

PERSONALIZED SELECTION OF TREATMENT STRATEGY FOR KERATOCONUS: FROM SIMPLE TO COMPLEX

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Annotation. Relevance. Keratoconus is one of the most significant progressive corneal diseases, leading to visual impairment in young individuals. Timely diagnosis and the selection of an individualized treatment strategy make it possible to slow disease progression, preserve vision, and postpone the need for corneal transplantation. **Purpose of the study.** To develop an algorithm for a personalized approach to the treatment of keratoconus depending on the stage of the disease. **Materials and methods.** An analysis of contemporary publications (PubMed, Scopus, 2015–2025), clinical guidelines (ESCRS, AAO), as well as the experience of leading centers (ELZA Institute, Europe, Turkey) was conducted. **Results and Conclusion.** A stepwise algorithm for the treatment of keratoconus has been developed. The analysis identified the main barriers to implementing personalized methods in Uzbekistan, including the lack of modern diagnostic equipment and the absence of a national keratoconus registry. A personalized stage-based approach to keratoconus management allows optimization of treatment strategies and postponement of corneal transplantation.

Keywords: keratoconus, cross-linking, corneal segments, scleral lenses.

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ПЕРСОНАЛИЗИРОВАННЫЙ ВЫБОР ТАКТИКИ ЛЕЧЕНИЯ КЕРАТОКОНУСА: ОТ ПРОСТОГО К СЛОЖНОМУ

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Аннотация. Актуальность. Кератоконус является одним из наиболее значимых прогрессирующих заболеваний роговицы, приводящих к снижению зрения у лиц молодого возраста. Своевременная диагностика и выбор индивидуальной тактики лечения позволяют замедлить прогрессирование, сохранить зрение и отсрочить необходимость трансплантации роговицы. **Цель исследования.** Разработать алгоритм персонализированного подхода к лечению кератоконуса в зависимости от стадии заболевания. **Материалы и методы.** Проведен анализ современных публикаций (PubMed, Scopus, 2015–2025 гг.), клинических протоколов (ESCRS, AAO), а также опыта ведущих центров (ELZA Institute, Европа, Турция). **Результаты и заключение.** Разработан поэтапный алгоритм лечения кератоконуса. В ходе анализа были выделены основные барьеры для внедрения персонализированных методик в Узбекистане, среди которых недостаток современного диагностического оборудования и отсутствие национального регистра кератоконуса. Персонализированный подход, основанный на стадийности кератоконуса, позволяет оптимизировать тактику лечения и отсрочить трансплантацию роговицы.

Ключевые слова: кератоконус, кросслинкинг, роговичные сегменты, склеральные линзы.

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KERATOKONUSNI DAVOLASH TAKTIKASINI SHAXSIYLASHTIRILGAN TANLOVI: ODDIYDAN MURAKKABGACHA

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Annotatsiya. Dolzarbligi. Keratokonus yosh aholida ko'rish qobiliyatining pasayishiga olib keladigan eng muhim progressiv kornea kasalliklaridan biridir. O'z vaqtida tashxis qo'yish va individual davolash taktikasini tanlash kasallik rivojlanishini sekinlashtirish, ko'rishni saqlash va kornea transplantatsiyasi zaruratini kechiktirish imkonini beradi.

Tadqiqot maqsadi. Keratokonusni davolashda kasallik bosqichiga qarab shaxsiylashtirilgan yondashuv algoritmini ishlab chiqish. **Material va usullar.** Zamonaviy nashrlar (PubMed, Scopus, 2015–2025 yy.), klinik protokollar (ESCRS, AAO), shuningdek yetakchi markazlar (ELZA Institute, Yevropa, Turkiya) tajribasi tahlil qilindi. **Natijalar va xulosa.** Keratokonusni davolash uchun bosqichma-bosqich algoritm ishlab chiqildi. Tahlil jarayonida O'zbekistonda shaxsiylashtirilgan metodlarni joriy etishga to'sqinlik qilayotgan asosiy omillar aniqlangan bo'lib, ular orasida zamonaviy diagnostik uskunalarning yetishmasligi va keratokonusning milliy reestri yo'qligi bor. Kasallik bosqichlariga asoslangan shaxsiylashtirilgan yondashuv davolash taktikasini optimallashtirish va kornea transplantatsiyasini kechiktirish imkonini beradi.

Kalit so'zlar: keratokonus, crosslinking, qovoq (kornea) segmentlari, skleral linzalar.

