Corneal Sensitivity after Refractive Surgery

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OBJECTIVE: To evaluate corneal reinnervation after different techniques of refractive surgery. STUDY DESIGN: Retrospective evaluation of corneal sensivity after keratotomy, epikeratophakia and photorefractive keratectomy. The measurements were performed with the Draeger electromechanical optical-controlled aesthesiometer which is extremely precise and independent of external changes in temperature and humidity. One measurement point was in the corneal centre of patients after radial keratotomy and photorefractive keratectomy and 5 approximately at 1 mm intervals to the limbus. Five measurement points were in the centre of the epikeratophakia lenticle and 4 next to the circumferential trephination on the host cornea. SETTING: Department of Ophthalmology, University of Hamburg, and Lombardi Eye-Clinic, Rome. PATIENTS: 35 patients after radial keratotomy, 7 patients after epikeratophakia and 82 patients after photorefractive keratectomy. RESULTS: Corneal sensitivity after radial keratotomy is not influenced by radial incisions. Even 3 years after epikeratophakia the lenticle centre showed reduced thresholds. The reinnervation of the cornea after photorefractive keratectomy almost parallels the wound healing and corresponds to the ablation depth.

Keywords: Corneal sensitivity; Radial keratotomy; Epikeratophakia; Photorefractive keratectomy; Refractive surgery.

INTRODUCTION

Touching the cornea triggers one of the most sensitive protective reflexes of the human body. The threshold of sensitivity, especially in the centre of the cornea, is exceedingly low, so that pathological changes can be diagnosed early and very precisely and can be used for different diagnosis, follow up and even prognosis of different corneal affections. Various refractive surgical procedures have been associated with a marked postoperative hypoaesthesia.

Koenig *et al.* [1] and Biermann *et al.* [2] demonstrated a long-term decrease in corneal sensivity after epikeratophakia. Shivitz *et al.* [3] reported that radial keratotomy also can reduce corneal sensitivity as long as one year postoperatively. Although these studies did not describe clinical complications attributable to the corneal hypaethesia, denervation of the cornea has been associated with decreased tear flow, reduced rate of mitosis of the corneal epithelium, and delayed wound healing, all of which could have adverse clinical implications.

The aim of our study was to evaluate and to compare the decrease of corneal sensitivity as a measure for corneal destruction after radial keratotomy, epikeratophakia and photorefractive keratectomy. Central corneal ablation, for example, means destruction of one of the two stabilizing membranes of the cornea. This not only means destabilizing the structure to withstand the continuous force of the intraocular pressure—like in keratoconus where it takes years and years to bulge the thinning centre forward, changing refractive power to myopia and irregular astigmatism—it also means destroying the corneal nerves, which follow the superficial structures.

PATIENTS

In a retrospective study between 1 month and 6 years the corneal sensitivity after keratotomy, epikeratophakia and photorefractive keratectomy was measured.

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Group 1

Thirty-five patients, 70 eyes, (14 women and 21 men, aged between 16 and 40 years, mean 28) after radial keratotomy with 4 to 16 radial incisions, with a preoperative myopia between 1.5 and 16 diopters, mean 4.3 D, and an optical centre between 3 mm and 4 mm were examined. No wound healing complications were reported in the patient charts. At the time of sensitivity measurement the operation dated back between 3 months and 6 years. Each patient was measured only once after operation.

Group 2

Seven patients, 14 eyes (4 women and 3 men, aged between 21 and 27 years, mean 25.4) after epikeratophakia with a preoperative myopia between 9 and 22.5 diopters, mean 15.6 D, were examined. The lenticle diameters ranged between 7.5 mm and 8.5 mm. No wound healing complications were reported in the patient charts. At the time of sensitivity measurement the operation dated back between 6 months and 3 years. Twelve eyes, 6 patients, were measured only once after surgery, 2 eyes, 1 patient, were measured twice after surgery. Two eyes were measured after 6 months, 2 eyes after 12 months, 2 eyes after 18 months, 4 eyes after 24 months and 30 months, 2 eyes after 36 months.

