EXTENDED REPORT

Linear deposits on the surfaces of intraocular lenses implanted through a hexagonal cartridge which mimic scratches/cracks on the lenses

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Aim: To describe unique linear deposits on the surface of posterior chamber intraocular lenses (IOLs) occurring after implantation through a hexagonal cartridge.
Methods: Five ACR6D SE IOLs (Corneal Laboratories, Pringy, France) were injected/implanted through hexagonal cartridges. Two of these were injected into a petri dish and the remaining three were inserted into the evacuated capsular bag of cadaver eyes. In addition, three other ACR6D SE IOLs were injected into a petri dish through round cartridges. The latter served as controls.
Results: All lenses that were injected/implanted through the hexagonal cartridges demonstrated linear deposits on the posterior surface of the IOL optic component. The IOLs that were injected through the round cartridges had no deposits. All the hexagonal cartridges showed signs of internal cracking. None of the round cartridges were cracked.
Conclusion: Implantation of at least one IOL model, the ACR6D SE IOL, through a hexagonal cartridge can result in linear deposits on the posterior optical surface of the IOL. The shape of the cartridge appears to be a significant factor in causing the depositions.

The technique of cataract extraction has evolved rapidly during the past decades. In sites where capability for small incision foldable intraocular lenses (IOLs) surgery is available, incision size has decreased from 10.0 mm to the present standard of less than 3.0 mm. The small incisions contribute to a faster recovery and decrease the complication rate after the surgery. This development has led to a need for new instruments, new surgical techniques, and new IOL technology.

One of the most popular ways to implant a foldable IOL through a small incision is by using an injector system. These systems usually consist of two parts: the injector and the cartridge. There are several reports regarding damage that has occurred to several acrylic IOLs while using injector systems, probably during the implantation. This includes marks or scratches,[1 2] stress fractures,[3] cracks,[4] and tear lines.[5]

This paper describes linear deposits that appeared on the surface of single piece, hydrophilic acrylic, high water content, IOLs after implantation through the hexagonal cartridge. These linear deposits, which we subsequently found to be exfoliated material derived from the cartridge, can be confused with scratches/cracks on the lens surface.

METHODS

The ACR6D SE IOL is a single piece acrylic IOL manufactured by Corneal Laboratories, Pringy, France. This IOL is made up of a combination of hydrophilic and hydrophobic methacrylates with 26% water content. It is biconvex without angulations, and has a refractive index of 1.47. The overall diameter of this lens is 12.0 mm and the optic diameter is 6.0 mm.

For insertion an ophthalmic viscoelastic device (OVD) (Hyalon, AMO, Santa Ana, CA, USA) was applied to the barrel and both sides of the inner side of the hexagonal cartridge of the injector (CEC 001, Corneal Laboratories, Pringy, France). In the first experiment using a petri dish, +21 dioptres lenses were removed from their container, grasped by the haptic, and placed on the central hinge of the cartridge. Slight downward pressure was exerted with a smooth Kelman-McPherson forceps, with special attention not to damage the IOL, and the wings of the cartridge were closed. The cartridge was then loaded into the injector hand piece. After 2 minutes in the cartridge, using gentle pressure on the inserter's plunger the IOLs were injected, while making sure that the plunger would never override the trailing optic edge, into a petri dish. This was done with two IOLs.

In a second experiment three lenses were implanted in a similar manner into the evacuated capsular bag of a cadaver eye, prepared according to the Miyake-Apple posterior video/photography technique that was filled with OVD (Hyalon, AMO). The injection/implantation times were always less than 20 seconds. Three controls using a round rather than hexagonal cartridges were also used. Three ACR6D IOLs, +21 dioptres were injected in the same way into a petri dish through a round cartridge (IC-2BU, Bausch and Lomb, Clearwater, FL, USA).

