Effect of Keratoconus Severity on Clinical Outcomes After Deep Anterior Lamellar Keratoplasty

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• PURPOSE: To evaluate the effect of keratoconus severity on the visual and refractive outcomes and complications after deep anterior lamellar keratoplasty (DALK).

• DESIGN: Consecutive interventional case series.

• METHODS: This study enrolled 227 keratoconus-affected eyes that underwent DALK. Amsler-Krumeich keratoconus classification was used to categorize the patients: stage II, 47 eyes; stage III, 60 eyes; and stage IV, 120 eyes. The outcome measures, including postoperative best spectacle-corrected visual acuity (BSCVA), spherical equivalent refraction, mean keratometry, keratometric astigmatism, and complications, were analyzed and compared based on keratoconus stage.

• RESULTS: The mean patient age was 27.6 ± 8.0 years, and the mean follow-up period was 38.0 ± 19.8 months. No significant differences were observed in postoperative BSCVA ($P = .55$), spherical equivalent refraction ($P = .27$), mean keratometry ($P = .09$), and keratometric astigmatism ($P = .14$) among the groups. Improvement in BSCVA were significantly greater in stage III and stage IV compared with stage II ($P = .04$ and $P < .001$, respectively). The decrease in spherical equivalent was significantly greater in stages III and IV compared with stage II ($P = .04$ and $P = .001$, respectively). Mean keratometry decreased to a greater degree in stage IV compared with stages II and III ($P < .001$ for both comparisons). The study groups were comparable with respect to intraoperative Descemet membrane perforation, the rate of successful big-bubble formation, suture-related complications, and graft rejection.

• CONCLUSIONS: DALK is a safe and effective procedure for the treatment of all stages of keratoconus. This technique of corneal transplantation is more effective in eyes with severe keratoconus compared with those with moderate keratoconus. (Am J Ophthalmol 2019;202:15–22. © 2019 Elsevier Inc. All rights reserved.)

AJO.com Supplemental Material available at AJO.com.

Accepted for publication Jan 24, 2019.

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THE MANAGEMENT OF KERATOCONUS HAS EXPERIenced great advances in recent years. Recent advances in contact lens technology and the introduction of new surgical techniques, including corneal collagen cross-linking, intracorneal ring segments, and phakic lens implants, have reduced the need for corneal transplants for keratoconus.[1,2] Therefore, corneal transplantation is indicated in advanced cases with contact lens intolerance or reduced best lens-corrected visual acuity as a result of central corneal scars.[3] Until recently, penetrating keratoplasty (PK) was the first-line corneal transplant procedure for the management of ectatic corneal disorders, including keratoconus. After the introduction of deep anterior lamellar keratoplasty (DALK) to the arsenal of corneal transplant surgery, PK is no longer the default choice of corneal transplant in patients with keratoconus.[4] DALK has gained popularity among surgeons owing to the elimination of complications encountered with full-thickness corneal transplantation, including expulsive hemorrhage and anterior synechiae as well as a less troublesome postoperative course owing to the absence of endothelial graft rejection.[4] Furthermore, the technique requires less rigid criteria for donor corneal tissue selection.[4] Several studies have demonstrated that visual acuity and refraction improve, and the long-term success rate is excellent for graft clarity following DALK for keratoconus.[5–9] However, little is known about the effect of keratoconus severity on outcomes and complications after this technique of corneal transplantation. Theoretically, advanced disease stage can negatively affect postoperative visual and refractive outcomes through different mechanisms. First, eyes with severe keratoconus and mean keratometry >60 diopters (D) may experience worse outcomes after DALK owing to interface wrinkling that develops over the visual axis.[10] Centrally located folds can affect vision quality, likely secondary to an increased amount of higher-order aberrations.[10] Second, DALK avoids an open-sky approach. Given that the recipient Descemet membrane remains intact, the sutured donor graft conforms, at least in part, to the curvature of the recipient bed. The steeper curvature of the recipient bed in more severe keratoconus can influence the graft radii of curvature, resulting in a steeper graft. Third, eyes with advanced keratoconus exhibit a large amount of astigmatism caused by a thin cornea that may

0002-9394/$36.00
https://doi.org/10.1016/j.ajo.2019.01.030

extend out to the limbus and thus cannot be totally excised. In such patients, residual astigmatism may be expected owing to the retained peripheral recipient cornea, even if an operation is performed flawlessly.