Group 3

Eighty-two patients, 156 eyes, (49 women and 33 men, age between 19 and 39 years, mean 27) after Excimer ablation with a preoperative myopia between 1 and 25 diopters, mean 10.8 dpt, with an ablated diameter between 5 and 6 mm were examined. Thirty-two patients had a preoperative myopia between 1 and 5 D and 11 patients between 15.1 and 25 D. All patients were treated with fluorometholon for 3 months. Three eyes with a myopia between 7 and 14 diopters showed after operation a haze of degree 2. Two eyes with a preoperative myopia between 15.1 and 22 diopters showed after the ablation a haze of degree 3. At the time of sensitivity measurement the operation dated back between 1 and 25 months. Each patient was measured only once after surgery.

METHOD

We used the Draeger electromechanical optical-controlled aesthesiometer for measuring the corneal sensitivity [4]. This aesthesiometer is mechanically very precise. Optical control of the instrument is mandatory in order to determine the precise location of contact with the corneal epithelium (Fig. 1). In comparison to the Cochet-Bonnet aesthesiometer it is independent from external changes in temperature, humidity and examiner. The instrument consists of a contact pin with a diameter of 0.5 mm. This contact pin is advanced perpendicular and automatically to the corneal surface until contact is made.

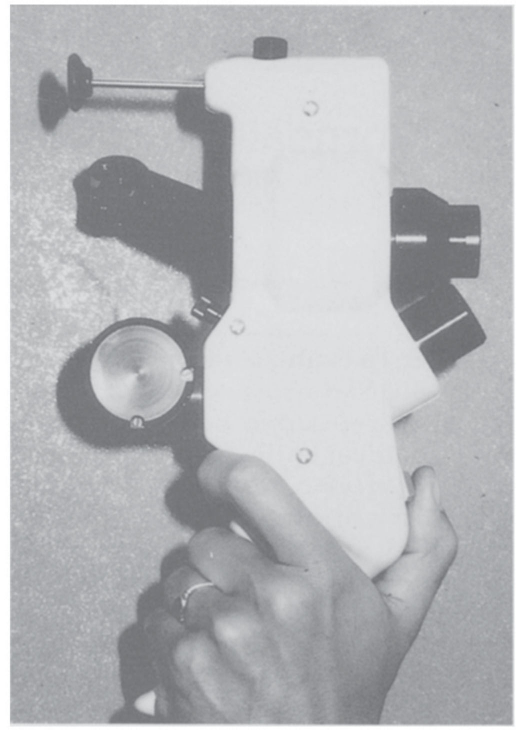

Fig. 1 Draeger electromechanical optical-controlled aesthesiometer.

If the patient felt the contact pin the response was considered positive. If no response was obtained the force of the contact pin was increased until a positive response was obtained. A digital display continuously indicates the force applied. This increase is faster the more the force of the contact pin increases. The upper limit is 1000×10^{-5} N and means no sensitivity. All measurements were performed at the centre of the cornea and at the periphery near the limbus in the 12, 3, 6, and 9 o'clock position by the same experienced observer. Each eye was measured at 9 different points. 1 measurement point was positioned in the corneal centre of patients after radial keratotomy and excimer ablation and 5 points on the epikeratophacic lenticle.

Results were determined as mean ± standard deviation.

