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Pathologic comparison of asymmetric or sulcus fixation of 3-piece intraocular lenses with square versus round anterior optic edges

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Abstract

Objective—To evaluate pathologic findings of 3-piece intraocular lenses (IOLs) with asymmetric or sulcus fixation in pseudophakic cadaver eyes, comparing IOLs with square or round edges on the anterior optic surface.

Design—Comparative case series with pathology.

Participants—661 pseudophakic cadaver eyes obtained from eye banks within the United States, implanted with different IOLs

Methods—Anterior segment scanning of whole eyes with a high-frequency ultrasound system, or with a high-resolution anterior segment magnetic resonance imaging, followed by gross examination. Selected eyes were processed for complete histopathologic analysis.

Main Outcome Measures—Findings from imaging, gross, and histopathologic evaluation that could be related to out-of-the-bag fixation of the lenses.

Results—Out of 661 pseudophakic cadaver eyes obtained, 13 had 3-piece hydrophobic acrylic IOLs with anterior and posterior square optic edges, and 14 had 3-piece lenses with anterior round edges (13 silicone lenses, and 1 hydrophobic acrylic lens) without symmetric in-the-bag fixation. These 27 selected eyes were processed for complete histopathologic analysis. Gross findings in both groups were composed of IOL decentration and tilt, pigmentary dispersion within the anterior segment and on the IOL surface, and iris transillumination defects. Histopathology of the 14 eyes with 3-piece IOLs with round anterior optic edges showed mild focal disruption of the iris

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Presented as a paper at the Annual Meeting of the American Academy of Ophthalmology (AAO), Chicago, IL, November 13, 2012. This study has also been presented in part at the 2012 meetings of the American and European Societies of Cataract and Refractive Surgery (ASCRS and ESCRS).

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pigmented layer, and loop protrusion/erosion in the ciliary sulcus. Additional changes observed in the 13 eyes with square anterior optic edge IOLs included iris changes such as vacuolization, disruption and loss of the pigmented epithelial layers, iris thinning and atrophy, synechiae, and pigmentary dispersion within the trabecular meshwork. One eye also exhibited initial signs of optic nerve disc cupping.

Conclusion—In this series, pathologic findings were more severe in eyes implanted with 3-piece IOLs with square anterior optic edges, suggesting that IOLs with round anterior edges are more suitable for sulcus fixation.

Introduction

Different studies have already described the advantages of symmetric in-the-bag posterior chamber intraocular lens (IOL) fixation, with a complete coverage of the optic periphery by the capsulorhexis edge.^{1–5} In surgery complicated by a posterior capsular rupture, one of the options is fixation of a posterior chamber IOL in the ciliary sulcus, provided sufficient peripheral capsular support is still present.⁶ It is usually recommended to implant an IOL having a smooth anterior optic surface with rounded edges in cases of sulcus fixation.⁷ This would minimize the possibility of iris chafing and subsequent uveitis-glaucoma-hyphema syndrome, should any posterior iris contact occur.^{8–13}

Studies based on clinical series have described pigmentary dispersion resulting from sulcus fixation of 3-piece lenses with a square edge on the anterior optic surface.^{14,15} In other studies, however, excessive interaction between the anterior square optic edge and the posterior iris surface was not found.^{16,17} To the best of our knowledge, there is no study comparing the outcomes of sulcus fixated 3-piece lenses with square or round anterior optic edges. The objective of this study was therefore to provide pathologic findings of human donor eyes with asymmetric or sulcus fixation of 3-piece square-edged IOLs and compare them to those from eyes with round-edged 3-piece IOLs. This is a follow up of a previously published study, which provided pathologic evidence of complications related to out-of-the-bag fixation of 1-piece or 3-piece hydrophobic acrylic IOLs with anterior and posterior square optic edges.¹⁸

Materials and Methods

This study was performed in cooperation with the San Diego Eye Bank and other eye banks nationwide; therefore, only Food and Drug Administration (FDA) approved IOLs were included. The employees of the participating eye banks were instructed to attempt to obtain the date of the implantation, generally attained through interaction with the donor family. Upon enucleation, the eye banks were instructed to place the whole globes in 10% neutral buffered formalin in order to prevent significant distortion of their geometry secondary to postmortem changes.