After the injection/implantation, all the IOLs and cartridges were evaluated. Care was taken to avoid any manipulation of the IOL's optics with forceps or other grasping instruments. Gross (macroscopic) analysis of the IOLs and cartridges were performed and gross photographs were taken (digital Nikon D1 X, Nikon Corporation, Tokyo, Japan). The lenses and cartridges were then evaluated microscopically and photographed under a light microscope (digital Sony DSC-F 707, Tokyo, Japan). One lens and two cartridges (one was opened to enable analysis of the cartridge's inner surface) were then sent to the electron microscopy centre of the University of South Carolina (Columbia, SC, USA) for further examination under a Jeol JSM 5410LV scanning electron microscope (SEM) and under a Hitachi 2500 Delta SEM equipped with a

Abbreviations: EDS, energy dispersive *x* ray spectroscopy; IOLs, intraocular lenses; OVD, ophthalmic viscoelastic device; SEM, scanning electron micrograph

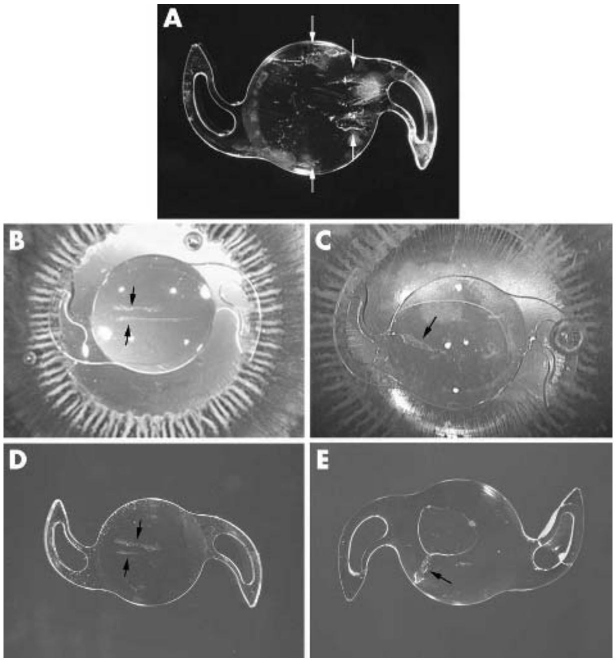

Figure 1 Gross photographs of IOLs that were injected/implanted through the hexagonal cartridges, demonstrating the linear deposits on the posterior surfaces of the optic components of these IOLs (arrows). The linear deposits' appearance mimics scratches or cracks of the IOLs. (A) Gross photographs of an IOL that was injected into the petri dish. (B, C) Posterior view of IOLs that were implanted into the cadaver eyes (Miyake-Apple posterior video/photography technique). (D, E) Gross photographs of IOLs that were implanted into cadaver eyes after explantation. The deposits were found to be loosely attached to the IOL surface as can be noticed from the change of the deposit location which occurred after the explantation (compare fig 2D with 2E) in spite of our efforts to be gentle.

Kevex X-ray detector with light element capabilities for energy dispersive *x* ray spectroscopy (EDS).

RESULTS

Findings on the IOLs

Gross examination of all the IOLs injected/implanted through the hexagonal cartridge revealed the presence of linear surface abnormalities on the posterior optic surface; at first glance they resembled scratches/cracks on the IOL's optics (fig 1). However microscopic evaluations demonstrated that there were no cracks/breaks of the IOL's optics. Rather, deposits were noted on the posterior surface of the IOL's optics. The deposits had a linear shape and could be divided into two types according to the morphological appearance: the corrugate type (figs 2A and B) and a box car pattern of deposits (figs 2C and D). SEM performed on one of the lenses (fig 3) confirmed the presence of the deposits on the posterior surface of the IOL. EDS analysis was found to be inconclusive as to the content of the deposits. The deposits were found to be loosely attached to the IOL's surfaces and could be easily removed from the IOL (fig 1C and E). No damage to the IOLs injected with the round cartridge was observed, nor were any deposits noted on the IOL's surface.

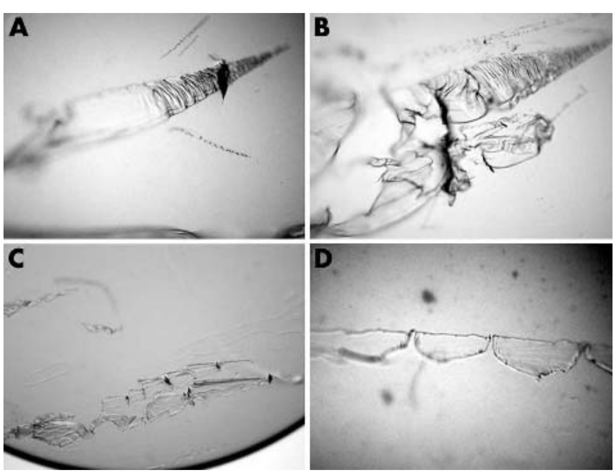

Figure 2 Photomicrographs of the two types of deposits observed. (A, B) The corrugate type of deposits (original magnification, (A) ×200, (B) ×400). (C, D) The box car pattern of deposits (original magnification, (C) ×100, (D) ×400).

