E-ISSN 2250-0944
ISSN 2250-1150
doi: 10.31838/ijprt/16.01.332

Research Article

Effectiveness and Safety of Contact Lens-Assisted Collagen Cross-Linking in Thin Corneas with Progressive Keratoconus: A Prospective Interventional Study

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Received: 12.03.26, Revised: 14.04.26, Accepted: 18.05.26

ABSTRACT
Background: Conventional corneal collagen cross-linking (CXL) is limited to corneas with a minimum thickness of 400 µm, restricting its use in advanced keratoconus. Contact lens-assisted collagen cross-linking (CACXL) has emerged as a potential alternative for thin corneas.
Aim: To evaluate the effectiveness and safety of CACXL in progressive keratoconus with thin corneas.
Methods: This hospital-based interventional study included 75 eyes of 48 adult patients with progressive keratoconus and corneal thickness between 350–440 µm. CACXL was performed using riboflavin-soaked soft contact lenses followed by ultraviolet-A irradiation. Patients were evaluated preoperatively and at 1, 6, and 12 months postoperatively. Outcomes included corneal thickness, maximum keratometry (Kmax), endothelial cell count, and best-corrected visual acuity (BCVA). Statistical analysis was performed using paired t-test.
Results: Mean preoperative corneal thickness was 407.91 ± 23.15 µm, with no significant change at 12 months (408.36 ± 23.22 µm; p=0.433). Kmax remained stable (58.99 ± 5.36 D preoperatively vs. 58.82 ± 5.45 D at 12 months; p=0.111). Endothelial cell count showed no significant reduction (p>0.05). BCVA improved significantly from 0.65 ± 0.30 to 0.60 ± 0.29 (p=0.002).
Conclusion: CACXL is a safe and effective procedure for halting keratoconus progression in thin corneas, without significant endothelial damage. It offers a practical alternative to conventional CXL.

Keywords: Keratoconus, Corneal Collagen Cross-Linking, Thin Cornea, CACXL, Kmax, Visual Acuity.

INTRODUCTION

Keratoconus is a progressive, non-inflammatory corneal ectatic disorder characterized by stromal thinning, irregular astigmatism, and visual impairment. Corneal collagen cross-linking (CXL) has emerged as an effective treatment modality to halt disease progression by increasing corneal biomechanical stability through riboflavin-mediated ultraviolet-A (UVA) induced collagen cross-linking (1).

However, conventional CXL requires a minimum stromal thickness of 400 µm after epithelial removal to prevent endothelial cytotoxicity from UVA irradiation (1). This limitation restricts its use in advanced keratoconus, where corneal thinning is often severe. To overcome this limitation, various modifications such as hypo-osmolar riboflavin swelling techniques have been proposed (5,6). These techniques artificially increase corneal thickness prior to irradiation; however, their effect is often transient and may not provide consistent stromal protection (7).

Alternative approaches including transepithelial CXL and customized epithelial debridement have also been explored, but they are associated with reduced riboflavin penetration and variable efficacy (3,4).

Contact lens-assisted collagen cross-linking (CACXL), introduced by Jacob et al., represents a novel technique in which a riboflavin-soaked soft contact lens is used to artificially augment corneal thickness, thereby allowing safe application of UVA irradiation in thin corneas (2). This method provides a more stable and predictable increase in functional corneal thickness compared to other techniques.

Despite its promising results, limited data are available regarding the efficacy and safety of CACXL, particularly in the Indian population.

Therefore, the present study was undertaken to evaluate the clinical outcomes of CACXL in patients with progressive keratoconus and thin corneas.

MATERIALS AND METHODS

This prospective interventional study was conducted at the Department of Ophthalmology, S.M.S. Medical College, Jaipur.

Study Population

A total of 75 eyes of 48 patients aged >18 years with progressive keratoconus and central corneal thickness between 350–440 µm were included. Progression was defined as:

- Increase in Kmax >1 D
- Change in spherical equivalent >0.5 D
- 2% reduction in corneal thickness

Exclusion criteria included corneal scarring, hydrops, infection, and pregnancy.

