Interchangeability between Placido disc and Scheimpflug system: quantitative and qualitative analysis

Permutabilidade entre o disco de Plácido e o sistema Scheimpflug: análise quantitativa e qualitativa

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ABSTRACT

Purpose: Many systems try to replace Placido disc-based topographers, such as those based in Scheimpflug principles. The purpose of this study is to check if they are interchangeable.

Methods: Quantitative analysis evaluated data obtained from EyeSys and Pentacam, i.e. simulated keratometric values, in addition to flattest and steepest keratometric values. Sixty-three maps from each device (EyeSys scale=0.5 D; Pentacam scale= 0.25 D) were used for the comparison. Qualitative analysis selected 10 EyeSys and 15 Pentacam topographies used in the quantitative evaluation. Aspheric, keratoconus suspects (KS) and established keratoconus corneas were included. Four groups (children [CH], non-physicians adults [AD], residents in ophthalmology [OP] and refractive surgeons [RS]) were asked to match the topographies belonging to the same eye.

Results: Analysis showed that the parameters are correlated; however they are not clinically similar. In the qualitative analysis, the percent of correct matches increased when KS was removed. CH group was statistically different from every group in these comparisons. When only KS was considered, CH *vs.* OP, CH *vs.* RS and AD *vs.* RS remained statistically different. AD *vs.* OP showed no relevant difference in any comparison.

Conclusions: The systems are not fully interchangeable, yet they are correlated. Practitioners who are adapting to Pentacam should use the 0.25 D scale maps and transform formulas that use EyeSys parameters. Only with persistent training may the topographies be properly matched; KS corneas are more difficult to be correctly paired.

Keywords: Corneal topography; Optometry; Refractive surgical procedures; Keratoconus; Cornea

RESUMO

Objetivo: *Muitos sistemas tentam substituir os topógrafos baseados no disco de Plácido, como aqueles baseados nos princípios de Scheimpflug. O objetivo deste estudo é verificar se eles são intercambiáveis.*

Métodos: *A análise quantitativa avaliou dados obtidos através do EyeSys e do Pentacam, os valores de ceratometria simulada, além dos menores e maiores valores ceratométricos observados. Sessenta e três mapas de cada dispositivo (escala do EyeSys=0,5D; escala do Pentacam=0,25D) foram utilizados na comparação. Para a análise qualitativa, foram selecionadas 10 topografias do Pentacam e 15 do EyeSys. Córneas asféricas, suspeitas de ceratocone (KS) e com diagnóstico de ceratocone foram incluídas. Quatro grupos (crianças [CH], os adultos não-médicos [AD], residentes em oftalmologia [OP] e cirurgiões refrativos [RS]) foram convidados a corresponder as topografias pertencentes ao mesmo olho.*

Resultados: *As análises mostraram que os parâmetros estão correlacionados, no entanto, não são clinicamente similares. Na análise qualitativa, o porcentual de acertos aumentou quando KS foram removidas. O grupo CH foi estatisticamente diferente de qualquer outro grupo, nestas comparações. Quando somente KS foram consideradas, CH vs. OP, CH vs. RS e AD vs. RS manteve-se estatisticamente diferente. AD vs. OP não mostrou nenhuma diferença relevante em qualquer comparação.*

Conclusões: *Os sistemas não são totalmente intercambiáveis, porém são correlacionados. Os profissionais que estão se adaptando ao Pentacam devem utilizar os mapas de escala 0,25 D e transformar fórmulas que usem parâmetros do EyeSys. Somente com treinamento persistente as topografias podem ser devidamente relacionadas; córneas KS são mais difíceis de ser pareadas corretamente.*

Descritores: *Topografia da córnea; Optometria; Procedimentos cirúrgicos refrativos; Ceratocone; Córnea*

INTRODUCTION

Placido disk corneal topography (PDCT) is the gold standard procedure to detect and diagnose corneal aberrations (i.e., keratoconus), analyze pre- and postoperative results of refractive surgery, and aid in contact lens fitting. Integrated values of central keratometry are also used to calculate intraocular lens (IOL) power in cataract surgery[1-3].