Findings on the cartridges

Gross and microscopic examination of the hexagonal cartridges demonstrated a similar finding of one major break/crack of the cartridge surrounded by several stress lines/cracks (figs 4A, B). SEM performed on one cartridge demonstrated the major break of the cartridge (figs 4C, D). SEM of the second cartridge, which was opened, showed only remnants of the viscoelastic material used during the implantation (fig 4E). No damage was observed on the round cartridges.

DISCUSSION

The two main methods of implanting a foldable lens are (1) a folding forceps, or (2) an injector. Folding the IOL can cause surface abnormalities, stress fractures, and fine tear lines to the IOL. Various complications can also occur with injector systems—for example, IOL non-delivery, IOL damage, or cartridge damage.[6 7]

In this study we demonstrated that using the hexagonal cartridge for implantation of at least one IOL model, the ACR6D SE IOL, can lead to linear surface abnormalities on the posterior optic surface of the IOL. These abnormalities are not cracks or fissures within the superficial IOL substance. Rather, they consisted of deposits which seemed to have been shaved from the cartridge's inner surface.

Hydrophilic lenses have become extremely popular in countries outside the United States for various reasons, including the fact that they are relatively easy to manufacture, therefore, can be sold inexpensively, and are easy to manage. Hydrophilic acrylic lenses have also been shown to have excellent uveal biocompatibility. The hydrophilic material showed the least interaction with silicone oil and, therefore, is probably the best possible IOL material in cases of vitreous retinal diseases where silicone oil injection may be anticipated. The advantage of the hexagonal cartridge is that it can prevent rotation of the IOL within the cartridge during implantation.

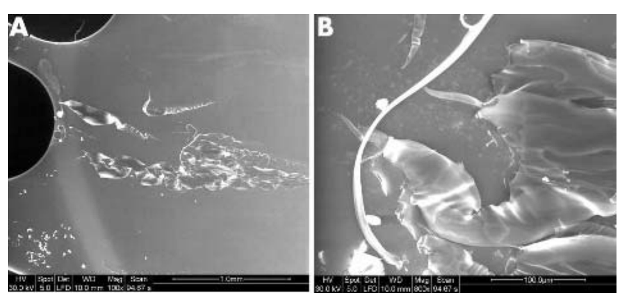

Figure 3 Scanning electron micrographs of one IOL with the surface deposits. This confirms that these are not scratches or cracks within the IOL. (A) Original magnification ×100; (B) original magnification ×800.

