ORIGINAL ARTICLE

Technology of the Local Cross-linking (Part 1): Keratotensotopography and Vacuum-compression Topographic Test—New Diagnostic Possibilities for Studying the Local Biomechanical Properties of Cornea

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ABSTRACT

Aim: The aim of this study is the development and evaluation of clinical significance methodology for determining mechanical stress (MS) and elasticity of the cornea comparable to its topographic settings.

Materials and methods: Combining the data of optical pachymeter, keratotopography, and pneumotonometry through our special software allows us to get Lokolink MS distribution in the cornea in the form of maps, which we propose to call keratotensotopogram (KTT).

Results: Normal KTT has the form of concentric, uniform, and symmetrical zones. In keratoconus (KC), the corneal center is more tense than peripheral part of cornea. The focus zone of KC may coincide with the region of maximum MS or may be out of this area. In the process of vacuum-compression test, the reaction of profile of the cornea was markedly different in patients with healthy corneas and in patients with KC. In all cases of healthy cornea, the curvature increased in the center. In KC, the cornea became more flat in the center under high intraocular pressure (in 100% of cases).

Conclusion: The KTT ineyes with the cornea without pathology differs from KTT in the different cases of KC. The KTT can be used for the diagnosis and prediction of cornea's state to perform the plan of UV irradiation areas for corneal collagen cross-linking.

Keywords: Corneal collagen cross-linking, Corneal topography, Keratotensotopogram, Vacuum-compression test.

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INTRODUCTION

At the present time, it is the need to develop the methods for *in vivo* assessment of biomechanical properties of cornea. Existing methods rely on different physical principles.[1-4] The most currently used techniques[3] do not allow us to estimate the distribution of the mechanical properties of cornea on its surface and are integrated. To study keratoconus (KC), we require techniques that allow us to detect local changes in the rigidity of the cornea that may reflect its topographical features. For more complete study of the biomechanics of cornea, it is necessary to estimate not only the distribution of mechanical stress (MS) but also their dependence on its stretchability. We have already published the data that allow us to estimate only the distribution of MS in the cornea in relation of its topography that does not allow us to estimate its elongation.[5]

THE PURPOSE OF THE STUDY

To develop and evaluate the clinical significance of novel methodology for determining MS and elasticity of the cornea and correlate to its topographic characteristics.

MATERIALS AND METHODS

A comparative study was conducted in patients that were treated with local crosslinking (Table 1). In every case the corneal zones with high and low rigidity with altered elasticity were identified (reduced or elevated mechanical stress).[6]

Table 1: Clinical characteristics of the patients

Eyes (patients), n	56 (72)
Average age (range)	32 (18-40)
Female (%)	64
Classification of keratoconus, n (%)	
Suspected keratoconus (patients)	(1) 2
Stage 1	(27) 31
Stage 2	(22) 33
Stage 3	(6) 6

The inclusion criteria of patients in the study were: KC stage I to III (concerning Amsler),[7] absence of associated ocular pathology.

Exclusion criteria of patients were KC stage IV, related ocular pathology, and previous surgical intervention on the cornea.

The reference group included 15 patients without pathology of the cornea in the age group 18 to 40 years.

Method to study the distribution of MS was carried out as follows: Performing corneal topography using corneal topograph Orbscan II. For further calculation, we used mean power topography's modes and optical pachymetry map. The data in each point of previous topograms are counted according to the Laplace equation,

$$T = PR/2d$$

To obtain the distribution of tension MS (T), data of corneal curvature (R) were multiplied by the amount of intraocular pressure (IOP) (P) and divided by twice the thickness of the cornea (d). To accelerate the process of calculations, special software calculator Lokolink was used. The resulting topogram we called keratotensotopogram (KTT). It shows the distribution of MS in the cornea, we consider MS also as value characterized by the rigidity of the cornea, i.e., its ability to resist deformation. A normal KTT is shown in Fig. 1 in comparison with the case of KC stage III. To study the distensibility of the cornea, we used vacuum-compression test with the help of vacuum apparatus[8]- in the field of sclera special hollow cone created vacuum - 40 mm Hg (Fig. 2) and in this moment, we registered corneal topogram. Topography before and after the vacuum-compression processed using differential maps and it clearly becomes evident how the curvature of the cornea changed under the influence of IOP. The ratio of stress and strain in the cornea was evaluated at the point corresponding to the visual axis.