PDCT was the pioneer method in videokeratoscopes[4], whereby a patient's cornea is illuminated by concentric rings, which create an image that is reflected by the anterior surface of the cornea. The reflected image is computer analyzed, and a curvature color map of the corneal surface is generated[4]. PDCT is established as a valid and reliable method of corneal evaluation, and its use has become part of routine clinical practice[1-2,5]. The EyeSys corneal analysis system (EyeSys Laboratories, Houston, TX, USA) is based on this imaging method.

As new technologies have been developed, new instruments have become available, claiming performance similar to that of systems based solely on PDCT[3-4,6-8]. For example, the Orbscan II (Bausch & Lomb, Inc., San Dimas, CA, USA) uses a slit-scanning system associated with a Placido disk to obtain curvature and elevation measurements[6,9-10]. The Pentacam (Oculus Inc., Lynnwood, WA, USA) stands out as a possible successor of Placido disk-based systems for obtaining images of the anterior segment. It uses a rotating Scheimpflug camera, and a second camera detects and makes appropriate corrections for eye movements[3,8,11-12]. Pentacam is also faster than traditional

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Placido disk-based systems, since it may capture up to 50 slit images of the anterior segment in fewer than 2 seconds[13]. These new instruments aggregate different views of the anterior segment that are referred to as anterior segment tomographs. It is not known if PDCT is interchangeable with Scheimpflug-based corneal elevation (SBCE), which can be mathematically-derived to produce a model of corneal curvature[4].

Quantitative information of corneal topography color maps generated by the EyeSys and the Pentacam was analyzed. Qualitative curvature maps generated by each instrument were also compared, in order to check the interchangeability and correlation of both systems.

METHODS

Maps of 63 eyes from refractive surgery candidates at the Federal University of São Paulo, Paulista School of Medicine, Vision Institute, São Paulo, Brazil were selected from October to November, 2006. All corneal topographies obtained during this period were considered for this study. Maps were excluded if they presented poor quality or if the imaged eyes had opacities. Inclusion evaluation was performed by a single trained examiner. Topography exams were carried out in October and November of 2006.

For the quantitative analysis, central 3 mm simulated keratometric (SimK) values[14] (i.e., SimK1 and SimK2) and flattest and steepest keratometric (FK and SK, respectively) values obtained from those maps were analyzed. FK and SK were obtained through the analysis of the color scale provided by each instrument, being FK the minimum and SK the maximum value observed. Pupil centroid was the reference point used to centralize both devices[15-16].

For the qualitative analysis, 10 of the same 63 EyeSys curvature sagittal topographies used before, (two aspheric corneas, five keratoconus suspects [KS], and three keratoconus) and 15 of the same 63 anterior surface elevation Pentacam maps (five aspheric corneas, five KS, and five keratoconus) were selected to a "shuffle-and-match game". All maps were printed at similar scale (Figure 1). An examiner shuffled the maps and asked individual evaluators from four groups (15 children 10-13 years of age [CH]; 30 non-physician adults [AD]; 10 residents in ophthalmology [OP]; 10 refractive surgeons [RS]) to match each Pentacam map with its corresponding EyeSys map, i.e. they were asked to identify the same corneas according to the topographies. No time limit was imposed, and correct matches were recorded.

A pilot unpublished study performed by the authors determined that Pentacam 0.25 D scale maps were more frequently correctly matched with the EyeSys maps than were the 0.5 D scale images. Therefore, Pentacam 0.25 D maps were used for comparison with EyeSys maps.

All statistical analysis were performed with SPSS for Windows version 15.0 (SPSS, Inc., Chicago, IL, USA). For the quantitative analysis, mean difference, standard deviation (SD), and Bland-Altman limits of agreement[17] of the SimK and minimum and maximum scale values were determined using t tests for paired samples. In addition, the correlation between the parameters was calculated, using Spearman's rank correlation coefficient. For the qualitative analysis, Kruskal-Wallis test was used to compare the percentage of correct match across the four evaluator groups; afterwards, Mann-Whitney test was performed to compare the correct match of the four groups pairwise.