Once available in our laboratory, the whole eyes underwent anterior segment scanning with a high-frequency ultrasound system with digital enhancement (Artemis, ArcScan Inc., Morrison, CO). The system uses a broad-band 50 MHz transducer (bandwidth 10 to 60 MHz), which sweeps in a reverse arc high-precision mechanism to acquire B-scans. Each scan sweep takes 0.5 seconds and is designed to follow the contours of the cornea, iris and ciliary body structures. This ultrasound provided imaging of the entire anterior segment of the eye via a noncontact, immersion technique.^{19,20}

Pseudophakic donor eyes were also obtained from MRI Research, Inc. Upon enucleation, the whole eyes underwent high-resolution anterior-segment magnetic resonance imaging (MRI) using a clinical magnetic resonance imager (1.5 Tesla, General Electric, Waukesha,

WI), a purpose-designed eye-imaging magnetic resonance receiver coil (MRI Research, Inc.), and a standard spin-echo radiofrequency pulse sequence (T1-weighted, single echo, multi-slice).^{21,22} The eyes were then fixated in formalin, and forwarded to the Moran Eye Center. Information such as the position of the implant in relation to intraocular structures, tilt, and decentration was obtained from ultrasound and MRI evaluation before any disruption was caused by sectioning.

The eyes were then bisected coronally just anterior to the equator. Gross examination of the anterior segment was done from the posterior aspect (Miyake-Apple view) to assess IOL fixation (e.g., bag-bag, bag-sulcus, sulcus-sulcus). Eyes containing 3-piece hydrophobic acrylic IOLs with a square edge on the anterior and posterior optic surfaces (control eyes) or 3-piece hydrophobic acrylic or silicone IOLs with a rounded anterior optic edge (study eyes), without symmetric in-the-bag fixation were selected for further analyses. IOL tilt was qualitatively scored by ultrasound or MRI evaluation as none, mild, moderate and severe, according to the angle formed by the plane of the IOL optic in relation to the plane of the ciliary sulcus. IOL centration was also qualitatively scored by ultrasound or MRI, and gross evaluations, in relation to the ciliary sulcus in each eye. Other aspects analyzed under gross examination were the presence of posterior capsular rupture, as well as pigmentary dispersion and iris transillumination defects (which were qualitatively scored from none to severe). After gross examination and scoring, anterior and posterior segments of each eye were processed for complete histopathologic evaluation. Following dehydration and embedding in paraffin, the eyes were sectioned and stained with hematoxylin and eosin (H&E) and Masson's trichrome stains. Multiple 3 micron-thick sections of each eye were then examined under a light microscope (Olympus, Optical Co. Ltd., Japan) for signs of chronic inflammation, pigmentary dispersion, glaucoma, and cystoid macular edema. Photomicrographs were taken for documentation.

Results

661 pseudophakic cadaver eyes sent from eye banks nationwide or from MRI Research, Inc. to our laboratory were examined. From this series, we identified asymmetric or sulcus fixation in 13 eyes implanted with 3-piece hydrophobic acrylic (AcrySof; Alcon Laboratories) lenses, which have square edges on the anterior and posterior optic surfaces (control eyes). Table 1 shows characteristics of these 13 eyes, including findings from ultrasound/MRI and gross examinations. The mean age of the donors was 86.6 $\pm$ 6.0 years, ranging from 74 to 97 years. Information on the time from cataract surgery to death was available for 4 eyes (mean: 64 $\pm$ 37.3 months; range: 35 to 114 months). All 13 eyes had some degree of IOL decentration in relation to the ciliary sulcus. Six eyes had mild, three had moderate, and four had severe IOL decentration. Imaging of the anterior segment via ultrasound or MRI revealed that 10 of the 13 eyes were found to have IOL tilt. Four eyes had mild, two had moderate, and four had severe tilt. Table 1 also shows that eleven of the thirteen eyes had a posterior capsule rupture. Other signs of complicated surgery included zonular desinsertion, and anterior capsular tears. All thirteen eyes had some degree of pigment dispersion. Three eyes had mild, nine had moderate, and one had severe pigment dispersion. Transillumination defects were also seen in all thirteen eyes. Three eyes had mild, seven had moderate, and three had severe transillumination defects. More significant defects were especially evident in relation to the side of the IOL fixated in the sulcus (in asymmetric fixation cases).