RESULTS

As can be seen in Fig. 1, the distribution of MS in a healthy cornea of the eye and affected with KC is significantly different. At the initial stage of KC the areas of reduced rigidity can be clearly identified. In the process of vacuum-compression test, the reaction of the profile of cornea was markedly different in patients with healthy corneas and in patients with KC (Fig. 3). A healthy cornea in all cases increased the curvature in the center. In KC, the cornea is more flat in the center under the IOP elevation (in 100% cases).
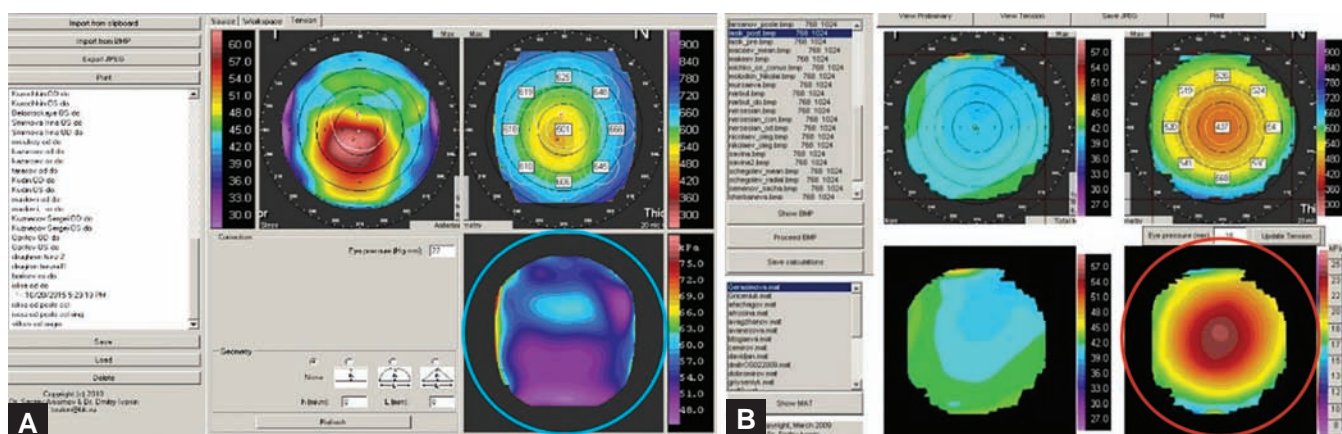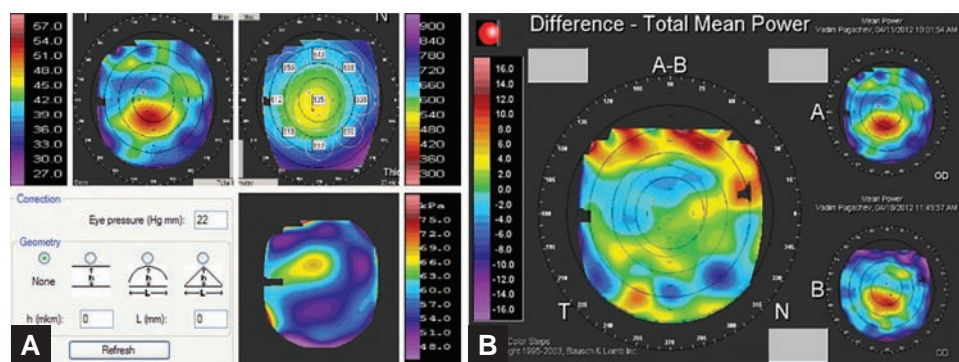

