Histological and ultrastructural study of corneal tunnel incisions using diamond and steel keratomes

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ABSTRACT

Purpose: To study the morphology of corneal tunnel incisions using diamond and steel keratomes.

Setting: Department of Ophthalmology, University of Giessen, Germany.

Methods: Corneal tunnel incisions were performed in six human cadaver eyes using three types of diamond keratomes and a steel keratome. The incision profile and morphology were evaluated and compared using light and scanning electron microscopy.

Results: The steel keratome caused more disruption of corneal stromal tissue, while the diamond keratomes produced a more regular, smoother incision. The dissecting incision resulted in a smoother surface of cut stromal tissue than the stab incision.

Conclusions: The high quality of corneal tunnel incisions produced with diamond keratomes is the result of their exceptional sharpness, which may have a beneficial effect on wound healing. *J Cataract Refract Surg 1998; 24:498–502*

Self-sealing clear corneal incisions for cataract surgery differ from other cataract incisions in that they are usually performed more like a stab incision than a true dissection of tissue. The keratome requires a very sharp tip and cutting edge to create a clean, self-sealing wound. A variety of diamond and disposable steel keratomes of different designs and configurations are available for clear corneal cataract surgery. Although each manufacturer claims the advantages of its product, there is a lack of objective comparative data. We performed a histological and ultrastructural study on fresh human cadaver eyes to compare the morphology of corneal tunnel incisions using three types of diamond keratomes and a steel keratome.

Materials and Methods

Six human cadaver eyes from the pathology laboratory were used in this study. The corneas were mildly opacified but showed no significant Descemet's membrane folds. The corneal changes were well in agree-

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ment with the postmortem time, which was no more than 12 hours.

The enucleated eyes were mounted on a suction device that raised the intraocular pressure (IOP) to normal values; IOP was checked digitally. The corneal tunnel incisions were placed on the temporal cornea just anterior to the conjunctiva in the beveled style. The length of the corneal tunnel was approximately 2.0 mm. Care was taken not to de-epithelialize the cornea at the site of the incision.

The incisions were made by a single pass using (1) a standard 3.0 mm wide, double-beveled, multifaceted, angled diamond keratome with a parallel configuration (thickness 0.2 mm, cutting angle 90 degrees) (Geuder); (2) a 3.0 mm wide, double-beveled diamond keratome similar to the standard keratome but with bevels of the anterior and posterior surfaces with different slopings to compensate for incising a spherical globe at an angle (Rhein 3-D Diamond Blade) (Figure 1); (3) a 6.0 mm long, stiletto-like diamond keratome with a 1.0 mm wide base and a 450 μm wide tip (Fine Finesse Triamond, Mastel); (4) a disposable 2.85 mm wide steel keratome with an angled bevel-down blade (thickness 0.2 mm, cutting angle 45 degrees) (MSP) (Figure 2).

The incisions with the stiletto-like diamond keratome were performed in a dissecting rather than a punching action. The corneoscleral rims were immediately removed. Specimens for light microscopy were sectioned perpendicular to the incision, fixed in formalin, and stained with hematoxylin and eosin. Corneal tunnel incisions for scanning electron microscopy (SEM) were cut using the stiletto-like diamond keratome to obtain two wedges of corneal tissue, both having a surface of cut stroma and an epithelial or endothelial surface. The specimens of the incisions performed with the stiletto-like diamond keratome were not sectioned