Given that new treatments permit corneal transplantation to be postponed in keratoconus, it would be interesting to evaluate whether the disease stage impacts postkeratoplasty outcomes. Therefore, the purpose of the present study was to evaluate the effect of keratoconus severity on the outcomes and complications after DALK.

METHODS

THIS CONSECUTIVE INTERVENTIONAL CASE SERIES WAS conducted on eyes with keratoconus that underwent DALK between March 6, 2004 and June 25, 2016. The Institutional Review Board, which was affiliated with Shahid Beheshti University of Medical Sciences in Tehran, Iran, approved the study, data collection, and subsequent analysis, which complied with the tenets of the Declaration of Helsinki. All participants signed informed consent after the nature and possible consequences of the study and surgery were explained.

Complete ophthalmic examinations were performed preoperatively, including uncorrected visual acuity (UCVA), best spectacle-corrected visual acuity (BSCVA), manifest refraction (when possible), slit-lamp examination, tonometry, and dilated funduscopy. Keratoconus was diagnosed based on clinical findings (Fleischer ring, stromal thinning and bulging, and Vogt striae) and keratometry and was confirmed by elevation tomography (Orbscan II system; Bausch & Lomb, Rochester, New York, USA). The Orbscan system was used to measure mean keratometry, keratometric astigmatism, and central corneal thickness.

Those who underwent corneal transplantation included patients with a corrected visual acuity of <20/40 with contact lens owing to corneal scar (74 eyes, 32.6%), inappropriate rigid gas-permeable contact lens fit (46 eyes, 20.3%), or contact lens intolerance (107 eyes, 47.1%). Preoperatively, no peripheral corneal vascularization or deep stromal scars due to previous hydrops was observed. In addition, the coexistence of other ocular diseases, such as Fuchs endothelial dystrophy, active vernal keratoconjunctivitis, cataract, retinal disorders, and glaucoma, led to patient exclusion.

All procedures were performed by a single experienced surgeon (M.A.J.) under general anesthesia using the big-bubble technique.[8] When the big bubble failed to form after several injections, the corneal stroma was manually dissected down to the Descemet membrane using a crescent knife. The recipient cornea was trephined 2.5 mm less than the vertical corneal diameter to prevent sutures from being too close to the limbus, reducing suture-related complications. A corneal graft without Descemet membrane and endothelium and oversized by 0.25 mm was sutured using a combined suturing technique. Suture tension adjustment was performed intraoperatively using a Maloney handheld keratoscope (Storz, St Louis, Missouri, USA).

Postoperatively, selective interrupted suture removal starting at least 1 month after keratoplasty was undertaken whenever keratometric astigmatism was ≥4 D, and it was continued until acceptable keratometric astigmatism (<4 D) was achieved or there were no more sutures in the steep meridian to remove. The remaining interrupted and running sutures remained in place until they were degraded or until any suture-related complications developed. All sutures were removed at the time of the final follow-up examination when postoperative UCVA, BSCVA, manifest refraction, mean keratometry, keratometric astigmatism, graft status, and intraoperative and postoperative complications were evaluated. If secondary interventions (eg, refractive surgeries) were performed, data obtained immediately before the interventions were considered for analysis.

• **STATISTICAL ANALYSIS:** Data analysis was performed using SPSS statistical software version 25 (IBM Corp, Armonk, New York, USA). The normality of continuous variables was evaluated using a Kolmogorov-Smirnov test and a Q-Q plot. Normally distributed data were presented as the mean and range. Patients were categorized according to the Amsler-Krumeich keratoconus classification, which is based on myopia, induced astigmatism, central keratometry, corneal transparency, and corneal thickness.[11] Paired *t* test was used to compare preoperative and postoperative visual acuity and refractive and keratometry readings in the whole study group as well as within each group of keratoconus severity. Univariate analyses were used to investigate associations between preoperative variables (central corneal thickness, mean keratometry, and keratometric astigmatism) and postoperative outcomes and complications. Postoperatively, UCVA, BSCVA, spherical equivalent refraction, mean keratometry, and keratometric astigmatism were compared among the groups of keratoconus severity using an analysis of variance test. The same analysis was used to compare changes in visual acuity, spherical equivalent refraction, and keratometry readings among the 3 keratoconus stage groups. The χ^2 test was used to compare the percentage of eyes with a BSCVA ≥20/40 and postoperative complications among the groups. Bonferroni correction was performed for multiple comparisons. A *P* value of <.05 was considered statistically significant. All reported *P* values were 2-sided.