Out of the 661 pseudophakic cadaver eyes analyzed, 14 had 3-piece lenses with anterior round edges (13 silicone lenses, and 1 hydrophobic acrylic lens) with asymmetric or sulcus fixation (study eyes). Table 2 shows characteristics of these 14 eyes. The mean age of the donors was 81.4 $\pm$ 11.1 years, ranging from 54 to 96 years. Information on the time from

cataract surgery to death was available for 7 eyes (mean: 54 $\pm$ 55.7 months; range: 3 to 174 months). All 14 eyes had some degree of IOL decentration. Five had mild, six had moderate, and three had severe decentration. IOL tilt was present in 9 of the 14 eyes with four having mild, four moderate, and one with severe tilt (Figure 1). All 14 of these eyes had posterior capsular rupture. Other signs of complicated surgery in this group of eyes also included zonular desinsertion, and anterior capsular tears. Pigment dispersion was mild in four eyes, moderate in eight, and severe in two eyes. Iris transillumination defects were mild in four eyes, moderate in eight, and severe in two eyes (Figure 2).

Gross examination findings were semi quantitatively described from 0 to 3 (none, mild, moderate, severe) for comparison between both groups of lenses using the two-tailed, Student's t-test to determine any significant difference. Gross/macrosopic decentration ($p=0.97$), tilt ($p=0.28$), pigment dispersion ($p=0.96$) and iris transillumination defects ($p=0.59$) did not appear to be statistically different between both groups.

Light microscopic examination of multiple sections from each of the 13 eyes implanted with 3-piece AcrySof IOLs (with anterior square optic edges) showed pigment dispersion, ranging from mild to severe. Pigment was observed in the trabecular meshwork, peripheral cornea, and on the lens capsule. All eyes exhibited changes at the level of the iris, including vacuolization of the pigmented layer on the posterior iris surface (which is consistent with chronic irritation), mild to severe disruption/loss of the pigmented layer, iris thinning, as well as iris atrophy. Disruption/loss of the iris pigmented layer was seen at the pupil border, iris root, and midperiphery. Additional histopathologic findings included peripheral anterior synechia, posterior synechia, and loop erosion through the sulcus. One of the eyes also exhibited initial signs of optic nerve disc cupping. No signs of cystoid macular edema were observed.

Light microscopic examination of multiple sections from each of the 14 eyes with 3-piece hydrophobic acrylic or silicone IOLs with anterior round optic edges showed mild focal disruption of the iris pigmented layer, generally observed at the pupil border and iris root. One eye exhibited minimal pigment dispersion into the trabecular meshwork. Additional histopathologic findings included variable degrees of loop erosion through the sulcus, including a case with complete encapsulation of the loop (Figures 3 and 4). No signs of cystoid macular edema were observed.

Discussion

In a previous study, we provided pathologic evidence of complications related to out-of-the-bag fixation of 1-piece or 3-piece hydrophobic acrylic IOLs with anterior and posterior square optic edges.¹⁸ The methodology used was the same as in the current study; basically, pseudophakic cadaver eyes obtained from eye banks within the United States, implanted with different IOLs were evaluated. Anterior segment scanning of whole eyes with the same high-frequency ultrasound system or the high-resolution anterior segment magnetic resonance imaging was done, followed by gross examination. Selected eyes were processed for complete histopathologic analysis; some of them were explanted before histopathology to allow for direct light microscopic evaluation of the lenses. We were looking for any findings from imaging, gross, and histopathologic evaluation that could be related to out-of-the-bag fixation of the lenses.¹⁸