Figs 1A and B: Keratotensotopogram in case of keratoconus (II-III stage) in blue ring (rigidity is too low) and normal KTT in red ring
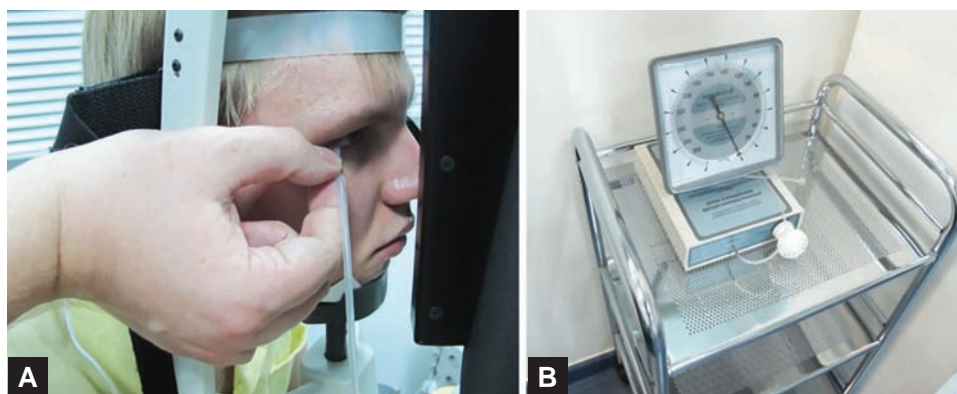
Figs 2A and B: Topographic vacuum-compression test–a method of determining the elasticity of the cornea in keratoconus
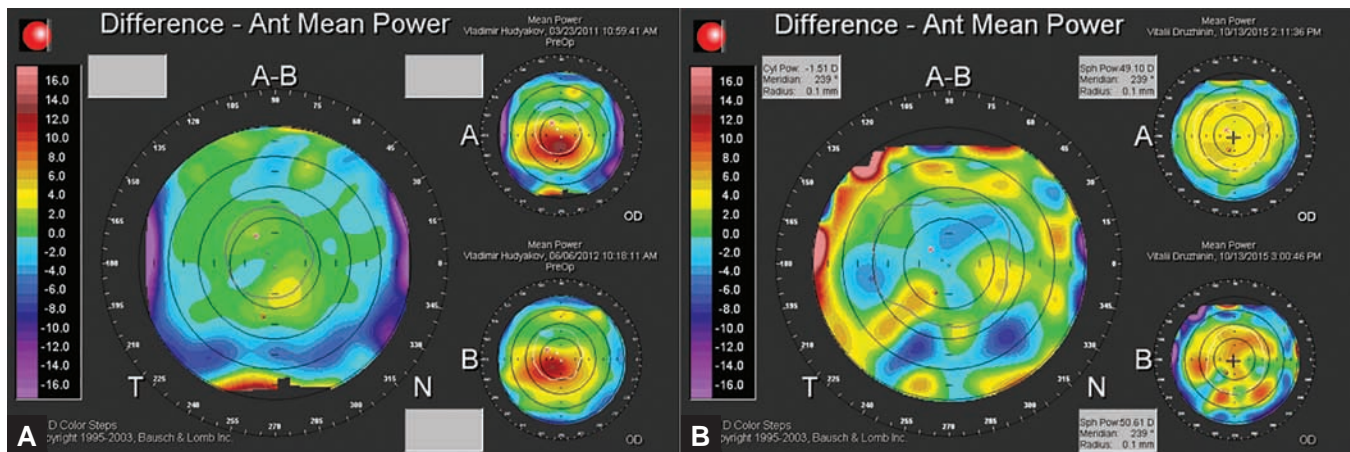
Figs 3A and B: Differential maps with vacuum-compression test. On the left–keratoconus; on the right–normal cornea

Figs 4A and B: Zone of reduced rigidity of the cornea in keratoconus: (A) Keratotensotopography; (B): differential map after vacuum-compression test

While we checked more advanced stage of KC, the flattening was more noticeable. This indicates the loss of elastic response of the cornea in the region of the apex of the cone. Protrusion of the cornea in KC remains noticeable on the periphery. This area corresponds to the region of reduced rigidity to be detected by KTT (Fig. 4).

We noted that during vacuum compression, the apex of the cone became more flat, and at the same time on periphery, the cornea was expanded. On KTT, the same eye (right) was also determined by the reduction of the rigidity at the periphery of the cornea.

CONCLUSION

The KTT in eyes with the cornea without pathology differs from KTT in the keratoconic cornea. The KTT and vacuum-compression test can be used in the diagnosis and prediction of biomechanical quality of cornea. Zones of reduced rigidity in the paracentral region contributed hyperextension of the cornea and formation of the apex of KC. Strengthening of weakened areas of cornea, e.g., using corneal segments explains the mechanism of their effect. The proposed diagnostic algorithm allows to determine more precisely areas of lesser corneal rigidity and helps us to provide treatment more accurately particularly in planning localization of UV irradiation for corneal collagen cross-linking.

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