RESULTS

Quantitative analysis

The mean ± SD SimK1 values of EyeSys (43.15 ± 2.74) and Pentacam (43.05 ± 2.83) maps were similar, as were the mean SimK2 values (EyeSys=44.93 ± 3.54; Pentacam=44.94 ± 3.40). However, there were considerable differences in the FK and SK values generated by the two systems. The mean EyeSys FK was 40.32 ± 3.07, and the mean Pentacam FK was 35.45 ± 1.70 ($p<0.001$ EyeSys vs. Pentacam). The mean EyeSys SK was 47.49 ± 2.84, and the mean Pentacam SK was 50.44 ± 1.69 ($p<0.001$ EyeSys vs. Pentacam).

Table1 summarizes the results of the comparisons of EyeSys and Pentacam values.

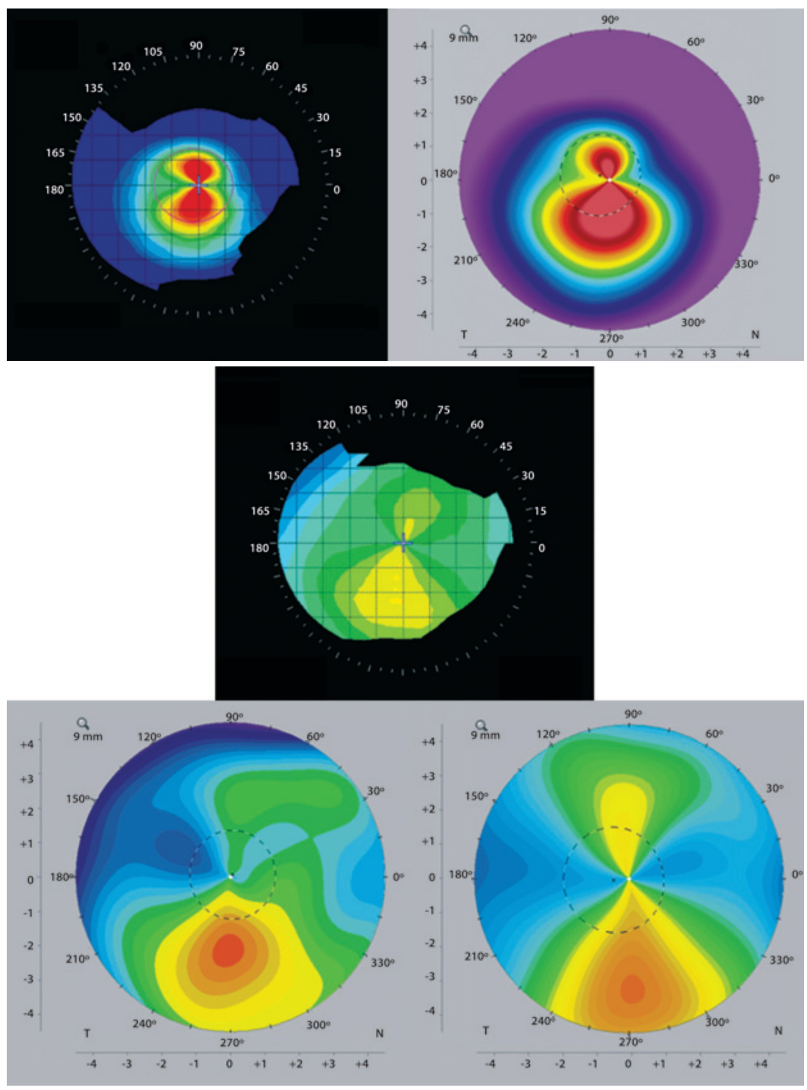

Figure 1. *Top pair*: Example of matched maps from EyeSys (left) and Pentacam (right) systems. *Bottom group*: A common error made in the qualitative analysis is demonstrated. The correct match for EyeSys map (top) is the bottom left Pentacam map. However, the Pentacam map on the right was frequently selected as a match for the EyeSys map, due to similarities in their shapes and colors.