RESULTS

A TOTAL OF 232 CONSECUTIVE EYES WITH KERATOCONUS were enrolled in the study. The procedure was converted intraoperatively into PK in 5 eyes owing to large tears in the Descemet membrane. These 5 eyes were excluded, and data analyses were performed in 227 eyes (122 right eyes)

of 219 patients (124 male subjects). The mean patient age was 27.6 ± 8.0 years at the time of surgery, ranging from 10 to 52 years. Preoperative central corneal thickness was 404.7 ± 62.4 μm and ranged from 284 to 543 μm.

Mean recipient and donor trephine size were 7.95 ± 0.12 mm (range: 7.5–8.5 mm) and 8.21 ± 0.12 mm (range: 7.75–8.75 mm), respectively. A big bubble was successfully formed in 182 eyes (80.2%), and predescemetic DALK was performed in 45 eyes (19.8%). The time interval from surgery to initial and complete suture removal was 9.6 ± 8.5 months (range: 1.5–18 months) and 17.1 ± 8.8 months (range: 9–53 months), respectively. The mean follow-up period was 38.0 ± 19.8 months (range: 12–89 months).

Table 1 presents data that are relevant to preoperative and postoperative visual acuity, refraction, mean keratometry, and keratometric astigmatism. As indicated, UCVA, BSCVA, spherical equivalent refraction, mean keratometry, and keratometric astigmatism significantly improved postoperatively. BSCVA ≥20/40 was observed in 15 eyes (6.6%) preoperatively. This value was 212 (93.4%) after the operation ($P < .001$).

• **COMPLICATIONS:** Double anterior chamber was observed in 8 eyes (3.5%) on postoperative day 1 owing to microperforation in the Descemet membrane. This complication resolved in all eyes after air injection into the anterior chamber. Suture-related complications included premature loosening (n = 68, 30.0%), stitch-associated abscesses (n = 44, 19.4%), and suture-tract vascularization (n = 35, 15.4%). In 48 eyes (21.2%), 1 or more episodes of subepithelial rejection occurred, which was successfully treated with 0.1% topical betamethasone over a period of 3–6 weeks. All grafts were clear at the final examination. We did not encounter interface wrinkling, graft haziness, or glaucoma in any cases.

• **CORRELATIONS:** Univariate analysis revealed that preoperative central corneal thickness had no significant correlations with the rate of successful big-bubble formation, postoperative BSCVA, mean keratometry, keratometric astigmatism, or suture-related complications (Table 2). Similarly, preoperative mean keratometry and keratometric astigmatism failed to demonstrate any significant association with postoperative outcomes or complications (Table 2). These results indicate that the preoperative corneal thickness and steepness had no influence on postoperative visual and refractive outcomes and complications.

• **COMPARISON OF OUTCOMES ACCORDING TO DIFFERENT KERATOCONUS STAGES:** There were 47 eyes (20.7%) with stage II keratoconus, 60 eyes (26.4%) with stage III, and 120 eyes (52.9%) with stage IV. The groups were comparable regarding demographic characteristics, recipient and donor trephine size, time interval from surgery to complete suture removal, and postoperative follow-up duration (Table 3). A bare Descemet membrane was successfully achieved in 38 eyes (80.9%) in the stage II group, 51 eyes (85%) in the stage III group, and 93 eyes (77.5%) in the stage IV group ($P = .48$).

Figure 1 demonstrates that BSCVA, spherical equivalent refraction, mean keratometry, and keratometric astigmatism significantly improved from preoperatively to postoperatively in the 3 groups. No significant differences in postoperative BSCVA, spherical equivalent refraction, mean keratometry, and keratometric astigmatism were noted among the groups (Table 4). BSCVA ≥20/40 was achieved in 44 eyes (93.6%) in the stage II group, 54 eyes (90%) in the stage III group, and 107 eyes (89.2%) in the stage IV group ($P = .08$). Figure 2 illustrates that the 3 groups were comparable in distribution of postoperative visual and refractive outcomes.

