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ORIGINAL RESEARCH

Impact of Corneal Arcus on the Sealing of Clear Corneal Incisions in Cataract Surgery

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Purpose: To determine whether the corneal arcus affects sealing of the clear corneal incision (CCI) in cataract surgery.

Patients and Methods: This study was a retrospective cohort study. The patients were divided into two groups based on whether stromal hydration was required to close the CCI. The corneal arcus was classified according to its degree as none, partial (if corneal arcus < 180 degrees), and circumferential (if corneal arcus ≥ 180 degrees). Multiple logistic regression was conducted to identify independent variables such as age at cataract surgery, sex, laterality, surgical time, and degree of corneal arcus associated with CCI sealing.

Results: Among a total of 83 eyes of 83 patients, a partial corneal arcus was found in 34 eyes (41.0%) and a circumferential arcus in 33 eyes (39.8%). Multiple logistic regression analysis revealed that the need for stromal hydration in wound sealing increased with surgical time (OR = 1.7313, 95% CI = 1.1500–2.6063, p = 0.0085) and decreased with severity of corneal arcus (partial, OR = 0.2901, 95% CI = 0.0451-–1.8665, p=0.1926; circumferential, OR = 0.0590, 95% CI = 0.0074–0.4722, p = 0.0085); age was not associated (OR = 0.9790, 95% CI = 0.9121–1.0507, p = 0.5555).

Conclusion: Eyes with corneal arcus required less stromal hydration. This finding suggests that corneal arcus may increase CCI sealing in cataract surgery.

Plain Language Summary: Corneal arcus is found in elderly persons, but its significance is unknown. Eyes with corneal arcus required less stromal wound hydration in cataract surgery. Corneal arcus may contribute to the closure of a clear corneal incision.

Keywords: clear corneal incision, cataract surgery, corneal arcus

Introduction

A clear corneal incision (CCI) has been commonly used as the main incision in cataract surgery because of its many advantages, such as faster visual rehabilitation, less damage to the conjunctiva, less induced astigmatism, minor post-operative discomfort, and shorter surgical time.[1–3] In CCI, establishing a watertight incision at the end of surgery is essential to prevent postoperative incision leakage and related complications such as hypotony, dislocation of intraocular lens (IOL), and endophthalmitis.[2,4]

CCI sealing is affected by various factors, such as wound architecture, incision width, surgical time, the time of ultrasonography, Descemet detachment, and surgical skill.[2,5–9] The stromal hydration, typically performed when incision leakage is observed,[2] is significantly more common in junior-operated eyes than in senior-operated eyes.[10] Moreover, corneal biomechanical properties also affect the sealability of CCI. Hyperopic LASIK, which causes peripheral thinning, can weaken the cornea and affect wound sealing in patients with CCI during cataract surgery.[2,11] In pediatric cataract surgery, suturing all incisions is recommended because of low rigidity and tissue elasticity in children, which leads to leakage of the wound.[12]

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Corneal arcus is a common ophthalmological finding characterised by bilateral grey-white-yellowish opacity appearing in the corneal periphery, separated from the limbus by a clear corneal zone.[13–15] It is an extracellular deposit in the corneal stroma, not associated with tissue breakdown. The deposits are composed of cholesteryl ester-rich lipid particles, primarily from low-density lipoproteins (LDL), phospholipids and triglycerides.[16,17] Apo B, the major LDL apoprotein is present in the corneal arcus.[16,18]

The presence of a corneal arcus is associated with male sex, older age, and thinner corneas.[14] Moreover, the corneal arcus alters corneal biomechanical properties,[19] suggesting it may affect the sealability of the CCI, which is affected by corneal biomechanical properties; however, this association has not been examined yet. A retrospective cohort study was conducted to determine whether the corneal arcus affects CCI sealing.

Materials and Methods

Study Population

This retrospective cohort study included all consecutive adult patients who underwent phacoemulsification and IOL implantation at Ichinoseki Hospital between 1 January 2019 and 30 June 2019. Only one eye per patient was included in this study. For patients who underwent bilateral cataract surgery during the study period, the eye operated on first was enrolled. We excluded eyes with a history of uveitis, glaucoma, corneal dystrophies, severe corneal surface disease, ocular allergies, or any other cause of previous ocular surface inflammation, and previous ocular surgeries, as well as those that experienced any intraoperative complications such as vitreous loss and dehiscence of the zonule.

Ethical approval was obtained from the Institutional Review Board of Iwate Medical University (MH2023-114). The committee at Iwate Medical University determined that patient informed consent was not necessary for the use of their medical record data, in accordance with the Japanese Guidelines for Epidemiologic Study issued by the Japanese Government. No identifiable data were used. This study adhered to the tenets of the Declaration of Helsinki.