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Relevance. Keratoconus (KC) is one of the most significant progressive corneal disorders, characterized by stromal thinning and irregular protrusion, leading to progressive visual impairment. The disease typically manifests at a young age and has a profound impact on quality of life and social adaptation. According to international studies, prevalence ranges from 1:375 to 1:2000, with higher rates and earlier onset observed in Asian populations [1–3]. In Uzbekistan, keratoconus represents an especially pressing issue due to delayed diagnosis, limited access to advanced imaging modalities, and frequent presentation at advanced stages of the disease.

Purpose of the study. The purpose was to develop a personalized treatment algorithm for keratoconus based on disease stage, incorporating modern therapeutic options such as corneal cross-linking (CXL), intrastromal corneal ring segments (ICRS), corneal allogenic intrastromal ring segments (CAIRS), and innovative methods like ELZA PACE [2,3,5].

Materials and methods. A comprehensive literature review was conducted using PubMed and Scopus databases (2015–2025), with a focus on clinical studies, international guidelines (ESCRS, AAO, Global Consensus 2015 [1]), and protocols from leading institutions including the ELZA Institute (Switzerland) [5], Moorfields Eye Hospital (UK), and Marmara University (Turkey).

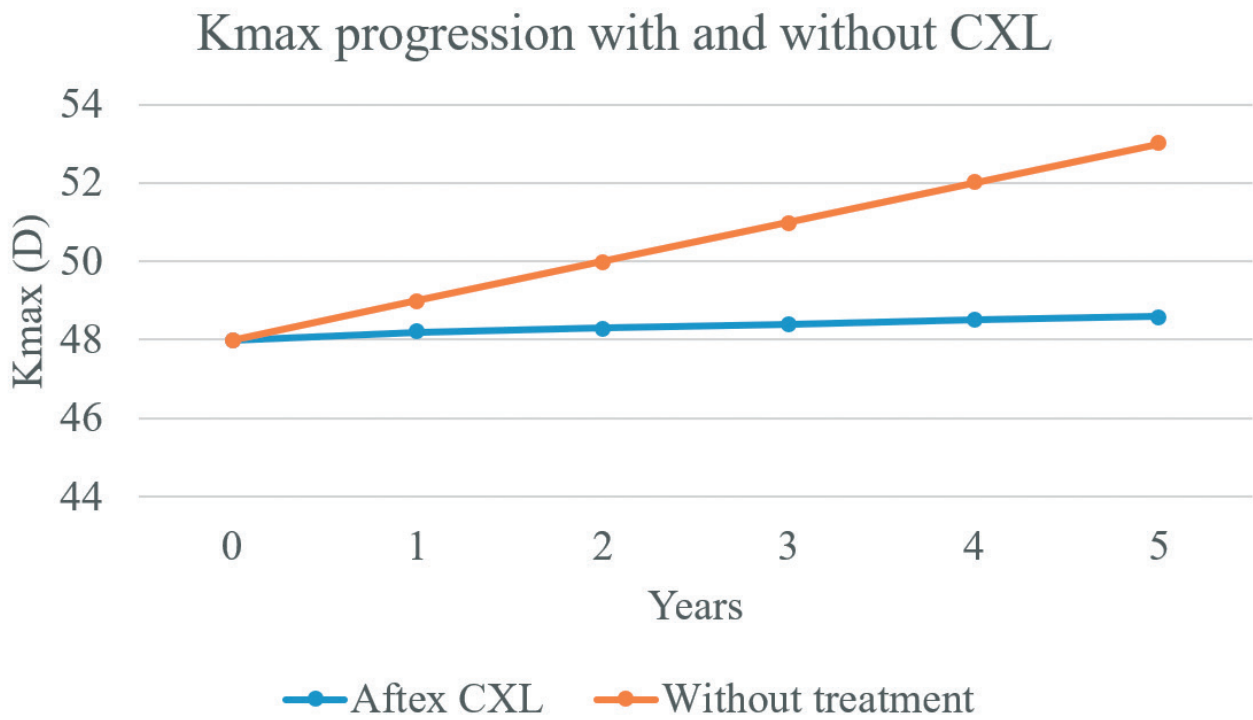
Additionally, clinical observations from the authors' own practice in Uzbekistan were analyzed. The evaluation criteria included treatment indications,

efficacy, safety profiles, and long-term outcomes of different therapeutic strategies across various keratoconus stages.

Results. The analysis resulted in the development of a comprehensive, stage-based algorithm for keratoconus (KC) management, integrating evidence from international clinical studies with the authors' own observations in Uzbekistan. This approach highlights the importance of tailoring therapy to disease severity, patient-specific factors, and local resource availability.