Table 5 compares the amount of change in BSCVA, refraction, and keratometry readings among the study groups. The improvement in BSCVA was significantly greater in stage III and stage IV keratoconic eyes compared with stage II keratoconic eyes ($P = .04$ and $P < .001$, respectively). No significant difference in the amount of improvement in BSCVA was observed between stage III and IV keratoconic eyes ($P = .12$). The decrease in spherical equivalent was significantly greater in stages III and IV compared with stage II ($P = .04$ and $P = .001$, respectively). However, this change was comparable between stages III and IV ($P = .19$). Mean keratometry decreased to a greater degree in stage IV keratoconic eyes compared with stage II and III keratoconic eyes ($P < .001$ for both comparisons). No significant difference in the change in mean keratometry was observed between the stage II and III groups ($P = .11$). No significant differences were noted among the groups with respect to changes in keratometric astigmatism ($P = .07$). No significant differences in postoperative complications were observed among the 3 groups (Table 6).

DISCUSSION

TO THE BEST OF OUR KNOWLEDGE, THIS IS THE FIRST STUDY that evaluates the effect of keratoconus severity on clinical outcomes after DALK, and only 3 previous studies compared visual outcomes after PK between early and advanced keratoconus.[12–14] Buzard and Fundingsland[12] grouped keratoconus-affected eyes that underwent PK according to preoperative mean keratometry (44–49 D, 50–59 D, and 60–90 D). No significant differences in postoperative mean keratometry and the percentage of eyes that achieved a UCVA ≥20/40 were noted among the groups.[12] In addition, Buzard and Fundingsland demonstrated no significant association between preoperative and postoperative spherical equivalent refraction, mean keratometry, and keratometric astigmatism.[12] They concluded that final visual and refractive outcomes of PK were similar for early and advanced keratoconus.[12] Liu and associates[13] divided keratoconus-affected

TABLE 1. Comparisons of Preoperative and Postoperative Visual Acuity, Refraction, Mean Keratometry, and Keratometric Astigmatism in Keratoconus Eyes That Underwent Deep Anterior Lamellar Keratoplasty

Parameters	Preoperative	Postoperative	*P* Value
Uncorrected visual acuity (logMAR)	1.32 ± 0.44 (0.40–2.40)	0.75 ± 0.43 (0.10–1.70)	<.001
Best spectacle-corrected visual acuity (logMAR)	1.25 ± 0.49 (0.18–2.40)	0.19 ± 0.11 (0.0–0.70)	<.001
Spherical equivalent refraction (D)	−10.68 ± 3.40 (−18.25 to −5.25)	−4.12 ± 3.32 (−16.0 to 4.50)	<.001
Mean keratometry (D)	53.48 ± 3.76 (48.0–59.75)	46.68 ± 2.63 (39.25–56.50)	<.001
Keratometric astigmatism (D)	5.31 ± 2.87 (0.50–13.5)	3.48 ± 1.87 (0.50–10.0)	<.001

D = diopter.
Data are mean ± standard deviation (range).

TABLE 2. Correlation Coefficients and Their Statistical Significance From Univariate Analyses of the Influence of Preoperative Variables on Postoperative Outcomes and Complications in Keratoconus Eyes That Underwent Deep Anterior Lamellar Keratoplasty

	Postoperative Outcomes				
Preoperative Variables	Successful Big-Bubble Formation	Best Spectacle-Corrected Visual Acuity	Mean Keratometry	Keratometric Astigmatism	Suture-Related Complications
Central corneal thickness	β = 0.03	r = 0.08	r = 0.05	r = −0.05	β = 0.12
	P = .50	*P* = .47	*P* = .64	*P* = .67	*P* = .22
Mean keratometry	β = 0.77	r = 0.14	r = 0.05	r = −0.09	β = −0.50
	P = .35	*P* = .09	*P* = .54	*P* = .30	*P* = .68
Keratometric astigmatism	β = −0.58	r = 0.12	r = −0.06	r = 0.03	β = −0.16
	P = .34	*P* = .15	*P* = .48	*P* = .72	*P* = .86

eyes into 1 of 4 groups according to their preoperative keratometry readings (<50 D, <60 D, ≥60 D, and unmeasurable readings). They observed no significant differences in BSCVA, central corneal power, keratometric astigmatism, surface regularity index, surface asymmetry index, spherical equivalent refraction, and refractive astigmatism after PK among the study groups.[13] Using the same grading system, Javadi et al.[14] also reported no significant differences in post-PK UCVA and BSCVA, spherical equivalent refraction, and refractive astigmatism among the groups.

