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Anatomic differences between a normal and two keratoconus corneas

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SUMMARY

Keratoconus is an anatomic deformity of the cornea characterized by progressive thinning and a cone-shaped protrusion of the central cornea. Thinning corneal disorders, such as keratoconus, should be identified before excimer laser refractive surgery.

An Orbscan System (Orbscan Corneal Topography System II, Orbscan Inc., Salt Lake City, UT, USA) was used to analyse and compare corneal thickness values and the anterior and posterior corneal elevation maps of three subjects who wished to undergo excimer laser refractive surgery. The quantitative differences between the minimum thickness value of the entire cornea and the values obtained in the central and paracentral cornea of the subjects were also analysed.

Analysis of corneal thicknessess revealed that normal corneas had higher central and paracentral values. Greater differences were found between the thinnest site of the entire cornea and the paracentral areas in the keratoconic corneas than in the normal cornea. The cone-shaped protrusion was detected in the anterior and posterior corneal elevation maps of one subject but only in the posterior elevation map of the other keratoconus subject. The detection of corneal anatomic deformities, such as keratoconus, should include the analysis of corneal thickness values and the analysis of both anterior and posterior corneal elevation maps.

Key words: Cornea – Corneal topography – Keratoconus – Corneal thickness

INTRODUCTION

Keratoconus is an anatomic deformity of the cornea characterized by progressive thinning and a cone-shaped protrusion of the central cornea. Typically, it presents in early adulthood (Rabinowitz, 1998) but the aetiology of keratoconus remains unclear.

The thinning of the corneal stroma and the resulting ectasia are presumed to be due to an abnormality of the corneal collagen or extracellular matrix (Rabinowitz, 1998). Although many cases occur sporadically, twin and family studies suggest that there is, at least in part, a genetic basis to the condition (Heaven et al., 2000). Candidate genes include those that code for the components of collagen.

Currently, assessment of corneal thickness values is of great importance for refractive surgeons because measurement of corneal thick-

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ness must be carried out before excimer laser eye surgery is performed (Pricet et al., 1999).

The basis of laser ablative refractive procedures is to modify the corneal anatomy in order to correct refractive errors. It has been stated that thinning corneal disorders, such as keratoconus, are a contraindication for excimer laser ablative refractive procedures (Schmitt-Bernard et al., 2000). Thus, corneas with anatomic deformities, such as keratoconus, should be identified because they may be at risk in excimer laser refractive surgery.

Early keratoconus is difficult to detect using clinical tests (Burns et al., 2004). However, scanning-slit corneal topography (SST) is a technique that allows anatomists and ophthalmologists to detect corneal thinning and changes in the anterior and posterior corneal elevation, even if the subject does not present clinical symptoms of keratoconus.

In light of the above, here we report an SST study of the cornea of three subjects who wished to undergo excimer laser refractive surgery.

Case report

We carried out SST (Orbscan Corneal Topography System II, Orbscan Inc., Salt Lake City, UT, USA) on three corneas of three different subjects who were candidates for excimer laser refractive surgery. The work was performed in accordance with the World Medical Association's Declaration of Helsinki and written informed consent was obtained from the patients.

SST creates true 3-D maps from the anterior segment of the eye using measurements based on the Scheimpflug principle (Rabsilber et al., 2003). The Orbscan system measures anterior and posterior corneal elevation (relative to a best-fit sphere), surface curvature, and corneal thickness values using a scanning-slit mechanism (Liu et al., 1999). Corneal thickness is calculated by measuring the distance in elevation between the anterior and posterior surfaces of the cornea (Rabsilber et al., 2003). In our study the corneal thickness readings were averaged in a 2-mm-diameter circle at the centre of the cornea and in temporal, superotemporal, inferotemporal, nasal, inferonasal and superonasal corneal areas, each located 3 mm from the visual axis. The minimum thickness of the entire corneal surface was also recorded. An Orbscan System II was used on the three subjects, with an acoustic equivalent factor of 0.92, as recommended by the manufacturer.

SST showed that one of the subjects had no keratoconus (referred to as normal cornea in this manuscript) while the other two were diagnosed with keratoconus (subjects identified as keratoconus 1 and keratoconus 2 in this manuscript).

Analysis of the corneal thickness revealed that the normal subject had higher values than those obtained in the two keratoconic subjects (Table 1).

Table 2 shows greater differences between the thinnest site of the entire cornea and the paracentral areas in the keratoconic corneas than in the normal cornea.

Table 1. Corneal thickness values obtained in the corneas analysed (micrometers).

	Sex	AG	MT	CT	SN	N	IN	ST	T	IT
Keratoconus 1	Male	32	384	395	569	583	553	547	542	546
Keratoconus 2	Female	27	462	477	646	618	601	648	596	584
Normal cornea	Female	30	577	589	710	693	664	689	647	641

AG = age (years old); **MT** = minimum thickness of the entire cornea; **CT** = central corneal thickness; **SN** = superonasal thickness; **N** = nasal thickness; **IN** = inferonasal thickness; **ST** = superotemporal thickness; **T** = temporal thickness; **IT** = inferotemporal thickness.