18 eyes with the targeted lenses exhibited asymmetric or sulcus IOL fixation (six 1-piece, and twelve 3-piece IOLs). They underwent complete histopathologic evaluation and were compared to the contralateral eyes with symmetric in-the-bag IOL implantation. Pathological findings were composed of IOL decentration and tilt, pigmentary dispersion

within the anterior segment and on the IOL surface, iris transillumination defects, iris changes including vacuolization/disruption/loss of the pigmented layer, iris thinning, and iris atrophy, as well as synechiae and loop erosion in the case of 3-piece lenses. Findings were more significant in comparison with the control contralateral eyes and were particularly evident in relation to the sulcus-fixated haptic in the case of 1-piece lenses.¹⁸

The majority of the eyes with 3-piece lenses in the previous study showed signs of complicated surgery; therefore all pathologic findings in those cases could not be strictly attributed to the out-of-the-bag fixation of the IOL.¹⁸ In order to further understand these findings we compared the previous series of 3-piece lenses (square anterior and posterior optic edges) to a series of eyes with out-of-the-bag fixation of 3-piece IOLs that had round anterior optic edges and similar signs of complicated surgery (e.g., posterior capsule rupture). Since the previous study, 1 additional eye with a 3-piece hydrophobic acrylic lens with square anterior and posterior optic edges was identified. Therefore, in the current study we compared 13 eyes with square anterior edge lenses to 14 eyes with round anterior edge lenses.

In both groups, more significant defects were especially evident in relation to the side of the IOL fixated in the sulcus (in asymmetric fixation cases). Gross/macrosopic decentration, tilt, pigment dispersion, and iris transillumination defects was statistically similar between both groups. The gross pathologic findings observed could have been in a great extent related to the complicated surgery itself. As an example, Figure 2B (eye with a round anterior edge lens) shows that the pattern of the iris transillumination defect could correspond to the area of insertion of the phacoemulsification handpiece. The same pattern was also found in the series of eyes with 3-piece lenses and square anterior optic edges. However, the most striking findings in our current study are related to analyses of the histopathologic sections from the eyes. The severity of the iris changes was more prominent in relation to 3-piece lenses with square anterior optic edges. Also, all eyes with these lenses had pigmentary dispersion within the trabecular meshwork, in comparison to only 1 eye in the group of lenses with round anterior edges. This indicates continuous trauma to the posterior surface of the iris, likely related to rubbing by the square optic edge, although the possibility of pre-existing pigmentary dispersion syndrome prior to cataract surgery cannot be ruled out.¹⁸

The finishing of the square edges of the 13 3-piece lenses analyzed in this study has an unpolished or “textured” appearance, which was found to improve postoperative glare phenomena.²³ Some reports in the literature describe a spectrum of disorders that include iris transillumination defects, and pigment dispersion with or without elevation of intraocular pressure (IOP) in association with 3-piece AcrySof lenses, in a piggyback configuration or standard sulcus fixation.^{14,15,24–26} In piggyback implantation, fixation of the anterior lens in the sulcus has been recommended to prevent interlenticular opacification.²⁷ However, a previous publication from our laboratory described a case of pigmentary dispersion syndrome resulting from secondary piggyback implantation of a low power 3-piece hydrophobic acrylic, square-edged IOL in the ciliary sulcus (AcrySof MA60MA; +5 D).²⁴ Chang and Lim,²⁶ as well as Iwase and Tanaka,²⁵ have also described cases of pigmentary dispersion syndrome with the same 3-piece hydrophobic acrylic lens implanted in a piggyback configuration.

Wintle and Austin reported a case of pigmentary dispersion syndrome one month following implantation of a three-piece hydrophobic acrylic lens (AcrySof IOL model MA60BM, 6.0 mm optic, 13.0 mm overall length) placed electively in the ciliary sulcus following a posterior capsule tear.¹⁴ In that patient, IOP control was achieved pharmacologically, with eventual discontinuation of treatment and stabilization of IOP after 6 months of therapy,

though hyperpigmentation of the trabecular meshwork continued. A similar case was also described by Almond et al.¹⁵

