A Simple Calculator to Decide UVA “On” Time for Cross-linking of Thin Keratoconic Corneas (< 400 µm)

We read the recent article by Knyazer et al1 on 1-year outcomes following cross-linking of thin keratoconic corneas. A concern arising from this study was that the same ultraviolet-A (UVA) light “on” time was used irrespective of the stromal thickness. A damage threshold of 0.35 mW/cm² for the endothelium of animal eyes is known and the endothelium is exposed to only 0.18 mW/cm² when the stroma is 400 µm thick.2,3 Therefore, the “on” time of UVA light should be titrated to minimize the risk of damage to the endothelium. The absorption coefficient of UVA light in riboflavin of different concentrations was presented in an earlier study.4

By using the Lambert-Beer equation, we present a simple calculator to decide the UVA light “on” time for an incident intensity of 3 and 9 mW/cm² (Figure 1). The assumption behind the calculator was that the incident energy density on the stroma was 5.4 J/cm² and this was attenuated at deeper depths of the stroma as determined by the Lambert-Bear equation. We used an absorption coefficient of 46.86 and 93.72 cm⁻¹ for riboflavin concentrations of 0.1% and 0.2%, respectively.4 The following equations were used to determine the time:

\[ T_{3\text{mW}} = e^{-46.86\times[400\text{-MST}]\times0.0001} \]  
\[ T_{9\text{mW}} = e^{-93.72\times[400\text{-MST}]\times0.0001} \]  

where MST is the minimum stromal thickness in micrometers. A riboflavin concentration of 0.2% was also chosen because the absorption of UVA light was better with 0.2% concentration and may benefit crosslinking of thin corneas by reducing the time.4

These equations provide the “on” time for continuous exposure only. Because the absorption coefficients were determined by fundamental experiments on tissue and riboflavin film, Equations 1 and 2 should provide a safer profile for thin keratoconic corneas (< 400 µm). An advantage of these equations is that any CXL device capable of generating an intensity of 3 or 9 mW/cm² can be used irrespective of the MST. There is no additional requirement of patient-specific customization of intensity. Nonetheless, the safety of these equations needs to be evaluated in prospective studies. A preoperative MST of 330 µm in thin keratoconic corneas was recommended for safety.5 However, the smallest MST that can be irradiated with UVA light without any adverse events also needs to be evaluated. For easy use by clinicians, Equations 1 and 2 were programmed into an online freeware calculator (https://jscalc.io/calc/VmanUJD6yQ13VQQ6).

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REFERENCES


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Reply

We thank Shetty et al for their comments regarding our article “Corneal Cross-linking in Thin Corneas: 1-Year Results of Accelerated Contact Lens-Assisted Treatment of Keratoconus” and for the ultraviolet-A (UVA) calculator they propose. Such a calculator could be of great importance and broad clinical value.

In our region, the proportion of patients with progressive keratoconus who present with thin corneas (<400 µm) is approximately 25% to 28% of the cases (unpublished data). As a solution for these patients with keratoconus who have thin corneas, we believed it was justified to perform contact lens–assisted cross-linking (CA-CXL). CA-CXL offers several potential advantages: it is affordable, does not require special equipment or a unique riboflavin formula, and does not require an extended amount of time or repeated measurements of corneal thickness during treatment.

In our study, we showed that 80% of patients showed stabilization at 1 year, without deterioration in vision, reduction in endothelial cell counts, delay in reepithelialization, or significant intraoperative or postoperative complications. We therefore find that CA-CXL is an effective and safe technique that can routinely be employed by corneal specialists treating patients with progressive keratoconus who have thin corneas.

However, we are aware of the potential theoretical drawbacks of high progression rates due to insufficient amounts or depth of collagen and proteoglycan covalent bonds in the stroma of these patients. Jacob et al achieved stromal demarcation lines within the range obtained in studies assessing corneas with a thickness greater than 400 µm.

We would like to congratulate and thank Shetty et al for the useful free online UVA calculator that they report.

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REFERENCES

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