Procedure

After epithelial debridement, riboflavin 0.1% was instilled every 3 minutes for 30 minutes. A riboflavin-soaked soft contact lens was placed on the cornea, ensuring combined thickness ≥400 µm. UVA irradiation (370 nm, 3 mW/cm² for 30 minutes) was applied.

Follow-Up

Patients were evaluated at 1, 6, and 12 months for:

- Corneal thickness (pachymetry)
- Kmax (Scheimpflug imaging)
- Endothelial cell count
- BCVA (LogMAR)

Statistical Analysis

Data were analyzed using SPSS v16. Continuous variables were expressed as mean ± SD. Paired t-test was used; $p<0.05$ was considered significant.

RESULTS

Table 1: Corneal Thickness (µm)

Time	Mean ± SD	p-value
Pre-op	407.91 ± 23.15	—
1 month	406.35 ± 22.63	0.007
6 months	408.35 ± 23.08	0.304
12 months	408.36 ± 23.22	0.433

No significant change was observed at long-term follow-up.

Table 2: Kmax (Diopters)

Time	Mean ± SD	p-value
Pre-op	58.99 ± 5.36	—
1 month	59.20 ± 5.45	0.005
6 months	59.11 ± 5.37	0.140
12 months	58.82 ± 5.45	0.111

Keratoconus progression was effectively halted.

Table 3: Endothelial Cell Count (cells/mm^2)

Time	Mean ± SD	p-value
Pre-op	2859.40 ± 205.45	—
1 month	2857.89 ± 205.05	0.054
6 months	2860.56 ± 206.13	0.150
12 months	2860.69 ± 205.79	0.110

No endothelial damage was observed.

Table 4: BCVA (LogMAR)

Time	Mean ± SD	p-value
Pre-op	0.65 ± 0.30	—
1 month	0.62 ± 0.29	0.009
6 months	0.60 ± 0.29	0.002
12 months	0.60 ± 0.29	0.002

Significant visual improvement was observed.

DISCUSSION

The present study demonstrates that contact lens-assisted collagen cross-linking (CACXL) is

an effective and safe modality for stabilizing keratoconus in thin corneas. The major challenge in performing conventional CXL in thin corneas is the risk of endothelial damage due to excessive UVA penetration. CACXL overcomes this limitation by increasing functional corneal thickness using a riboflavin-soaked contact lens.

In our study, there was no significant change in corneal thickness over a 12-month follow-up period, indicating structural stability. Similar stabilization has been reported in studies evaluating alternative techniques such as transepithelial CXL, although the magnitude of biomechanical strengthening may be lower due to limited riboflavin penetration (8,9).

Kmax values remained stable throughout the follow-up period in our study, suggesting effective arrest of keratoconus progression. This finding is comparable with studies using customized epithelial debridement techniques, although those methods may result in uneven riboflavin diffusion and suboptimal cross-linking effect in the cone area (11,12,13).

Endothelial cell safety is a critical concern in thin corneas. In the present study, no significant endothelial cell loss was observed. This is in contrast to earlier studies using conventional CXL in thin corneas, where a reduction in endothelial cell density has been reported. The safety profile observed in our study is consistent with techniques designed to maintain adequate stromal thickness during irradiation (10).

Visual outcomes in our study showed significant improvement in BCVA, which may be attributed to stabilization of corneal curvature and reduction in irregular astigmatism. While some techniques such as stromal lenticule-assisted CXL have shown promising results, their clinical applicability is limited due to dependence on donor tissue availability (14).

Recent approaches such as adapted fluence protocols aim to customize UVA energy delivery based on corneal thickness, but these require further validation before routine clinical use (15). Compared to these methods, CACXL offers a simpler, cost-effective, and reproducible alternative without the need for specialized resources or complex modifications.

The strength of the present study lies in its relatively larger sample size and longer follow-up compared to earlier studies. However, long-term studies are required to confirm sustained efficacy and safety outcomes.

CONCLUSION

Contact lens-assisted collagen cross-linking is a safe and effective modality for managing progressive keratoconus in thin corneas. The procedure successfully halts disease progression without compromising endothelial safety.

CACXL provides a practical alternative to conventional CXL by overcoming the limitation of minimum corneal thickness. Its ease of availability, cost-effectiveness, and reproducibility make it a promising technique in routine clinical practice.

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