Other studies did not show excessive interaction between these 3-piece, sulcus-fixed lenses and the posterior iris surface. Brazitikos et al. prospectively followed 28 eyes implanted with the MA60BM lens in the sulcus because of posterior capsule rupture.¹⁶ The most common postoperative complications were transient corneal edema in 12 eyes and increased IOP in 11 eyes. Slight asymptomatic decentralization from the center of the pupil (1.0 to 2.0 mm) and pseudophacodonesis were observed in 5 eyes each. Friction of the IOL with the iris occurred in only 1 eye. Clinically significant cystoid macular edema occurred in 3 eyes. It has to be highlighted that the follow up in that study was of only 6 months. Mackool described no instances of persistent IOP elevation or pigmentary dispersion syndrome after implanting more than 100 AcrySof MA60 BM IOLs in the ciliary sulcus (follow up time not specified).¹⁷ The author suspected that a transient pigmentary dispersion might have occurred because many of the procedures involved iris-IOL contact during insertion or iris manipulation.

In summary, pathologic findings of 13 eyes with 3-piece hydrophobic acrylic IOLs with anterior and posterior square optic edges were compared to those from 14 eyes with 3-piece lenses with anterior round edges (13 silicone lenses, and 1 hydrophobic acrylic lens). The IOLs in both groups of eyes had asymmetric or sulcus fixation, likely done electively after complicated surgery. Gross findings were similar in both groups, and were composed of IOL decentration and tilt, pigmentary dispersion within the anterior segment and on the IOL surface, and iris transillumination defects. However, pathologic findings were more severe in eyes implanted with 3-piece IOLs with square anterior optic edges, especially with regards to pigmentary dispersion within the trabecular meshwork. Our pathologic findings therefore appear to confirm that IOLs with round anterior edges are more suitable for sulcus fixation.

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Figure 1. High-frequency ultrasound scans (A and B) and magnetic resonance imaging scans (C and D) of 4 study eyes, showing various degrees of intraocular lens decentration. Significant tilt is also observed in B. The * in C and D indicate pupillary aperture/visual axis to better illustrate lens decentration. The final scoring of lens decentration was done after imaging and gross examination of each eye. A through D: Eyes number 3, 7, 13 and 14 (Table 2), respectively.

Figure 2.

Gross photographs from the posterior view of the anterior segment (Miyake-Apple view) of study eyes implanted with a 3-piece hydrophobic acrylic lens (A) or with 3-piece silicone lenses (B, C, D, E and F), without symmetric in-the-bag fixation. Various degrees of intraocular lens decentration, pigment dispersion, iris transillumination defects, as well as Soemmering's ring formation within the capsular bag can be seen. A through F: Eyes number 3, 5, 6, 7, 12 and 13 (Table 2), respectively.

Figure 3.

Light photomicrographs of representative sections cut from study eyes (Table 2; all eyes with 3-piece hydrophobic acrylic or silicone intraocular lenses with round anterior optic edges) illustrating different histopathologic findings. A: Mild erosion of the haptic into the ciliary sulcus, without disruption of the iris pigmented layer (arrow) (eye number 13; Masson trichrome stain; original magnification X40). B: Mild erosion and encapsulation of the haptic into the ciliary sulcus, with mild disruption of the iris pigmented layer (eye number 5; Masson trichrome stain; original magnification X40). C: Mild erosion and encapsulation of the haptic in the ciliary sulcus, with minimal disruption of the iris pigmented layer (eye number 8; Masson trichrome stain; original magnification X40). D: Localized disruption of the iris pigmented layer near the ciliary sulcus, where a residual material (*) corresponding to one of the lens loops can be found (eye number 12; Masson trichrome stain; original magnification X20). E: Localized disruption of the iris pigmented layer near the ciliary sulcus (eye number 3; Masson trichrome stain; original magnification X100). F: Localized disruption of the iris pigmented layer near the pupil (eye number 8; Masson trichrome stain; original magnification X100).

Figure 4.

Gross photograph (A) and light photomicrographs (B and C) obtained from eye number 10 (Table 2), implanted with a 3-piece silicone lens with bag-sulcus fixation. A posterior capsular rupture is present. The arrows in A and B indicate the haptic in the sulcus.

Although the haptic on the left was in the sulcus, the iris pigmented layer is intact. The * in A and C indicate the haptic in the bag. The iris pigmented layer on this side also does not exhibit any significant disruption. B and C: Masson trichrome stain; original magnification X20.