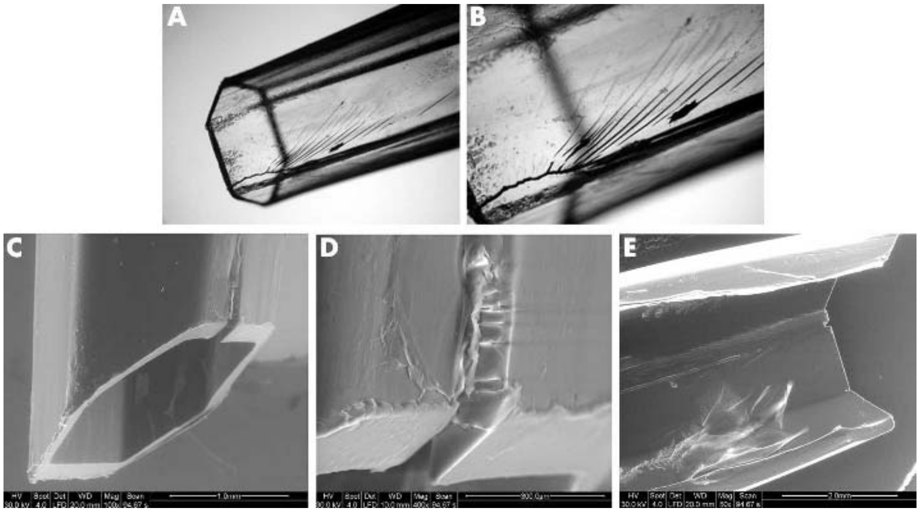

Figure 4 Photomicrographs of hexagonal cartridges after implantation, demonstrating the crack and the stress lines/cracks extending from it. (A, B) Light microscopy (original magnification (A) ×40, (B) ×100). (C, D) Scanning electron micrographs (SEM) (original magnification (C) ×100, (D) ×400). (E) SEM of one of the hexagonal cartridges after implantation that was opened to enable imaging of the cartridge's internal portion, showing remnants of the viscoelastic material that was used during the implantation (original magnification ×50).

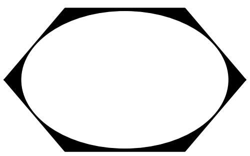

Figure 5 Schematic drawing of the barrel of hexagonal cartridge loaded with a folded IOL (sagittal cut). This drawing demonstrate the mismatch between the round/oval folded IOL and the hexagonal barrel cartridge. This leaves some residual spaces (black) of the cartridge forcing the lens to be further compressed.

Faschinger[8] described surface abnormalities that occurred on the optic surface of the Chiron Vision EasAcryl lens and the Distra Inject-A lens. The exact cause for these abnormalities was not clear, but several factors were suggested by the author and include the loading technique. He also postulated that the hydrophilic nature of the IOLs, which cause absorption of any aqueous solution, may lead to friction of the IOL against the injector's barrel. Although he reported that these lines could not be removed by irrigation or by forced rinsing with a cannula, a careful observation of the figures presented in this report lead us to conclusion that the phenomenon he reported was the same as we found. Most of these abnormalities disappeared within a few weeks without the need for further intervention.

In a second study, Faschinger[9] described plastic exfoliative material derived from the cartridge after implantation of three cases of the ACR6SE IOL. He used the hexagonal cartridge for each implantation. He did not include the use of OVD.

Some reports have described cartridge cracks, possibly related to stress forces and to the tensile strength and extensibility of the cartridge, which can be optimised by the cartridge shape and polymer morphology.[7 10 11] Sing and coauthors[6] noted the importance of the type of the OVD used during the implantation suggesting that Healon, because of its "pseudoplasticity," caused increased initial resistance followed by overriding of the plunger on the IOL and in this way facilitated the cracks.[6] This claim was ruled out by Dick and coauthors,[11] and Olson.[12]

In our cases, OVD was used and special attention paid to loading the IOLs gently into the cartridge without damaging them or allowing the plunger to override the IOLs. Like Rath and coauthors,[7] we suggest that the shape and polymer morphology of the cartridge may be an important factor. An IOL that creates an oval surface when folded does not completely fit within the hexagonal cartridge, in sharp contrast with an oval shaped cartridge, thus causing residual spaces within the cartridge (fig 5). This can cause an extra increase of the stress forces applied to the cartridge and thus cause extensive friction of the IOL's posterior surface (external surface of the IOL when folded) against the inner part of the cartridge. This could result in a shaving or exfoliation with deposit formations onto the posterior surface of the IOL derived from the inner part of the cartridge surface. This can explain the creation of the cracks on the cartridge that we have described here. The appearance of the deposits, as well as the appearance of the hexagonal cartridge after the injection/implantation, with formation of crack and stress lines, as opposed to the normal appearance of the round cartridge, supports our contentions. The inner surfaces of several cartridges are being coated to enable easier implantation of the IOLs. This can be another contributing factor to the creation of these deposits.

As to the optical performance of the IOLs with these deposits, our own experience showed that when the deposits were located at the periphery no visual disturbance was found. Because deposits located at the centre of the IOL were peeled, we were unable to comment on the optical performance of these IOLs when the deposits involved the visual axis.

In conclusion, surface deposits were observed on the posterior surface of the ACR6D SE IOL after injection/implantation through hexagonal cartridge. Although the surface deposits had a linear appearance similar to scratches or cracks of the IOL, the deposits' origin in this scenario is probably from the inner part of the hexagonal cartridges used for the implantation. The deposits were loosely attached to the IOL's surfaces and could be easily removed. Further studies evaluating all lenses material and types should be carried out.

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