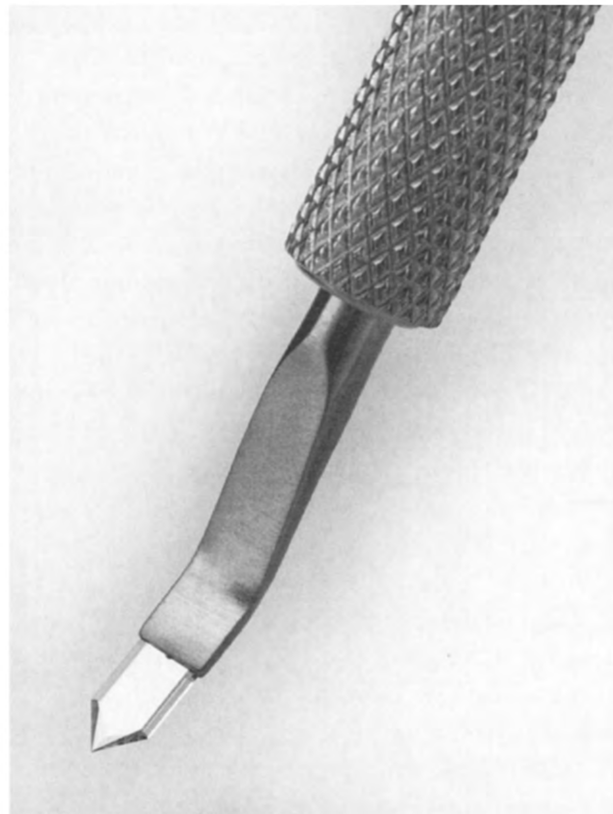

Figure 1. (Jacobi) The Rhein 3-D diamond blade.

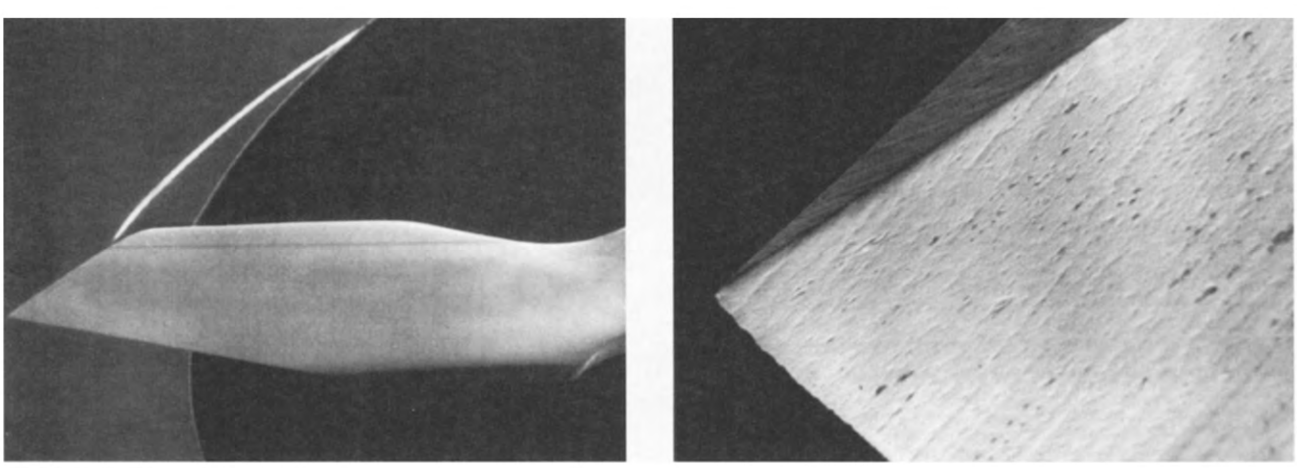

Figure 2. (Jacobi) Scanning electron microscopy of the steel keratome. *Left:* Original magnification × 45. *Right:* Original magnification × 175.

into halves, but the tunnel incision was opened and placed to provide a view of the cut stromal surface.

After the wedges of each corneal incision were prepared, the specimens were fixed in glutaraldehyde and rinsed with in 0.1 molar phosphate buffer. The specimens were postfixed in osmium phosphate 1% buffer, dehydrated in graded ethanol, and critical point dried. They were then mounted on aluminum stubs, exposing the cut stromal surface, and sputtered with gold. Viewing and photography were performed with the PSEM 500 (Phillips) scanning electron microscope.

The steel keratome was studied under SEM to evaluate the quality of the cutting edge.

Results

Cross-section light micrographs of bevel incisions showed that the standard diamond keratome created a smoother, cleaner incision contour than the steel keratome (Figure 3).

