Biomechanics: a complementary concept for understanding the cornea

Corneal biomechanics is the science that studies the behaviour and deformation of corneal tissue in the steady state, on being subjected to any external action. Thus, corneal biomechanics explores the function and structure of the cornea, and seeks to establish physical and mathematical bases that define it.

Although the concept seems technical and innovative, in reality, its essence has coexisted with our clinical practice for decades, and is implicit in most of our therapeutic and surgical procedures. Corneal biomechanics will become an indispensable tool for characterising the healthy cornea and differentiating it from the diseased one, before this has resulted in an alteration of its morphological parameters.

The morphological parameters for defining the cornea (thickness and curvature) are fundamental for characterising it, but they are not sufficient in the field of refractive surgery, especially when assessing the suitability of a patient to undergo surgery. Nowadays, in addition to characterising the cornea using morphological parameters, it is essential to determine its biomechanical properties\(^1-3\). Hence, it is important to establish which factors affect the biomechanics of the cornea, and which parameters characterise it.

There are multiple factors that affect the corneal biomechanics. The geometry of the cornea is obtained mainly through the tissue characteristics themselves, such as thickness, density, hydration, composition and collagen cross-linking (intra-corneal factors); however, other external agents also affect it (extra-corneal factors), especially intraocular pressure, together with other external actions such as atmospheric pressure, the compression exerted by the eyelids and the traction exerted by the extra-ocular and ciliary muscles. Furthermore, the soft tissues of the body have the ability to modify their structure and behaviour according to the environment and the mechanical, biological or chemical stimuli that surround them. Thus, excessive mechanical friction can induce deformation of the cornea, and an acute glaucoma can cause corneal opacification. In addition, systemic diseases also form part of the biological environment of the cornea, and can modify the behaviour and structure of the corneal tissue, as is the case in collagen diseases for example.

The huge growth of refractive surgery in the 1990s meant the development of technological devices for studying the cornea. The potential to cause an ectasia with our surgical intervention encouraged and continues to inspire the use and development of diagnostic instruments that provide more information on corneal shape and thickness (topography-tomography and pachymetry systems). New devices have been developed in recent years that can assess the structural properties, confirming the biomechanical alterations in diseased corneas. Right now, the possibility of detecting structural alterations opens a new diagnostic window for understanding the cornea.

The practical applications of biomechanics include two aspects in parallel development: the clinical diagnostic aspect, based on the study and development of devices for clinical measurement of the corneal biomechanics, useful in the diagnosis and in vivo assessment of certain eye diseases; and the aspect of development of behavioural models, which create and improve biomechanical models that can analyse and predict the response of the cornea in surgical procedures, such as refractive surgery, incisional surgery, intra-stromal segments or corneal cross-linking\(^4,5\).
Recognising the properties of the corneal tissue structure also marks a beginning in enriching the study and understanding of clinical procedures as routine as tonometry\textsuperscript{1}, and in the assessment of clinical or sub-clinical diseases such as keratoconus\textsuperscript{6,7}, post-surgical ectasias, endothelial dystrophies\textsuperscript{8}, keratoplasties or glaucoma\textsuperscript{1}.

If we consider an ectasic disease like keratoconus, technology has marked different evolutionary steps in its diagnosis, associated with the refractive surgery setting:

1. Clinical diagnosis. Clinical keratoconus. The diagnosis was made prompted by a refractive alteration that caused a visual deficit, and was proven with the clinical examination with slit-lamp, keratometry and refractometry. The advent of topography confirmed the protrusion and thinning of the cornea in the earlier stages.

2. Topographic diagnosis. Sub-clinical keratoconus. With the widespread use of topography, the concept of sub-clinical keratoconus arose. This is a condition that, without causing clinical signs, presents pathological or suspicious topographic signs that make refractive surgery inadvisable.

3. Biomechanical diagnosis. This would correspond to an early diagnosis stage. The arrival of the optical response analyser (ORA), and other subsequent equipment such as the CorVis\textsuperscript{*}, verified a notable structural deterioration in diseases such as keratoconus. Diagnosing a structural weakness prior to the change in shape would lead to a new diagnostic step that we could call "sub-topographical or pre-topographical keratoconus", such as that found in the contralateral eyes of patients with a keratoconic eye, with no evidence of topographic abnormalities, but with a reduction in their biomechanical parameters.

At present, the study of ocular biomechanics is not limited to knowledge of the structural alteration in cases of corneal diseases\textsuperscript{1}. Studies show that some corneal biomechanical parameters are altered in eye diseases such as glaucoma, and may reflect the state of other ocular structures that share their embryonic origin, such as the lamina cribrosa. In turn, ocular processes such as myopia magna have altered corneal biomechanics, which may be reflected in the state of the tissues that share their mainly collagen structure, such as the sclera. Recent studies have even found a relationship between systemic diseases, such as rheumatoid arthritis and a biomechanical deterioration detected with the ORA. All this suggests that the study of the corneal biomechanics with clinical devices that are non-invasive and easy to use (ORA, CorVis\textsuperscript{*}) could become a new diagnostic window for both ocular and systemic diseases, where it is difficult to determine the structural status of the damaged tissues, such as joints, synovial tissue, sclera or lamina cribrosa.

We can conclude that the study of biomechanics enriches our knowledge of diseases that affect the eye, and will provide new information to better understand its physiopathology. The application of new technologies to knowledge of the cornea allows us to redefine the concepts and thus move forward.

REFERENCES


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