Characteristics of the donor eyes implanted with hydrophobic acrylic intraocular lenses with square anterior and posterior optic edges, without symmetric in-the-bag fixation.

Table 1

Eye	Age at Death (years)	Postoperative Time (months)	IOL design	Fixation	Decentration *	Tilt *	Posterior Capsule Rupture	Pigment Dispersion *	Iris Transillumination Defects *
1	84	N/A	3-piece/PMMA haptics	Bag-Sulcus	2	2	Yes	2	3
2	87	N/A	3-piece/PMMA haptics	Sulcus-Sulcus	1	0	Yes	1	1
3	86	N/A	3-piece/PMMA haptics	Bag-Ciliary body	1	3	No	2	2
4	87	N/A	3-piece/PMMA haptics	Sulcus-Sulcus	1	1	Yes	2	2
5	86	N/A	3-piece/PMMA haptics	Bag-Sulcus	1	3	Yes	2	2
6	90	N/A	3-piece/PMMA haptics	Bag-Sulcus	3	0	No	2	2
7	78	N/A	3-piece/PMMA haptics	Ciliary body-Sulcus	3	3	Yes	1	1
8	88	35	3-piece, multifocal/PMMA haptics	Ciliary body-Sulcus	2	1	Yes	2	2
9	74	36	3-piece/PMMA haptics	Ciliary body-Sulcus	3	2	Yes	3	3
10	85	71	3-piece/PMMA haptics	Sulcus-Sulcus	1	1	Yes	2	2
11	97	114	3-piece/PMMA haptics	Bag-Sulcus	3	3	Yes	2	3
12	93	N/A	3-piece/PMMA haptics	Sulcus-Sulcus	2	0	Yes	2	1
13	91	N/A	3-piece/PMMA haptics	Sulcus-Sulcus	1	1	Yes	1	2

N/A = Not available. IOL = Intraocular Lens. PMMA = Polymethylmethacrylate.

* Parameters semi quantitatively described from 0 to 3 (none, mild, moderate, severe).

Table 2

Characteristics of the donor eyes implanted with 3-piece hydrophobic acrylic or silicone intraocular lenses with round anterior optic edges, without symmetric in-the-bag fixation.

Eye	Age at Death (years)	Postoperative Time (months)	IOL design	Fixation	Decentration*	Tilt*	Posterior Capsule Rupture	Pigment Dispersion*	Iris Transillumination Defects*
1	75	39	Silicone/PMMA haptics	Bag-Ciliary body	2	2	Yes	1	2
2	71	33	Silicone/PMMA haptics	Bag-Sulcus	3	3	Yes	3	3
3	54	61	Hydrophobic acrylic/PMMA haptics	Sulcus-Ciliary body	3	2	Yes	1	1
4	94	28	Silicone/Prolene haptics	Sulcus-Sulcus	1	0	Yes	2	2
5	96	174	Silicone/Prolene haptics	Bag-Sulcus	3	1	Yes	1	2
6	85	N/A	Silicone/Prolene haptics	Bag-Sulcus	2	2	Yes	2	1
7	82	N/A	Silicone/PMMA haptics	Sulcus-Ciliary body	2	2	Yes	2	2
8	85	N/A	Silicone/PMMA haptics	Sulcus-Sulcus	1	0	Yes	2	2
9	89	N/A	Silicone/Prolene haptics	Bag-Sulcus	2	1	Yes	3	3
10	91	N/A	Silicone/PMMA haptics	Bag-Sulcus	2	1	Yes	2	1
11	71	3	Silicone/PMMA haptics	Sulcus-Sulcus	1	0	Yes	2	2
12	87	N/A	Silicone/Elastimide haptics	Bag-Sulcus	1	1	Yes	1	1
13	79	40	Silicone/Elastimide haptics	Sulcus-Sulcus	2	0	Yes	2	2
14	81	N/A	Silicone/PMMA haptics	Sulcus-Sulcus	1	0	Yes	2	2

N/A = Not available. IOL = Intraocular Lens. PMMA = Polymethylmethacrylate.

* Parameters semi quantitatively described from 0 to 3 (none, mild, moderate, severe).