Table 1. Comparison of keratometric values between EyeSys and Pentacam

Variable	EyeSys Mean (SD)	Pentacam Mean (SD)	Difference between EyeSys and Pentacam Mean (SD)	95% Limits of Agreement	P value
SimK1 (D)	43.15 (2.74)	43.05 (2.83)	0.10 (0.59)	-1.06 to 1.26	0.180
SimK2 (D)	44.93 (3.54)	44.94 (3.40)	-0.01 (0.44)	-0.87 to 0.85	0.860
FK (D)	40.32 (3.07)	35.45 (1.70)	4.86 (1.85)	1.23 to 8.49	<0.001
SK (D)	47.49 (2.84)	50.44 (1.69)	-2.95 (1.68)	-6.24 to 0.34	<0.001

SD= standard deviation; SimK= simulated keratometric value; D= diopter; FK= flattest keratometric value; SK= steepest keratometric value

Table 2. Spearman's ρ value for EyeSys and Pentacam parameters

Comparisons	Spearman (ρ)	P value
ESimK1 vs. PSimK1	0.982	<0.001
ESimK2 vs. PSimK2	0.988	<0.001
EFK vs. PFK	0.938	<0.001
ESK vs. PSK	0.959	<0.001

ESimK= EyeSys simulated keratometric value; PSimK= Pentacam simulated keratometric value; EFK= EyeSys flattest keratometric value; PFK= Pentacam flattest keratometric value; ESK= EyeSys steepest keratometric value; PSK= Pentacam steepest keratometric value

Spearman's r was calculated for each paired parameter analyzed. Results are detailed in table 2, where a strong correlation may be observed.

Qualitative analysis

Table 3 describes all qualitative analysis results.

There was a statistically significant tendency to make correct matches as evaluator age increased. The percent correct matches were significantly lower in the CH evaluator group compared with each of the other groups. The comparison between AD and RS was also significantly different. The percent correct matches of AD vs. OP and OP vs. RS were both not significantly different.

The percent correct matches for only aspheric and established keratoconus topographies or KS topographies alone was also analyzed. When only aspheric and keratoconus topographies were evaluated, the comparisons did not change their pattern, except for OP vs. RS, which was statistically significant.

When the analysis included only KS topographies, the percent correct matches decreased in every evaluator group and the CH group was no longer statistically different from AD group, but the difference remained when comparing CH with OP and RS groups.

DISCUSSION

As demonstrated by the quantitative results, SimK values generated by EyeSys and Pentacam systems were similar, which could indicate that the systems are interchangeable for these parameters. However, the calculated limits of agreement were wide, indicating that, clinically, the systems differ from each other, even though the statistical difference between them is not significant. Therefore, both devices may not be interchangeable, considering these factors. SimK1 and SimK2 readings are clinically useful; for instance, they can be used to calculate IOL power during surgical procedures[1-3]. In fact, an important implication of this study is the use of Scheimpflug devices for such an application. Nevertheless, the values obtained from Pentacam should not be used in formulas that were developed using, originally, EyeSys values. Therefore, prior to using Pentacam values in these cases, they should be correlated and corrected. This fact might explain why Savini *et al.* and Shammas *et al.* did not find Scheimpflug system the most reliable method to calculate IOL power[18-19]. The results of FK and SK analysis also suggest that the systems are not interchangeable, since the comparison between EyeSys and Pentacam values showed statistically significant differences concerning these parameters, corroborating with similar studies, which tried to analyze the interchangeability of both instruments[20-21].

We analyzed some irregular surface features, and the edge detection algorithm, mathematical functions, and parallax effect may have affected the results. In addition, peripheral readings are more variable since they are less consistent than central readings[12]. Marginal data from irregular corneas are suppressed by the EyeSys, while the Pentacam interpolates them, which may explain the difference in FK and SK values for the two systems. Future studies that compare interpolated topographies with non-interpolated topographies from Scheimpflug-based videokeratoscopes may confirm this hypothesis.

