of the KXL System With VibeX (Riboflavin Ophthalmic Solution) for Corneal Collagen Cross-Linking in Eyes With Keratoconus	92	Apr 2017 (terminated)
NCT02721628	Femtosecond Laser Assisted Epi-keratoplasty Versus Collagen Cross-Linking in Progressive Keratoconus	60	Mar 2018
NCT01189864 ^a	Collagen Crosslinking With Ultraviolet-A in Asymmetric Corneas	500	Dec 2018 (terminated)

NCT: national clinical trial.

^a Denotes industry-sponsored or cosponsored trial.

CODING

The following codes for treatment and procedures applicable to this policy are included below for informational purposes. Inclusion or exclusion of a procedure, diagnosis or device code(s) does not constitute or imply member coverage or provider reimbursement. Please refer to the member's contract benefits in effect at the time of service to determine coverage or non-coverage of these services as it applies to an individual member.

CPT/HCPCS

0402T	Collagen cross-linking of cornea (including removal of the corneal epithelium and intraoperative pachymetry when performed)
J2787	Riboflavin 5'-phosphate, ophthalmic solution, up to 3 mL

ICD-10 Diagnoses

H18.601	Keratoconus, unspecified, right eye
H18.602	Keratoconus, unspecified, left eye
H18.603	Keratoconus, unspecified, bilateral
H18.621	Keratoconus, unstable, right eye
H18.622	Keratoconus, unstable, left eye
H18.623	Keratoconus, unstable, bilateral
H18.711	Corneal ectasia, right eye
H18.712	Corneal ectasia, left eye

H18.713 Corneal ectasia, bilateral

REVISIONS

04-28-2017	Policy added to the bcbsks.com web site.
04-11-2018	Updated Description section.
	Updated Rationale section.
	Updated References section.
08-01-2018	In Policy section: <ul style="list-style-type: none"> Revised Policy Guidelines Item 1 c, removed "decrease in the" to read, "A myopic shift (spherical equivalent) of 0.50 D on subjective manifest refraction."
	Updated References section.
01-01-2019	In Coding section: <ul style="list-style-type: none"> Added new HCPCS code: J2787.
04-24-2019	Updated Description section.
	In Policy section: <ul style="list-style-type: none"> In Item A, removed "after" and added "resulting from" to read, "Corneal collagen cross-linking using riboflavin and ultraviolet A may be considered medically necessary as a treatment of progressive keratoconus or corneal ectasia resulting from refractive surgery in patients who have failed conservative treatment (eg, spectacle correction, rigid contact lens) (see Policy Guidelines)."
	Updated Rationale section.
	Updated References section.

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