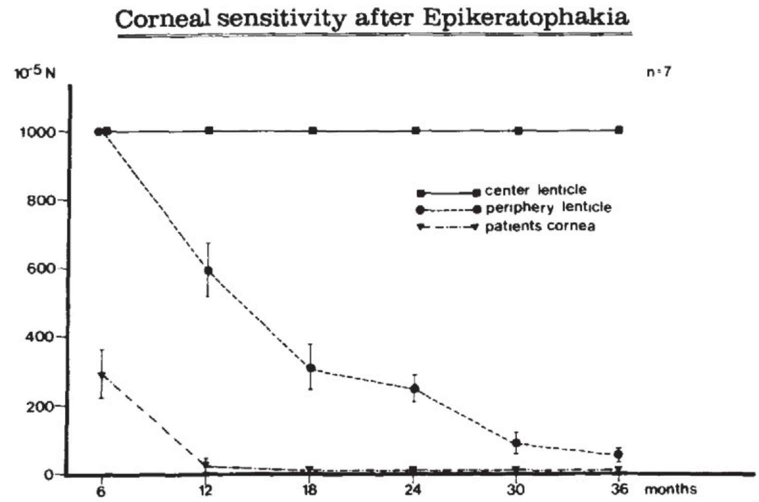

Fig. 2 Results after epikeratophakia.

RESULTS

In our measurements at corneas after radial keratotomy it could be shown that the corneal sensitivity is normal even 1 month after surgery. There was no difference in corneal sensitivity in areas adjacent to radial incisions. The central and peripheral threshold patterns are similar with healthy corneas.

The mean sensitivity of the central corneal epithelium overlying the donor lenticle was totally depressed even three years after epikeratophakia surgery. The peripheral parts of the refractive lenticle of each still showed a marked hyposensitivity three years later. On the operated eye the corneal sensitivity peripheral to the trephination was reduced six months after surgery and showed one year after surgery an almost normal corneal sensitivity (Fig. 2). The preoperative refractive error and the results of corneal sensitivity measurements were obtained from 82 patients who underwent photorefractive surgery for correction of myopia.

During the first postoperative month the corneal sensitivity was decreased up to anaesthesia. In the following wound healing period patients with a preoperative myopia up to 15 diopters achieved at the third month a slightly reduced corneal sensitivity, whereas patients with higher myopia up to 25 diopters showed a markedly depressed corneal sensitivity.

One year after surgery corneal sensitivity showed only a minimal decrease in the first three groups with a preoperative myopia up to 15 diopters. Patients with a higher preoperative myopia had a slightly reduced corneal sensitivity even 2 years after surgery. The high standard deviations in measurement of sensitivity might have reflected variable rates of reinnervation (Fig. 3).

Two of the 3 patients with haze degree 2 showed 1 year after surgery a slightly reduced corneal sensitivity, the 2 patients with haze degree 3 showed 6 months and 13 months after surgery a markedly depressed corneal sensitivity.

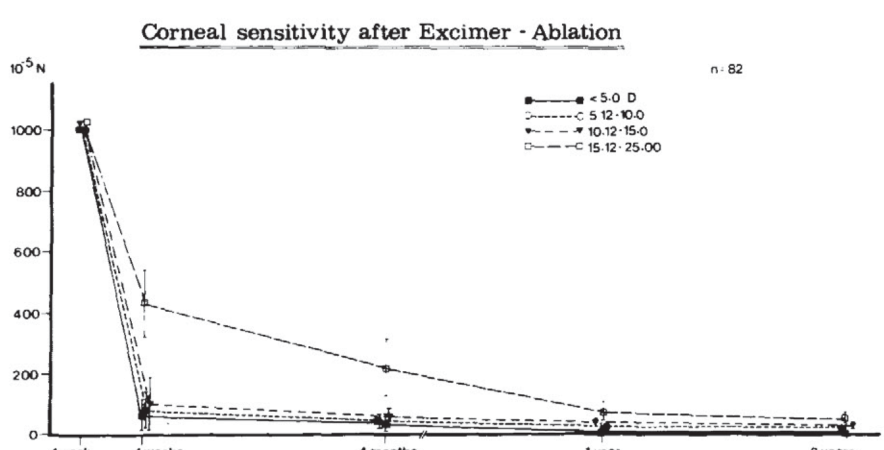

Fig. 3 Results after photorefractive keratectomy.

DISCUSSION

Central corneal epithelial sensation is mediated by stromal nerves originating from the ciliary nerves [4]. Twelve to 16 large radial branches of the ciliary nerve enter the cornea at the midstromal level. As these nerves course to the centre of the cornea, they branch horizontally and vertically, giving rise to the dense subepithelial plexus beneath Bowmans membrane. Fibres from this plexus lose their Schwann cell investment as they pass into the epithelium through openings in Bowmans membrane. Within the epithelium axon terminals end at all levels enwrapped by epithelial cell processes [5, 6].

