ORA waveform-derived biomechanical parameters to distinguish normal from keratoconic eyes

Parâmetros biomecânicos derivados da forma da curva do ORA para discriminar olhos normais de ceratocones

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ABSTRACT

Purpose: To evaluate the ability of the Ocular Response Analyzer (ORA; Reichert Ophthalmic Instruments, Buffalo, NY) to distinguish between normal and keratoconic eyes, by comparing pressure and waveform signal-derived parameters.

Methods: This retrospective comparative case series study included 112 patients with normal corneas and 41 patients with bilateral keratoconic eyes. One eye from each subject was randomly selected for analysis. Keratoconus diagnosis was based on clinical examinations, including Placido disk-based corneal topography and rotating Scheimpflug corneal tomography. Data from the ORA best waveform score (WS) measurements were extracted using ORA software. Corneal hysteresis (CH), corneal resistance factor (CRF), Goldman-correlated intraocular pressure (IOPg), cornea-compensated intraocular pressure (IOPcc), and 37 parameters derived from the waveform signal were analyzed. Differences in the distributions among the groups were assessed using the Mann-Whitney test. Receiver operating characteristic (ROC) curves were calculated.

Results: Statistically significant differences between keratoconic and normal eyes were found in all parameters ($p<0.05$) except IOPcc and W1. The area under the ROC curve (AUROC) was greater than 0.85 for 11 parameters, including CH (0.852) and CRF (0.895). The parameters related to the area under the waveform peak during the second and first applanations (p2area and p1area) had the best performances, with AUROCs of 0.939 and 0.929, respectively. The AUROCs for CRF, p2area, and p1area were significantly greater than that for CH.

Conclusion: There are significant differences in biomechanical metrics between normal and keratoconic eyes. Compared with the pressure-derived parameters, corneal hysteresis and corneal resistance factor, novel waveform-derived ORA parameters provide better identification of keratoconus.

Keywords: Cornea; Keratoconus; Corneal diseases; Refractive surgical procedures; Software; Biomechanics

RESUMO

Objetivo: *Avaliar a capacidade do* Ocular Response Analyzer *(ORA; Reichert Ophthalmic Instruments, Buffalo, NY) em discriminar olhos com ceratocone de olhos normais e comparar parâmetros derivados da pressão dos parâmetros derivados da forma da curva.*

Métodos: *Estudo comparativo retrospectivo série de casos que incluiu 112 pacientes com olhos normais e 41 pacientes com ceratocone bilateral. Um olho de cada indivíduo foi randomicamente selecionado para análise. O diagnóstico de ceratocone foi baseado em exame clínico, incluindo topografia de Plácido e tomografia Scheimpflug. Informação do melhor* waveform score *foi extraída do software do ORA. Histerese corneana (CH), fator de resistência corneana (CRF), pressão intraocular correlacionada com Goldman (IOPg), pressão intraocular compensada pela córnea (IOPcc) e 37 novos parâmetros derivados da forma da curva do sinal do ORA foram analisados. Diferenças nas distribuições dos grupos foram avaliadas pelo teste Mann-Whitney. Curvas ROC foram calculadas.*

Resultados: *Diferenças estatisticamente significantes foram encontradas entre os olhos normais e ceratocones em todos os parâmetros ($p<0,05$) salvo IOPcc e W1. A área sob a curva ROC (AUROC) foi maior que 0.85 em 11 parâmetros, incluindo CH (0,852) a CRF (0,895). Os parâmetros relacionados com a área sob o pico da forma de onda durante a segunda e primeira aplanação (p2area e p1area) obtiveram as melhores performances, com AUROCs de 0,939 e 0,929, respectivamente. Os valores de AUROCs do fator de resistência corneana, p2area e p1area foram significativamente maiores que os valores de histerese corneana.* ***Conclusão:*** *Existem diferenças significantes nas medidas biomecânicas entre olhos normais e com ceratocone. Comparados com os parâmetros derivados da pressão, histerese corneana e fator de resistência corneana, os parâmetros derivados da forma da curva proporcionaram melhor identificação dos ceratocones.*

Descritores: *Córnea; Ceratocone; Doenças da córnea; Procedimentos cirúrgicos refrativos; Software; Biomecânica*

INTRODUCTION

In 2005, the Ocular Response Analyzer (ORA; Reichert Technologies, Depew, New York) was launched as the first commercial device claiming to provide *in vivo* measurements of corneal biomechanics[1]. It utilizes a dynamic bi-directional applanation process in which two applanation pressure measurements are recorded: the first, while the cornea is moving inward (P1); and the second, while the cornea returns[2].

The primary output measurements, derived from the air puff recorded pressure during the first and second applanations, are Goldmann-correlated intraocular pressure (IOPg), defined as the average between P1 and P2; corneal hysteresis (CH), defined as the difference between P1 and P2; corneal resistance factor (CRF), which includes a constant factor designed to optimize the correlation with central corneal thickness (CCT); and corneal compensated intraocular pressure (IOPcc), which includes a constant based on CRF for correlation with CCT[2].

Further information about the corneal response is provided by infrared waveform signal analysis, which corresponds to the deformation movement of the cornea caused by the air puff[3]. These novel

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