Under SEM, the exposed surfaces of the corneal incisions appeared similar in all incisions made with the stab keratomes (Figure 4). The incisions produced a mechanical distortion of stromal lamellae with a fishtail configuration. The bottom surface of the tunnel incision had a central linear groove with a corresponding ridge of torn stromal lamellae on the top surface. The groove was narrow and distinct in the incision made with the 3-D diamond keratome and less well-defined and irregular in the incision made with the standard diamond keratome. In the steel keratome incision, the groove was wider, pushing the lamellae aside rather than dissecting them. The texture of torn stromal lamellae of the cut surfaces appeared rougher in incisions made with the steel knife than in those made with the diamond keratome, especially the 3-D. The corneal incisions made with the dissecting, stiletto-like keratome were distinct from the other incisions, having a smoother stromal surface and much less disruption of stromal tissue.

The SEM study of the steel keratome showed a slightly irregular cutting edge under high magnification (Figure 2).

Discussion

The morphology and histopathology of corneal incisions made with different knives have been reported in several studies, some of which evaluated radial keratotomy (RK) incisions.[1–7] However, few have evaluated the morphology of corneal tunnel incisions for clear corneal cataract surgery.[8] Various reports give conflicting results on the importance of blade material to incision morphology. Some found that diamond keratomes produce less disruption of corneal tissue,[1,4] while others could not confirm these findings.[5,6] The purpose of our study was to evaluate the morphology of corneal tunnel incisions made with different diamond keratomes and a steel keratome.

The cross-section light micrographs showed that incisions made with a diamond keratome had a smoother contour than those made using a steel keratome. However, cross sections alone may not be conclusive because

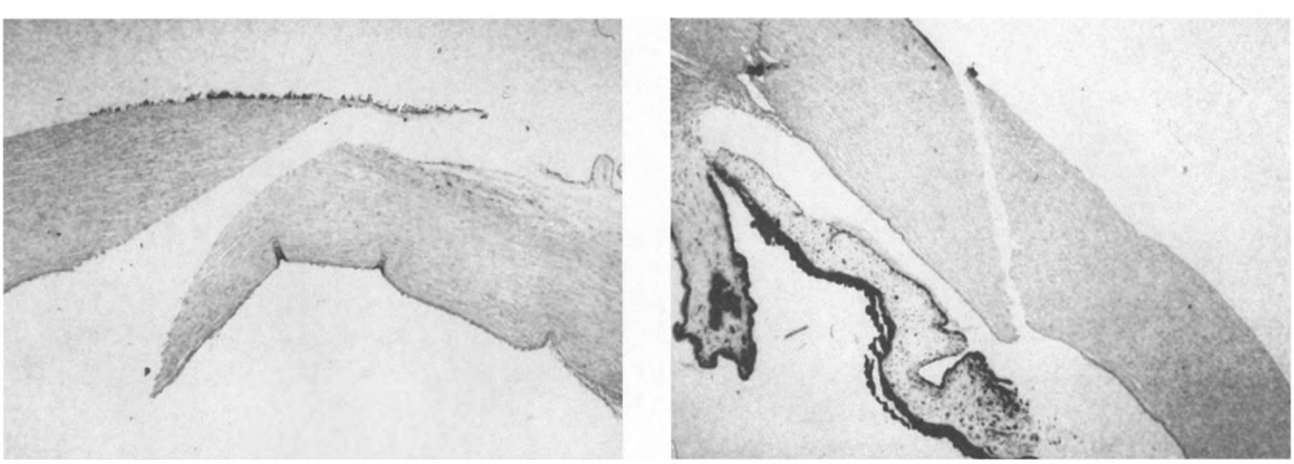

Figure 3. (Jacobi) Cross-section light micrograph of the corneal tunnel incision using a diamond *(left)* and steel *(right)* keratome (hematoxylin eosin stain; original magnification ×4).