Table 2. Quantitative differences between the minimum thickness value of the entire cornea and the values obtained in the central and paracentral cornea (micrometers).

	MT *vs* C	MT *vs* SN	MT *vs* N	MT vs IN	MT *vs* ST	MT *vs* T	MT *vs* IT
Keratoconus 1	11	185	199	169	163	158	162
Keratoconus 2	15	184	156	139	186	134	122
Normal cornea	12	133	116	87	112	70	64

MT = minimum thickness of the entire cornea; **C** = central thickness; **SN** = superonasal thickness; **N** = nasal thickness; **IN** = inferonasal thickness; **ST** = superotemporal thickness; **T** = temporal thickness; **IT** = inferotemporal thickness.

Moreover, we detected anatomic differences in the anterior and posterior corneal elevation maps between the two keratoconic corneas (identified as keratoconus 1 and keratoconus 2). Figure 1 presents the anterior and posterior corneal elevation maps of the subject identified as keratoconus 1, while Figure 2 presents the anterior and posterior corneal elevation maps of the subject identified as keratoconus 2. Finally, Figure 3 presents the anterior corneal elevation maps of the normal cornea and the subject identified as keratoconus 2.

Discussion

We present an analysis of corneal thickness values and anterior and posterior corneal elevation by means of SST. The most frequently used technique for the measurement of corneal thickness is ultrasound pachymetry (Doughty

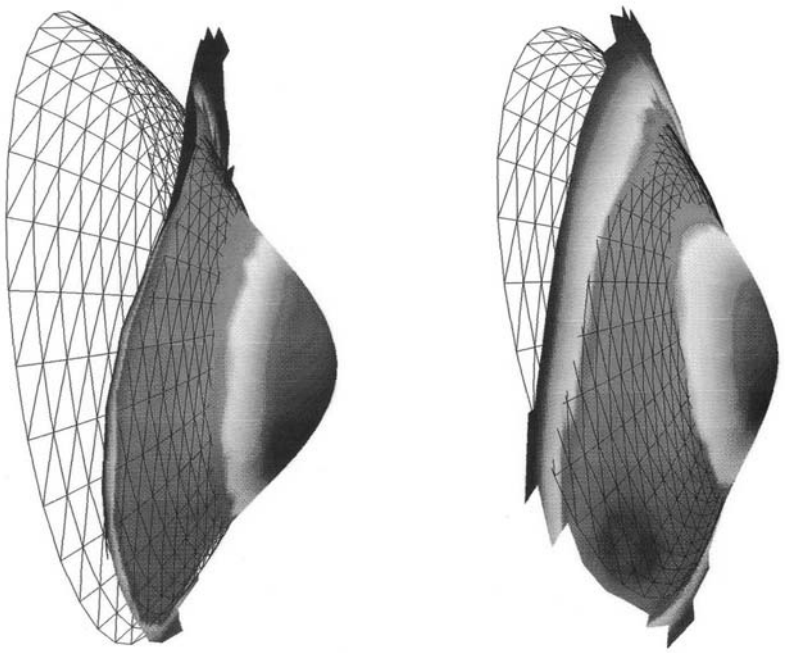

Fig.1. Scanning-slit corneal topography detected the cone-shaped protrusion of the central cornea in both posterior (left-hand image) and anterior (right-hand image) corneal elevation maps of the subject identified as keratoconus 1.

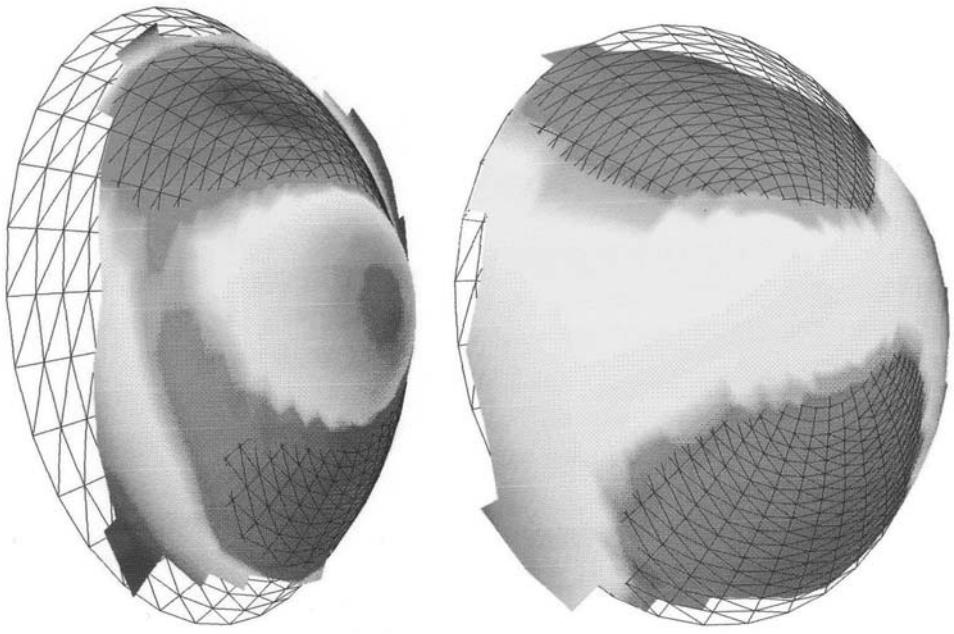

Fig. 2. Scanning-slit corneal topography only detected the cone-shaped protrusion of the central cornea in the posterior corneal elevation map (left-hand image), but not in the anterior elevation map (right-hand image), of the subject identified as keratoconus 2.

