学位論文の要旨

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学位論文名	Measurement of Force Required for Anterior Displacement of Intraocular Lenses and Its Defining Parameters
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INTRODUCTION

Soft acrylic intraocular lenses (IOLs) that entered the market in the early 1990s are the major IOL material used currently. The roles of IOL design on development of posterior capsular opacity (PCO) has been studied extensively. Current one-piece soft acrylic IOLs have adopted the sharp edge design to achieve a sharper capsular bend, prompt capsular adhesion, and a greater PCO preventive effect. A bulky haptic, such as those of the foldable one-piece IOLs can hamper capsular bend formation and adhesion. The current designs of one-piece IOLs are associated with significantly less dysphotopsia than three-piece IOLs which has thin haptics. Haptic angulation may have a greater effect on the amount and scatter of postoperative IOL movement and resulting deviations from the calculated target refraction. Thus, one-piece, soft-acrylic IOLs with a sharp edge design and bulky non- or small-angulated haptics becomes popular IOLs used during current cataract surgeries.

During or immediately after cataract and glaucoma filtration surgeries and vitreous surgery with gas tamponade, the IOL position is likely to become unstable due to the pressure difference between the anterior chamber and vitreous cavity. Unstable position of IOL can associate with shallow anterior chamber depth that may lead to corneal endothelial damage. Although the current one-piece IOLs are similar at a glance, the details of their designs and material hardness differ. In the current study, we used six different one-piece IOL models and measured the force required to displace the IOLs from the vitreous cavity side to the anterior chamber side as a measure of stability against the pressure gradient between the front and back of the IOL. We also performed three measurements to elucidate the factors that determine the IOL displacement force.

MATERIALS AND METHODS

2.1. IOLs

In this study, 18 IOLs representing six IOL models were used. All IOL models were single-piece, soft acrylic, with a 6.0-mm optic diameter and +20 diopter (D) power. The HOYA 255 had a 12.5-mm diameter and a 5 ° haptic angle. The other five IOL models had 13-mm diameters and 0 ° haptic angles.

2.2. Experimental Settings

2.2.1. IOL Displacement Force

To estimate the intraocular stability of IOL against its anterior displacing effect from the vitreous cavity, the force required to anteriorly displace the IOLs was measured. The IOLs were set in a fixture and immersed in water at a temperature of 35 °C. The IOLs were pushed from the posterior side by a pusher until they moved 1 mm anteriorly. The force required for anterior IOL displacement was monitored using a micro-load measuring system connected to a pusher at 0.1-second increments.

2.2.2. IOL Hardness

The IOL hardness was measured using the automatic hardness tester at room temperature. The IOLs were pushed vertically with constant pressure by an indenter for 30 seconds, the IOLs were released, and the amount of rebound of the IOL material was measured for 5 seconds.

2.2.3. Haptics Junction Area

Digitized photographs of the haptics/optics junction area were obtained using a multi-angle stereo microscope and digital camera system from two angles. Using equipped software, the string length and thickness were measured at the haptics/optics junction. The arc length of the junction was calculated from the measured string length and IOL radius of 3 mm, and the area of the haptics junction was estimated by multiplying the arc length and lens thickness.

2.2.4. Posterior IOL Bulge

The IOL was set in a clear cylinder with a 10-mm inner diameter according to the posterior side of IOL was to be top. The digitized pictures then were obtained using a multi-angle stereo microscope system from a side of the IOL, and the distance from the bottom of the cylinder and anterior surface was measured as the posterior IOL bulge.

RESULTS AND DISCUSSION

The statistical comparisons showed that the KOWA YP2.2 required significantly greater force than the HOYA XY1, HOYA 255, Alcon SN60WF, and Nidek NS60YG; the J&J ZCB00V required greater force than the HOYA XY1 and HOYA 255; and the Nidek NS60YG required greater force than the HOYA 255.

To assess the factors that may determine the IOL displacement force, we predicted three parameters. We estimated them in each IOL model. Using a linear regression model, the haptics junction area was correlated positively with the IOL displacement force, while the correlations of the other two parameters with the IOL displacement force were not significant. After adjusting for confounding effects among the three parameters using a mixed-effects regression model, the haptics junction area again was correlated significantly with the IOL displacement force, while the IOL hardness and posterior IOL bulge remained statistically non-significant.

We measured the force required for anterior displacement of IOLs and its three defining parameters among the currently available major IOL models. The results showed that the forces

differed markedly depending on each IOL model, and the haptics junction area was the major determinant of the force. Since the introduction of IOLs, their intraocular stability has been discussed.

The anterior displacement force of the KOWA YP2.2 was three times higher than that of the HOYA 255; thus, the forces are widely distributed. Although the hardness values of the HOYA 255 and XY1 differed by a factor of 2, the anterior displacement forces of these IOLs were equivalent; the Nidek NS60YG was by far the hardest IOL but did not require the greatest force. Thus, the IOL hardness is unlikely the sole determinant of the IOL displacement force. To the best of our knowledge, the posterior IOL bulge and junction area have not been described previously as major parameters of the IOL design. The IOL bulge was greatest with the Nidek NS60YG but was 0 μm with the HOYA XY1, HOYA 255, and Alcon SN60WF. The IOL size and haptic angle did not differ greatly among these IOLs; thus, factors other than the IOL size and haptics angle affect the amount of posterior IOL bulge, but these remain to be elucidated. The current results suggested that the IOL bulge is not the sole determinant of the IOL displacement force. The haptics junction area of the KOWA YP2.2 is 3 times greater than that of the HOYA XY1 and HOYA 255; the distributions of the haptics junction areas were well correlated with the distribution of the IOL displacement forces; thus, the results indicated that the anterior displacement forces can be predicted by the IOL junction areas.

It is important to note that the IOL displacement force is the measure of the biomechanical features of IOLs, thus the clinical significance of its role remains to be clarified.

CONCLUSION

In conclusion, the forces required to displace IOLs anteriorly differed among modern one-piece soft acrylic IOLs, and the optics-haptics junction area is a major determinant of the force.