Our patients were subdivided according to the Amsler-Krumeich scale, which remains the most widely used scale to grade keratoconus severity. Our results demonstrate that visual and refractive outcomes improved after DALK; furthermore, most of the eyes (93%) achieved a BSCVA ≥20/40. An important objective of the present study was to assess the visual and refractive outcomes of DALK in different stages of keratoconus. Our results demonstrated that the groups of the disease severity exhibited comparable visual and refractive outcomes, including BSCVA, spherical equivalent refractive error, mean keratometry, and keratometric astigmatism after DALK. These results indicate that the preoperative corneal steepness and refractive condition has no negative influence on visual and refractive outcomes of DALK in keratoconus. In this regard, our results are consistent with the results of the abovementioned PK studies.[12–14] In addition, we investigated the efficacy of DALK for different keratoconus stages and compared the extent of improvement in vision and refraction among the groups. Although the final outcomes were not significantly different in various groups, our results demonstrated that keratoconus-affected eyes with very steep cornea or corneal scars (stage IV) exhibited the highest gain in BSCVA, refraction, and keratometry readings. This is attributable to the fact that patients with more advanced stages of the disease had lower visual acuities and higher refractive errors preoperatively. These findings suggest that DALK is more effective for advanced keratoconus compared with moderate disease.

The present study enabled us to compare the rate of surgical complications among groups with different stages of keratoconus. One of the major problems with DALK is intraoperative Descemet membrane perforation, which may occur in 0–50% of the eyes.[15] According to published studies, this risk increases with deep corneal stromal scarring, with advanced ectasias with severe corneal thinning (<250 μm), and when the surgery is performed by an inexperienced surgeon.[16,17] Including the eyes in which the procedure was converted to PK, the rate of intraoperative Descemet membrane perforation was 5.6% in the current study, and this rate did not differ among the study groups. Similarly,

TABLE 3. Comparison of Basic Demographic Data, Trephine Size, Time Interval From Surgery to Complete Suture Removal, and Follow-up Duration After Deep Anterior Lamellar Keratoplasty Among the 3 Groups[a]

Parameters	Stage II	Stage III	Stage IV	*P* Value
Eye (right/left)	26/21	31/29	65/55	.95
Sex (male/female)	25/20	34/25	65/50	.36
Age (years)	26.0 ± 7.5 (14–46)	29.3 ± 7.8 (17–48)	27.4 ± 8.2 (10–52)	.09
Recipient trephine size (mm)	7.94 ± 0.11 (7.75–8.0)	7.96 ± 0.13 (7.75–8.50)	7.94 ± 0.12 (7.50–8.25)	.65
Donor trephine size (mm)	8.20 ± 0.12 (8.0–8.50)	8.22 ± 0.14 (8.0–8.75)	8.20 ± 0.12 (7.75–8.50)	.58
Time interval from surgery to complete suture removal (months)	18.5 ± 10.6 (10–53)	15.2 ± 8.3 (9–36)	17.6 ± 8.2 (12–48)	.12
Follow-up (months)	37.2 ± 16.1 (12–81)	36.1 ± 18.3 (12–86)	39.2 ± 21.7 (12–89)	.60

Data are mean ± standard deviation (range).
[a]Based on the Amsler-Krumeich classification for keratoconus.