Corneal sensitivity was normal in our patients after radial keratotomy. Linnick reported a complete recovery of corneal sensitivity in 288 eyes at 6 months after radial keratotomy [7]. Shivitz *et al.* reported that 31% of eyes undergoing radial keratotomy for myopia had a loss of corneal sensitivity at 6 months, and 9.5% had a loss of sensitivity 12 months postoperatively [3]. In the group of patients undergoing radial keratotomy and T-incisions to correct myopia and astigmatism, 70% and 47% had a loss of sensitivity at 6 and 12 months, respectively. The loss of sensitivity was most significant in the areas central to the T-incisions. Recovery of the loss of sensitivity was less in the group that had combined radial and transverse incisions. Although the numbers are small, the data showed a trend that a loss of sensitivity was more likely in patients with deeper transverse incisions and also with a higher amount of preoperative astigmatism [3]. Measuring corneal sensitivity in this way, we demonstrated that radial corneal incisions do not damage the centripetal nerve fibres like after transverse incisions.

During epikeratophakia surgery, a superficial circumferential trephination and keratectomy is performed [1], and radial nerve fibres located at the midstromal level could possibly be damaged as a result of this procedure. Our findings indicate that this superficial circular trephination of the cornea as a preparatory procedure for the epikeratophakia leads to peripheral mild hyposensitivity which corresponds to the retrograde nerve fibre degeneration.

Because of the circular deep wound surface, the dissected superficial nerves and the reduced metabolism at the lenticle, regeneration and ingrowth of nerve fibres are slowed down. After experimental non-penetrating circumferential keratotomy, neural degeneration and loss of corneal sensitivity are found peripheral and central to the wound [5, 6]. These findings might be the reason for wound healing, especially epithelial wound healing problems after epikeratophakia. It is well known that a decreased corneal sensitivity interferes with an abnormal tear film and a thinner epithelial cell layer. However, although corneal sensitivity is depressed 6 months to 1 year only in the region of the donor lenticle, patients appear clinically to retain normal blinking and reflexes.

Biermann *et al.* reported reduced corneal sensitivity following epikeratophakia [2]. They could also, like in our retrospective study, demonstrate that the corneal sensitivity peripheral to the trephination was significantly reduced. On the epikeratophakia lenticle the sensitivity was significantly reduced at all points, the centre showing the largest difference. No correlation with age, sex or the indication for the procedure was observed.

Koenig *et al.* reported a relative hypoaesthesia of the epikeratophakia lenticle when compared with the peripheral host cornea and contralateral cornea [1]. However, corneal sensitivity tested in 11 patients with more than 1 year follow-up was increased compared with the sensitivity of 19 patients whose postoperative recovery was less than 1 year.

Histopathologic findings in two lenticles from a non-human primate demonstrated sparse epithelial axon terminals. Host corneal nerves appear to innervate the lenticles by intraepithelial extension and by penetration of the superficial keratectomy scar.

Corneal wound healing can effect the outcome of refractive corneal surgery in general and Excimer-Laser ablation in particular. During photorefractive keratectomy, a central corneal ablation of variable depth and diameter is performed depending on the desired correction. The ablation is performed over a previously deepithelialized cornea, and removes the Bowmans membrane in the ablated area. Nerve endings are thus damaged and destroyed during this procedure. The temporal response of the cornea to the ablation can be divided into 3 phases: Acute phase 0–4 weeks, intermediate phase 4 weeks to 6 months and long-term phase 6 months and more. During the acute phase of wound healing, the cornea starts its initial response to epithelial removal and photoablation. In this period corneal sensitivity is decreased. In the intermediate phase the epithelium remodels itself to a normal structure. Nerve fibres regenerate inside the ablated area. However, corneal sensitivity is still decreased because a large number of fibroblasts populates the anterior stroma which corresponds to a clinical subepithelial haze and loss of refractive effect. In the long-term phase the subepithelial stroma remodels itself and corneal haze is diminished. However, ablating more than approximately 100 Microns leads to instable refractive results and a decreased corneal sensitivity. The more stroma that is ablated, the worse is the sensitivity and even refractive stability.