Clinical Assessment and Data Collection

Medical records were analysed for age at the time of cataract surgery, sex, laterality, surgical time, and degree of corneal arcus. The corneal arcus was evaluated by an ophthalmologist using photographs from a surgical video captured at the beginning of the procedure. The corneal arcus was classified according to its degree, as none, partial (if the corneal arcus < 180 degrees), and circumferential (if the corneal arcus ≥ 180 degrees).[20] The surgical time was defined as the time until the intraocular lens was inserted. This was to eliminate the effects of the time taken to check that the wound had closed and the time taken for additional procedures if the wound had not closed properly.

Surgical Procedure

All the surgeries were performed by the same experienced surgeon (K.H). The surgeon created a one-sided port with a 22.5- degree slit knife (MANI Inc., Utsunomiya, Tochigi, Japan) at the 3-o'clock meridian. A 2.4-mm superior CCI was performed using a 2.4-mm steel keratome blade (MANI, Inc). After phacoemulsification and cortical cleanup using Centurion phacoemulsification machine (Centurion ® Vision System, Alcon, USA), a preloaded 1-piece foldable acrylic intraocular lens (AcrySof IQ in UltraSert, model AU00T0, ALCON) was inserted via CCI. After removing the ophthalmic viscosurgical device, a balanced salt solution was injected through the side port and CCI to reform the anterior chamber, aiming for a slightly higher IOP. To confirm wound sealing, we checked for leakage from the wound using the methods reported by Chee et al.[21] Briefly, the movement of the anterior chamber particles was visually checked. In the case of leakage, the particles could be observed tracking toward the leaking incision. Next, pressure was applied to the cornea to check the approximate intraocular pressure and anterior chamber stability. Finally, the 5% povidone-iodine solution was applied to the cornea. If clear liquid flowed out of the incision and iodine was washed away from the wound, it was considered inadequately sealed. Corneal stromal hydration was performed when wound closure was inadequate. After hydration, the wound sealing was rechecked in the same manner.

Statistical Analysis

Continuous variables are presented as mean ± standard deviation (SD). Unpaired t-tests and Jonckheere-Terpstra trend test were used. Categorical variables are presented as absolute and relative frequencies (%) and were analysed using the chi-square test and Cochran-Armitage test to assess incidence rates. Multiple logistic regression was conducted to identify independent variables associated with the need for stromal hydration at CCI closure. Statistical significance was set at $p < 0.05$. Data were processed using statistical analysis software (Bell Curve for Excel; Social Survey Research Information Co., Ltd., Tokyo, Japan).

Results

A total of 83 eyes of 83 patients met the inclusion criteria, and their medical records were analysed (no patients met the exclusion criteria). The baseline characteristics are summarised in Table 1. Of 83 eyes, partial and circumferential corneal arcus were found in 34 (41.0%), 33 (39.8%) eyes, respectively, totalling 67 eyes with corneal arcus. The mean age was higher in the group with more severe corneal arcus ($p<0.001$; Table 2).

The patients were divided into two groups according to CCI sealing with or without stromal hydration. Of the 83 eyes, 48 required stromal hydration to obtain CCI sealing and 35 did not. The clinical characteristics of the two groups are summarised in Table 1. No significant differences were found between the two groups in terms of sex, laterality, or IOL power. However, patients in the group without stromal hydration were older ($p = 0.0323$) and had a more severe

Table 1 Patient Characteristics

Variables	All Patients (n=83)	Stromal Hydration (-) (n=35)	Stromal Hydration (+) (n=48)	*p-value*
Age, years	76.2 ± 9.9	78.9 ± 6.5	74.2 ± 11.4	0.0323[a]
Sex, male	34	17	17	0.2288[b]
Right eyes	39	20	19	0.1134[b]
Corneal arcus				<0.001[c]
None	16	2	14	
Partial (<180°)	34	11	23	
Circumferential (≥180°)	33	22	11	
IOL power, D	20.9 ± 3.3	20.9 ± 3.5	20.8 ± 3.2	0.8913[a]
Surgery time[d], min	4.6 ± 1.4	4.4 ± 1.1	4.8 ± 1.6	0.1927[a]

Notes: [a]*t*-test, [b]χ^2-test, [c]Cochran-Armitage test, [d]time until the intraocular lens was inserted.

Table 2 Status of Corneal Arcus

Variables	All Patients (n=83)	Corneal Arcus None (n=16)	Partial (<180°) (n=34)	Circumferential (≥180°) (n=33)	*p*-value
Age, years	76.2 ± 9.9	65.8 ± 12.1	76.7 ± 7.1	80.7 ± 7.1	<0.001[a]
Sex, male	35	5	11	18	0.1235[b]

Notes: [a]Jonckheere-Terpstra trend test, [b]χ^2-test.