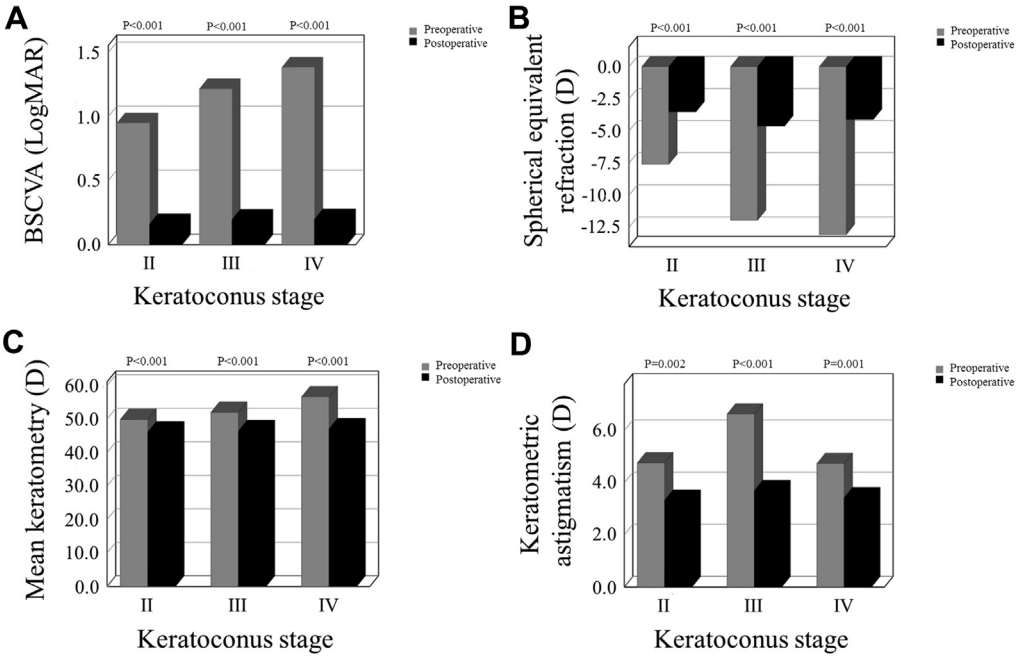

FIGURE 1. Comparisons of preoperative and postoperative best spectacle-corrected visual acuity (BSCVA;A), spherical equivalent refraction (B), mean keratometry (C), and keratometric astigmatism (D) after deep anterior lamellar keratoplasty among the 3 groups based on the Amsler-Krumeich classification for keratoconus. *P* values indicate the statistical significance of comparisons between preoperative and postoperative measurements using paired *t* test.

the rate of successful big-bubble formation was comparable among the groups, indicating that the stage of the disease had no influence on the rate of successful big-bubble formation, which is consistent with the results of a previous study.[18] In contrast, some authors reported that the severity of keratoconus can influence the rate of successful big-bubble formation.[16,19,20] Michieletto and associates[16] observed an increased rate of failure to achieve a big bubble during DALK in very thin corneas (<250 μm). Contrary to this report, some investigators reported that a big bubble is formed more frequently in eyes with advanced keratoconus compared with those with moderate keratoconus.[19,20] They attributed this finding to a weaker adhesion between Descemet membrane and posterior stroma in advanced cases of keratoconus, allowing air to reach the Descemet membrane more easily.[19,20]

Evidence suggests that keratoconic eyes with severe corneal steeping (>60 D) exhibit the worse visual acuity outcome after DALK owing to Descemet membrane folds that appear postoperatively.[10] These folds arise from the discrepancy in the size of donor and recipient tissues,

TABLE 4. Comparison of Visual and Refractive Outcomes After Deep Anterior Lamellar Keratoplasty Among the 3 Groups[a]

Parameters	Stage II	Stage III	Stage IV	*P* Value
Best spectacle-corrected visual acuity (logMAR)	0.16 ± 0.08 (0.0–0.30)	0.19 ± 0.12 (0.05–0.70)	0.20 ± 0.11 (0.05–0.60)	.55
Spherical equivalent refraction (D)	−3.52 ± 2.54 (−10.50 to 1.25)	−4.61 ± 3.93 (−16.0 to 4.50)	−4.11 ± 3.25 (−14.50 to 2.88)	.27
Mean keratometry (D)	46.10 ± 2.57 (40.25–53.50)	46.42 ± 2.30 (41.75–53.50)	47.04 ± 2.77 (39.25–56.50)	.09
Keratometric astigmatism (D)	3.33 ± 1.62 (0.50–6.50)	3.70 ± 2.27 (0.50–10.0)	3.43 ± 1.73 (0.50–9.0)	.14

D = diopter.
Data are mean ± standard deviation (range).
[a]Based on the Amsler-Krumeich classification for keratoconus.