In early keratoconus (Stage I), conservative optical correction with spectacles or soft toric contact lenses can provide satisfactory vision, but does not influence the natural course of the disease. Corneal cross-linking (CXL) remains the cornerstone of treatment at this stage, as it is the only intervention proven to halt progression. Large-scale studies, including long-term prospective cohorts, report progression arrest in 85–90% of cases after 5 years with the standard Dresden protocol. Accelerated CXL protocols (9 mW/cm² for 10 minutes, or 18 mW/cm² for 5 minutes) show comparable efficacy, though some reports suggest slightly less flattening of Kmax. Despite these advantages, the challenge in Uzbekistan is that many patients are diagnosed only when progression is clinically evident, due to the absence of widespread access to corneal tomography. As a result, CXL is often performed later than optimal, limiting its ability to preserve vision.

In moderate keratoconus (Stage II), a combination of biomechanical stabilization and optical rehabilitation

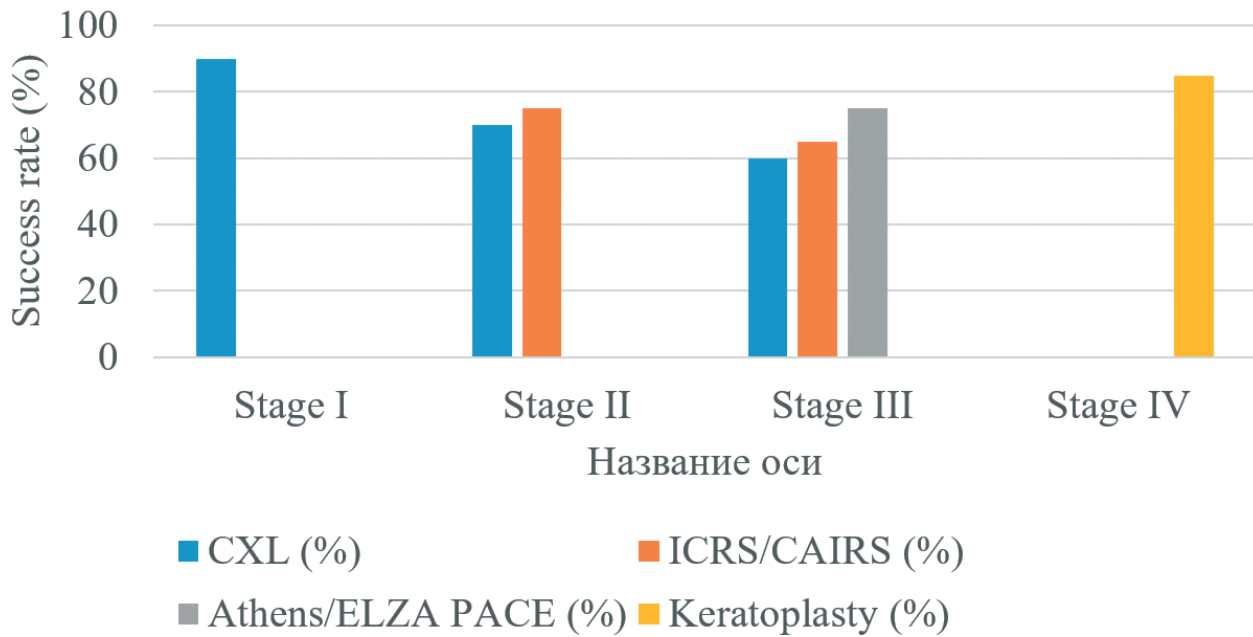


Pic. 1. Kmax progression with and without CXL.

is required. Rigid gas-permeable (RGP) and scleral lenses provide superior optical correction compared to spectacles, with reported success rates of 70–80% tolerance in young patients. However, they do not prevent disease progression, thus CXL remains mandatory if progression is documented. Intrastromal corneal ring segments (ICRS) have demonstrated significant efficacy in improving corneal symmetry, reducing irregular astigmatism, and enhancing

visual function. Published clinical data report an average reduction in maximum keratometry (Kmax) by 1.5–3.0 D, and an improvement in best-corrected visual acuity (BCVA) by 2–3 Snellen lines (Pic 1). The introduction of corneal allogenic intrastromal ring segments (CAIRS) represents an important innovation, combining the biomechanical and optical benefits of ICRS with lower risk of extrusion and higher biocompatibility. Early results indicate better

Effectiveness of treatments by stage



Pic. 2. Effectiveness of treatments by stage.