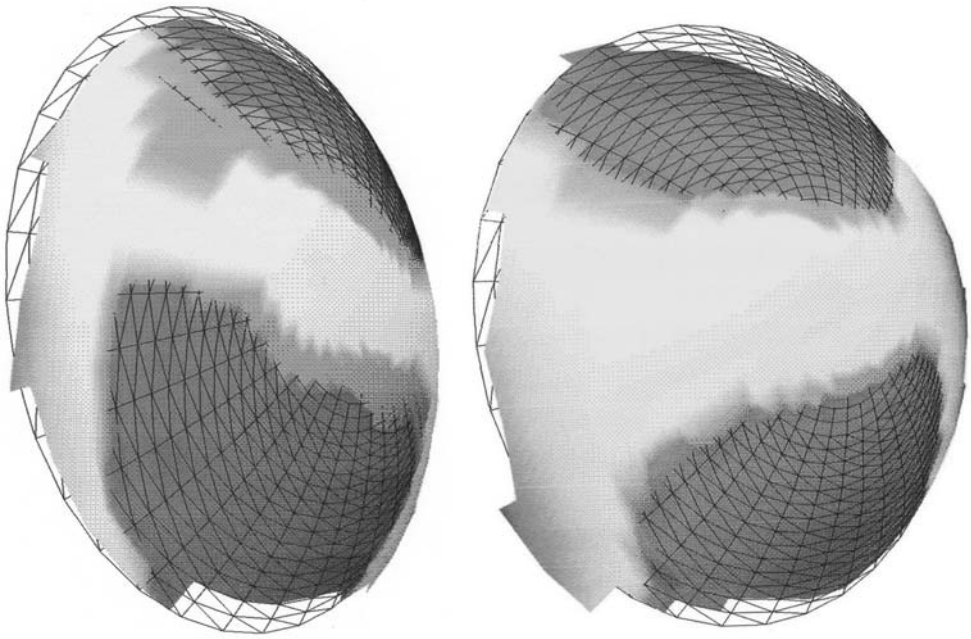

Fig. 3. The left hand image presents the anterior corneal elevation map of the normal cornea while the right hand image presents the anterior corneal elevation map of the subject identified as keratoconus 2. Neither image presented the cone-shaped protrusion of the central cornea.

and Zaman, 2000). However, during this technique it is difficult to locate the same points of measurement accurately in serial examinations (Liu et al., 1999); central and paracentral corneal thicknesses cannot be measured simultaneously and, in addition, it is not possible to locate the thinnest site of the entire cornea.

In a review study, Cairns and McGhee (2005) observed that SST measurements of central and peripheral pachymetry were 15 and 95 microns greater than ultrasound pachymetry. In order to minimize the differences between SST and ultrasound measurements, the manufacturers introduced the acoustic equivalent factor of 0.92 used in this study.

We believe this is the first study to analyse the differences between the minimum thickness value of the entire cornea and the values obtained in the central and paracentral cornea of keratoconus corneas. In our study we observed a general thinning in the keratoconus corneas. It has been suggested that even though the thinning in keratoconus occurs primarily in the stroma, the corneal epithelium may also be involved in the development of the disease (Sawaguchi et al., 1998). Histopathologic and ultrastructural studies have demonstrated that in the early stages of the disease fragmentation of the epithelium basement occurs, with disintegration of the Bowman's layer and fibrillation of the anterior stroma. The central cornea then becomes thinned, with destruction of the Bowman layer and stromal scarring (Sawaguchi et al., 1998). However, we found that corneal thinning was generalized and that it did not only occur in the central cornea.

SST enables the morphology of the cornea to be analysed by means of study of the anterior and posterior corneal elevation. Thus, ultrasound pachymetry cannot detect morphologic differences between normal and keratoconic corneas. However, the anatomic differences between normal and keratoconic corneas can be shown by analysing corneal elevation.

In the past, 3-dimensional electron microscopic studies of keratoconus corneas were made (Sawaguchi et al., 1998). However, SST makes it possible to analyse the anterior and posterior corneal elevation maps without contacting the ocular surface, and the results are obtained immediately.

Corneal elevation analysis by means of SST revealed the anatomic differences between the normal and the keratoconus corneas. Moreover, analysis of the posterior corneal elevation maps disclosed the keratoconus in subjects with reduced corneal thickness values but with anterior corneal elevation maps similar to those observed in normal corneas. Thus, examinations to detect corneal anatomic deformities such as keratoconus should include an analysis of corneal thickness values and an

analysis of both anterior and posterior corneal elevation maps in all subjects before excimer laser refractive surgery can be performed.

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