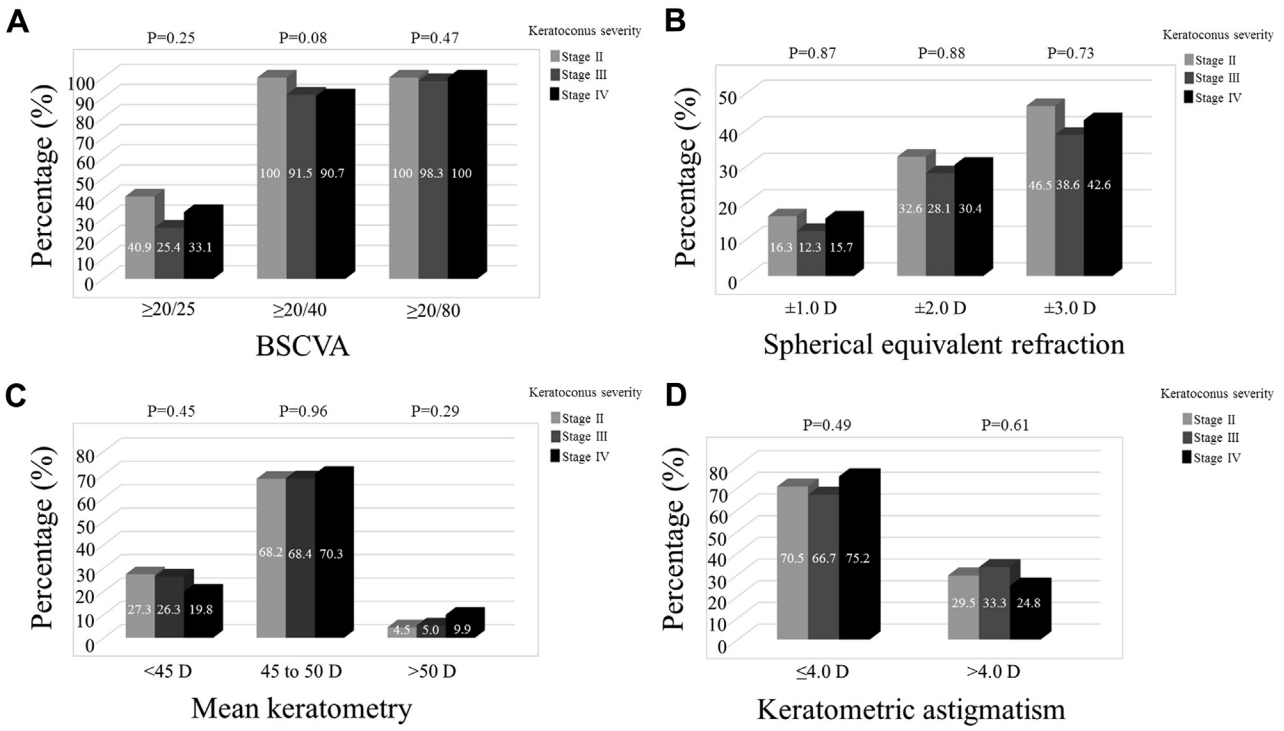

FIGURE 2. Comparisons of distribution of postoperative visual acuity, refraction, and keratometry readings after deep anterior lamellar keratoplasty among the 3 groups based on the Amsler-Krumeich classification for keratoconus. (A) Percentage of eyes with best spectacle-corrected visual acuity (BSCVA) ≥20/25, ≥20/40, and ≥20/80. (B) Percentage of eyes within ±1.0 diopter (D), ±2.0 D, and ±3.0 D of emmetropia. (C) Percentage of eyes with mean keratometry < 45 D, 45–50 D, and > 50 D. (D) Percentage of eyes with keratometric astigmatism ≤4 D and > 4 D. *P* values indicate the statistical significance of comparisons among the groups using χ^2 test.