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Table 3 Associations Between Stromal Hydration Sealing and Age, Sex, Operated Eye, Degree of Corneal Arcus, IOL Power, and Surgery Time Multiple Logistic Regression Analysis

	Odds Ratio	95% CI	*p-value*
Age	0.9790	0.9121–1.0507	0.5555
Sex, male	0.7512	0.2481–2.2739	0.6126
Right eyes	0.4057	0.1407–1.1701	0.1412
Corneal arcus			
None	Reference		
Partial (<180°)	0.2901	0.0451–1.8665	0.1926
Circumferential (≥180°)	0.0590	0.0074–0.4722	0.0085
IOL power	1.0337	0.8764–1.2193	0.6937
Surgery time[a]	1.7313	1.1500–2.6063	0.0085

Note: [a]Time until the intraocular lens was inserted.

corneal arcus (p<0.001). Moreover, although not statistically significant, the mean surgical time in the group without stromal hydration was slightly shorter than that with stromal hydration (4.4 ± 1.1 mins vs 4.8 ± 1.6 mins; p=0.1235).

Multiple logistic regression analysis (Table 3) revealed that the need for stromal hydration in wound sealing increased with surgical time (OR = 1.7313, 95% CI =1.1500–2.6063, p = 0.0085) and decreased with severity of corneal arcus (partial, OR = 0.2901, 95% CI = 0.0451–1.8665, p<0.1926; circumferential, OR = 0.0590, 95% CI = 0.0074–0.4722, p =0.0085), although the patient's age was unrelated (OR = 0.9790, 95% CI = 0.9121–1.0507, p = 0.5555).

Discussion

In this retrospective cohort study, multiple logistic regression analysis revealed that the rate of stromal hydration of the CCI was related to the severity of corneal arcus and surgical time. Conversely, the rate of stromal hydration was not related to patient age, sex, or IOL power. With regard to the surgical time, cataract surgeries with prolonged surgical times or increased manipulation through the incision may weaken the CCI and lead to leakage. The harder the lens nucleus, the more ultrasound energy could potentially damage the cornea.[2,7] Incision-related Descemet membrane detachment is related to the time of ultrasonography, equivalent mean ultrasonic power, and surgeon`s skill.[8,9] These might damage the architecture of CCI and affect the sealing of CCI.

On the other hand, there is no known explanation for the association of corneal arcus with the CCI sealing. However, corneal hysteresis (CH) is a biomechanical property of the cornea related to its viscoelasticity, where lower CH indicates a stiffer cornea.[22] Corneal arcus alters corneal biomechanical properties, with CH being lower in corneas affected by corneal arcus than those without it.[19] CH is positively linked to central corneal thickness (CCT).[22] Two large population-based studies have revealed that the presence of a corneal arcus is associated with a thinner cornea.[14,23] These suggest that a cornea with a corneal arcus is stiffer than one without a corneal arcus. The CCI of a stiffer cornea may resist deformity and maintain wound sealing. Although the CH and CCT were not examined in this study, measuring the CH and CCT may be important to reveal the relationship between the sealing ability and corneal arcus.

CH has been reported to decrease with age,[24] which may suggest that the cornea of older patients is stiffer and more resistant to deformities. In the present study, the group without stromal hydration was older than that with stromal hydration. These results suggest that age is an important factor in wound sealing. However, multiple logistic regression analysis revealed that the rate of stromal hydration was independent of age and dependent on the corneal arcus. Moreover, the CCT has been reported to decrease with age.[25] However, a population-based cross-sectional study revealed that the corneal arcus was associated with a lower CCT independent of age.[23] In this study, the mean age was higher in the group with a more severe degree of corneal arcus, which is consistent with the results of previous studies.[26] These

results suggest that corneal arcus is more precisely related to changes in corneal biometrics than age. Even if the patients are older, if they do not have corneal arcus, stromal hydration may be needed.

This study had certain limitations. This study was retrospective, and there may have been some bias due to the data from a single hospital and a single surgeon. The sample size is modest for subgroup analysis. Collecting larger sample sizes enhances the reliability of findings and power for detecting differences between subgroups. Because ultrasound energy and equivalent mean ultrasonic power are related to damage the CCI, these variables and cataract grade instead of surgical time may better demonstrate the relationship between surgery-induced corneal damage and wound sealing. In this study, CH and CCT were not measured, limiting insight into biomechanical implications. Future studies should measure CH and CCT to directly evaluate their role in wound sealing and correlate these parameters with the degree of corneal arcus.

Conclusion

In this study, multiple logistic regression analysis revealed that the rate of stromal hydration in CCI was related to the severity of corneal arcus. Eyes with corneal arcus required less stromal hydration. Corneal arcus may affect CCI sealing during cataract surgery.

Author Contributions

Mizuho Yoshida and Kouhei Hashizume contributed equally to this paper. All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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