In addition, Pentacam provides a wider range of scale colors and, in some cases, this may be problematic, because the topography may not show relevant details. Thus, practitioners who are familiar with PDCT systems, such as EyeSys, and are trying to adapt to an SBCE system such as Pentacam, should be aware of the potential to underestimate curvature variations when the color map is based on a 0.5 D scale. It may be easier to use Pentacam 0.25 D scales, as they produce images more similar to the EyeSys 0.50 D scale, the more commonly used scale for this system. Future studies, with a larger number of subjects and additional analysis with different scales may corroborate the results presented.

The qualitative analysis determined that, when considering all topographies (aspheric, KS, keratoconus), the percent of correct matches by children was significantly different than that of adults, indicating that for one to correctly match corneal topography generated by EyeSys and Pentacam systems, cognitive maturity is relevant. A possible explanation for this phenomenon is that, in general, children compare patterns according to features that make sense to them. An example of this is the memory game, in which images that are familiar to the children, that is to say that they know the meaning and what the utilities of the image that is being offered are the subject of the game. The significant low rate of correct matches by children may be due to the "meaninglessness" of the images that were presented, that is, the topographies. As children grow older, they learn to "tolerate" this lack of meaning, and the number of correct matches increases. The difference between adults and refractive surgeons was also significant. These groups have a big dissimilarity in their formation, indicating that a considerable difference in knowledge and expertise is an important factor.

Table 3. Percentage of correct match between EyeSys and Pentacam topographic maps

Topographic pattern	Evaluator group: Children (CH) correct match mean (SD), %	Adults (AD) correct match mean (SD), %	Ophthalmology residents (OP) correct match mean (SD), %	Refractive surgeons (RS) correct match mean (SD), %	P value - comparison between groups: Overall	CH vs. AD	CH vs. OP	CH vs. RS	AD vs. OP	AD vs. RS	OP vs. RS
Aspheric and established keratoconus	41(22)	72(18)	82(15)	96(8)	<0.001	<0.001	<0.001	<0.001	0.13	<0.001	0.02
Keratoconus suspect	16(14)	24(23)	32(19)	36(13)	0.02	0.360	0.030	0.002	0.20	0.040	0.57
Overall	29(16)	48(18)	57(13)	66(8)	<0.001	0.002	<0.001	<0.001	0.09	0.002	0.08

SD = standard deviation

When KS was removed from the "shuffle-and-match" game, the rate of correct matches increased for all groups and provided new information: the number of correct matches made by RS became different from each of the other groups. This phenomenon can be explained by the fact that, in the case of KS, one may get confused and mismatch some topographies, lowering the rate of correct matches and eliminating all group differences (except those of the CH group). When KS topographies were excluded from the analysis, the number of correct matches increased in each group and the greatest increase was observed in RS, making it significantly different from AD and OP. However, the increase in the number of correct matches was not enough to make the difference between AD and OP significant. Therefore, we infer that only with persistent training over many years might one be able to match topographies correctly, as the differences between evaluators who were not trained and those who had minimal training were not considerable.

Finally, when the rate of correct matches of KS topographies was isolated analyzed, the percents decreased drastically, eliminating most of the group differences. The group differences that remained significant were CH vs. OP; CH vs. RS and AD vs. RS. From these results we can assume that: KS topographies are more difficult to match than aspheric or keratoconus topographies and knowing what the topographies mean is an important fact that helps to match the maps correctly.

It is widely accepted that topographic values, when applied without the aid of other tests, are not sensitive or specific enough to clearly diagnose KS corneas[22-23]. Some methods, though, such as the Rabinowitz-McDonnell test, try to assist the clinician in the diagnosis of keratoconus[8,24]. Therefore, for non-KS subjects, the systems are equally able to analyze the cornea anterior curvature, what was also observed in similar studies on this area[21]. Overall, the systems are correlated and are partially interchangeable.

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