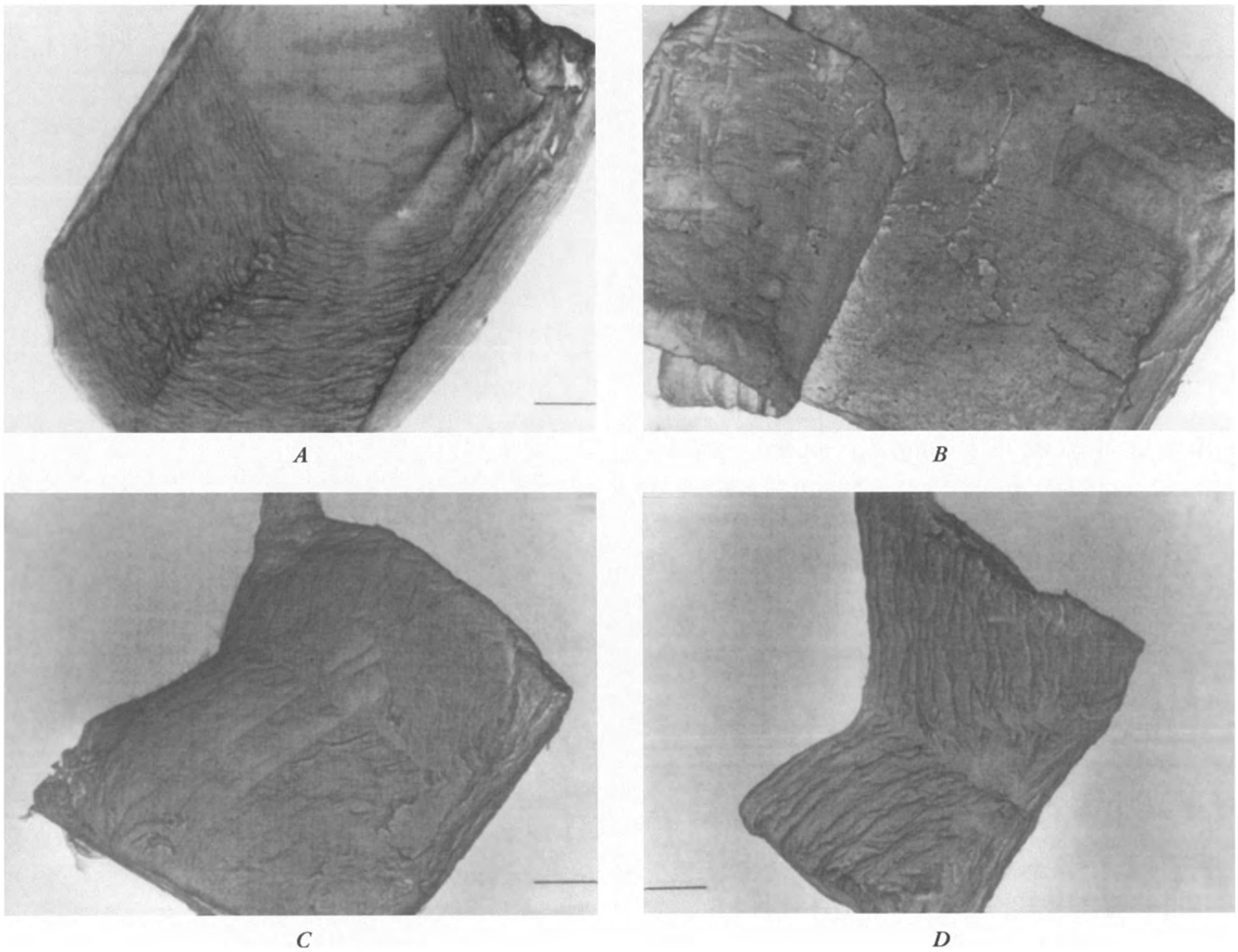

Figure 4. (Jacobi) Scanning electron microscopy of the top surface of a clear corneal tunnel incision using a standard diamond keratome *(A)* and a stiletto-like keratome *(B)* and of the bottom surface using the 3-D diamond keratome *(C)* and a steel keratome *(D)* (original magnification ×22).