Campos *et al.* reported a temporary slight decrease in corneal sensitivity in their patients after photorefractive keratectomy that did not persist for longer than 3 postoperative months [8]. Compared with their study we noticed a slight hypoaesthesia even 6 months after ablation in patients with a preoperative myopia up to 15 D and a markedly reduced corneal sensitivity in patients with a preoperative myopia up to 25 D. This difference between these two studies might be explained by the different corneal sensitivity measurement techniques. Using the Draeger electromechanical optical-controlled aesthesiometer is more precise than using the Cochet-Bonnet aesthesiometer [4].

Five patients who underwent surgical procedures to correct higher amounts of myopia developed extensive subepithelial fibrosis and an incomplete return of corneal sensation. However, the relationship between the depth of ablation, amount of postoperative subepithelial haze, and return of corneal sensation is not clear at this time, but will require larger prospective studies [9].

Histopathological observations on a human specimen 4 months after Excimer-Laser ablation with a previous myopia of 7 D and an astigmatism of 3 D showed a destroyed Bowmans membrane in the corneal centre. The epithelial layer in this area is thickened up to 12 cells compared to a normal cell of 6 to 8 cells. The basal layer of this ablated zone is irregular, there is no stable junction between epithelial cell layer and basal layer. Proteoglycans can be found and an increase of keratocyte migration. These findings indicate that the subepithelial nerve fibre plexus is reduced, that the nerve fibre regeneration might be reduced due to the absence of Bowmans layer and to several vacuoles in the superficial stroma.

In summary, corneal refractive procedures might lead to a marked delay of reinnervation within the corneal centre whatever method is used. New questions have arisen and more questions have been asked by other investigators. The numerous problems of corneal wound healing have not yet been exhaustively investigated. A rich harvest of clinical applications should result from these investigations.

REFERENCES

1 SB Koenig, RA Berkovitz, RW Beuermann, MB McDonald. Corneal sensitivity after Epikeratophakia. *Ophthalmology*, 1983; **90**: 1213–1218.

2 H Biermann, G Grabner, I Baumgartner, M Reim. Zur Hornhautsensibilität nach Epikeratophakia. *Klin. Mbl. Augenheilk.*, 1992; **201**: 18–21.

3 IA Shivitz, PN Arrowsmith. Corneal sensitivity after radial keratotomy. *Ophthalmology*, 1988; **95**: 827–831.

4 J Draeger. *Corneal sensitivity.* Wien/New York, Springer, 1984.

5 T Chan-Ling, K Tervo, T Tervo, A Vannas, B Holden, L Eranko. Long-term neural regeneration in the rabbit following 180° limbal incision. *Invest. Ophthalmol. Vis. Sci.*, 1987; **28**: 2083–2087.

6 T Chan-Ling, A Vannas, B Holden, D O'Leary. Incision depth affects the recovery of corneal sensitivity and neural regeneration in the cat. *Invest. Ophthalmol. Vis. Sci.*, 1990; **31**: 1533–1541.

7 EA Linnick. Sostoinie chuvstvitel'nosti rogovitsy u bol'nykh posle perednei radial keratotomii. *Oftalmol. Zh.*, 1984; **3**: 164–167.

8 M Campos, L Hertzog, JJ Garbus, BS McDonnell, J Peter. Corneal sensitivity after photorefractive keratectomy. *Am. J. Ophthalmol.*, 1992; **114**: 51–54.

9 M Kohlhaas, J Draeger, A Böhm, M Lombardi, M Abbondanza, M Zuppardo, M Görne. Zur Aesthesiometrie der Hornhaut nach refraktiver Hornhautchirurgie. *Klin. Mbl. Augenheilk.*, 1992; **201**: 221–223.