Table 1. Stage-based management of keratoconus

Stage	Main treatment strategies	Efficacy (literature)	Limitations / Challenges (Uzbekistan)
I (Early KC)	Glasses, soft toric CL; CXL (Dresden / accelerated)	Progression halted in 85–90% at 5 years; Accelerated CXL comparable to Dresden	Late diagnosis due to limited tomography; CXL available only in few centers
II (Moderate KC)	CXL + RGP or scleral CL; ICRS / CAIRS	Kmax ↓ 1.5–3.0 D, BCVA ↑ 2–3 lines; CAIRS shows better biocompatibility	CAIRS not yet available; high cost limits access
III (Advanced KC)	CXL + ICRS/CAIRS; Athens Protocol, ELZA PACE	Spherical equivalent ↓ 2.0–4.0 D; BCVA improved in 70–80%	Excimer laser platforms scarce; lack of trained specialists
IV (Late KC)	DALK (preferred), PK, DMEK/DSEK if endothelial failure	Graft survival: DALK 85–90% (10 yrs), PK 70–80%	Shortage of donor corneas; delayed surgery common

long-term stability compared to synthetic ICRS. In Uzbekistan, access to ICRS is sporadic and CAIRS is not yet implemented, but clinical cases managed with CXL plus RGP/scleral lenses confirm stabilization and functional improvement in most patients.

In advanced keratoconus (Stage III), corneal thinning and irregularity become more pronounced, reducing the efficacy of optical correction alone. At this stage, combined procedures offer the greatest benefit. The Athens Protocol (topography-guided PRK combined with CXL) and ELZA PACE (progressive customized ablation with CXL) have demonstrated significant improvements in both visual acuity and corneal regularity. Studies show that these approaches lead to a reduction of mean spherical equivalent by 2.0–4.0 D and a BCVA gain in 70–80% of cases, while maintaining long-term stability. Comparative analysis suggests that ELZA PACE may provide more tissue-sparing customization, which is especially relevant for thin corneas. Nevertheless, these advanced laser-based procedures remain largely unavailable in Uzbekistan due to the limited number of excimer laser platforms and lack of trained specialists. This highlights the need for the establishment of regional centers with access to modern keratoconus surgery.

In late-stage keratoconus (Stage IV), characterized by severe thinning, scarring, or hydrops, optical and intracorneal approaches become insufficient. In these cases, keratoplasty remains the only effective treatment. When the corneal endothelium is preserved, deep anterior lamellar keratoplasty (DALK) is the preferred option, offering better graft survival and reduced risk of endothelial rejection. International series report 10-year graft survival rates of 85–90% for DALK, compared to 70–80% for penetrating keratoplasty (PK) (Pic. 2). However, DALK is technically demanding and requires specialized surgical expertise. In cases with endothelial decompensation or stromal-endothelial scarring, PK or endothelial keratoplasty (DMEK/DSEK) is indicated. In Uzbekistan, the major limiting

factor is the shortage of donor corneas, leading to significant delays in transplantation. Consequently, many patients present with advanced, untreated keratoconus that could have been managed earlier with less invasive strategies.

Overall, the staged algorithm demonstrates that a patient-centered, multimodal approach significantly improves outcomes compared to monotherapy. Integration of modern methods such as CAIRS and ELZA PACE, where available, not only delays the need for keratoplasty by an average of 5–7 years, but also improves functional vision and quality of life. Clinical experience from Uzbekistan confirms the relevance of stage-adapted treatment: patients managed with timely CXL maintained stable keratometry for up to 4–5 years, while those undergoing combined CXL and intracorneal interventions achieved meaningful improvement in BCVA. These findings underscore the importance of expanding diagnostic infrastructure, increasing access to CXL across the country, and training surgeons in advanced keratoconus techniques.

Discussion. The staged algorithm emphasizes that keratoconus management must transition from a uniform strategy to an individualized, patient-centered approach [1]. CXL continues to be the cornerstone of therapy [2], particularly in early stages, but its efficacy is enhanced when integrated with adjunctive techniques such as ICRS, CAIRS [3], or topography-guided surface ablation [4]. The emergence of CAIRS [3] and ELZA PACE [5] represents a paradigm shift in surgical management, offering less invasive alternatives that combine corneal stabilization with optical improvement. These innovations highlight the trend toward “function-preserving” strategies, where transplantation is postponed as long as possible. At advanced stages, keratoplasty remains indispensable, but global trends favor lamellar over penetrating approaches, reflecting the broader principles of personalized medicine and tissue preservation [1,2]. In Uzbekistan, the main challenges include late presentation, restricted

access to diagnostic technologies, and limited availability of modern surgical options. Establishing a national keratoconus registry, expanding access to CXL, and training specialists in advanced techniques such as CAIRS and ELZA PACE would significantly improve patient outcomes.

Conclusion. A personalized, stage-based treatment algorithm for keratoconus allows clinicians to preserve corneal integrity, delay keratoplasty,

and provide tailored visual rehabilitation. For Uzbekistan, the priority steps include the creation of a patient registry, integration of CAIRS and ELZA PACE into clinical practice, expansion of diagnostic infrastructure, and continuous training of ophthalmologists in modern keratoconus management.

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