of the variation in tissue disruption across the width of the tunnel incision. Our subsequent SEM study showed that a beveled-style stab incision into the cornea results in a fishtail distortion of stromal lamellae with a central linear groove on the bottom surface of the incision and a central linear ridge on the top surface. The diamond keratomes appeared to produce cleaner, less disrupted corneal incisions than the steel keratome. This is not surprising because of the extreme sharpness of diamond keratomes. In contrast, incisions made with the steel blade had an irregular cutting edge on SEM, which creates a risk of greater tissue damage. The 3-D diamond blade with differently sloping bevels on the anterior and posterior blade surfaces produced the smoothest incisions and keeps the best track among the stab incision keratomes. The dissecting incision using the stiletto-like diamond keratome was ideal with respect to the degree of disruption of stromal tissue. However, it was also less practical when fashioning a 3.0 mm wide corneal tunnel incision.

Whether this discussion of wound morphology is of functional significance must be determined; however, it can be assumed that a sharper keratome puts less stress on the cornea and that a smoother corneal incision results in a better apposition of stromal lamellae and thus has a beneficial effect on the healing process. Wound disfiguration incurred in the incision process has a significant impact on the healing process, the outcome of which is considered to determine the refractive result after RK.[9]

Our study is limited by the fact that our steel keratome was not representative of all metal keratomes on the market, and there may be differences in quality from one manufacturer to the other. Double-beveled keratomes that may be superior to the bevel-down blade as used in our study are now available. Yet we believe that a reliable, sharp knife such as a diamond keratome is preferable in clear corneal incisions.

We are aware that postmortem IOP and tissue changes may have affected the incision procedure. It is reasonable to expect greater stress on corneal tissue and hence more wound disfiguration in eyes with a low IOP, as in the case of prolonged preoperative oculopression. In our study, IOP was maintained normotensive by placing the globes on a suction device; IOP was then controlled digitally.

The postmortem corneal edema can be counteracted by immersing the globe in hyperosmolar agents. However, we believe it may also affect the histology.[10]

References

1. Galbavy EJ. Use of diamond knives in ocular surgery. Ophthalmic Surg 1984; 15:203–205
2. Unterman SR, Rowsey JJ. Diamond knife corneal incisions. Ophthalmic Surg 1984; 15:199–202
3. Colin J, Volant A, Mimouni F. Comparaison en microscopie à balayage des keratomies par bistouri diamant et bistouri à lame d'acier. J Fr Ophtalmol 1988; 11:293–295
4. Huebscher HJ, Goder GJ, Lommatzsch PK. The sharpness of incision instruments in corneal tissue. Ophthalmic Surg 1989; 20:120–123
5. Fongione A, Leger F, Riss I, Le Rebeller MJ. Qualité de cornéenne des lames céramique et diamonte. Comparaison en microscope optique. J Fr Ophtalmol 1991; 14:183–185
6. Van Meter WS, Breen C, Hainsworth DP, Geissler R. Scanning electron microscopy of corneal incisions using steel, diamond, and sapphire blades. Ophthalmic Surg 1990; 21:475–480
7. Melles GR, Wijdh RH, Cost B, et al. Effect of blade configuration, knife action and intraocular pressure on keratotomy incision depth and shape. Cornea 1993; 12:299–309
8. Radner W, Menapace R, Zehetmayer M, Mallinger R. Die Auswirkung der Inzisionbreite auf das Gewebetrauma an der Hornhaut nach Implantation einer faltbaren AMO PhacoflexII®. Spektrum Augenheilkd 1997; 11:12–15
9. Deg JK, Zavala EY, Binder PS. Delayed corneal wound healing following radial keratotomy. Ophthalmology 1985; 92:734–740
10. Terry MA, Ousley PJ, Zjhra ML. Hydration changes in cadaver eyes prepared for practice and experimental surgery. Arch Ophthalmol 1994; 112:538–543