especially when the same-size donor is transplanted. However, this complication was not encountered in the present study. Folds in the recipient Descemet membrane after DALK are generally transient and improve with time (ie, generally greater than 1 year after surgery).[10] In addition, oversizing the donor button by 0.25 mm, as performed in this study, could prevent interface wrinkling even in advanced cases.[10,21] The disadvantage of using an oversized donor, however, is the occurrence of more myopic refractive errors than when transplants are performed with the same-size donor.[22]

Suture-related complications after DALK include sterile stitch abscesses, suture tract vascularization, premature suture loosening, and cheese wiring. It has been reported that eyes with advanced keratoconus exhibit an increased rate of suture-related complications such as cheese wiring

TABLE 5. Comparison of Change (Preoperative Minus Postoperative) in Visual and Refractive Outcomes After Deep Anterior Lamellar Keratoplasty Among the 3 Groups[a]

Parameters	Stage II	Stage III	Stage IV	*P* Value
Best spectacle-corrected visual acuity (logMAR)	0.79 ± 0.40 (0.08–1.32)	1.03 ± 0.43 (0.12–1.91)	1.18 ± 0.50 (0.05–2.30)	<.001
Spherical equivalent refraction (D)	−4.25 ± 2.44 (−8.38 to 1.13)	−7.45 ± 3.92 (−13.63 to −1.50)	−10.21 ± 4.38 (−17.0 to −2.88)	.001
Mean keratometry (D)	3.85 ± 3.22 (−3.50 to 12.0)	5.52 ± 3.17 (0.0–11.75)	9.91 ± 3.79 (−6.0 to 17.50)	<.001
Keratometric astigmatism (D)	1.58 ± 2.77 (−4.0 to 7.0)	2.77 ± 3.96 (−8.50 to 11.0)	1.29 ± 3.06 (−7.0 to 8.50)	.07

D = diopter.
Data are mean ± standard deviation (range).
[a]Based on the Amsler-Krumeich classification for keratoconus.

TABLE 6. Comparison of Complications After Deep Anterior Lamellar Keratoplasty Among the 3 Groups[a]

Complications	Stage II	Stage III	Stage IV	*P* Value
Double anterior chamber	2 (4.3%)	2 (3.3%)	4 (3.3%)	.50
Stitch-associated abscesses	12 (25.5%)	11 (18.3%)	21 (17.5%)	.40
Suture-tract vascularization	8 (17.0%)	9 (15.0%)	18 (15.0%)	.88
Premature suture loosening	16 (34.0%)	12 (20.0%)	40 (33.3%)	.12
Subepithelial graft rejection	14 (29.8%)	12 (20.0%)	22 (18.3%)	.20

Data are n (%).
[a]Based on the Amsler-Krumeich classification for keratoconus.

because the thin recipient corneal rim fails to function as an effective resistant barrier to suture tension.[23,24] Unlike published results, we did not observe an association between suture-related complications and keratoconus severity in our study. We attribute this difference to the fact that a single experienced surgeon who was capable of passing sutures at the correct depth even in very thin recipient corneas performed all procedures in this study. Therefore, our results cannot be applied in settings where less experienced surgeons are performing DALK.

There is 1 limitation in this study. Our study involved a nonhomogenous distribution of eyes in different stages of keratoconus, and the group with the most severe cases contained the highest number of eyes compared with the group with moderate keratoconus. This limitation is expected, given that the eyes with the most severe disease are more likely to undergo surgery. However, our post hoc power analysis results indicated that our study had a power of 99.9% to detect the observed difference in improvement of mean keratometry among the study groups.

In conclusion, for the first time, we compared outcomes after DALK in eyes with different keratoconus stages. Our results reflect the facts that DALK is a viable option for the treatment of patients with moderate-to-severe keratoconus and that this technique of corneal transplantation is more effective in eyes with severe keratoconus. These findings support the current strategy of not performing corneal transplantation in the early stage of keratoconus and offering DALK as the final alternative when the patient becomes contact lens intolerant or visual acuity decreases owing to central corneal scars.

FUNDING/SUPPORT: THE AUTHORS REPORT NO FUNDING OR GRANT SUPPORT. FINANCIAL DISCLOSURES: NONE OF THE AUthors has any financial disclosures in this study. All authors attest that they meet the current ICMJE criteria for authorship.

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