Knowledge assessment of the importance of corneal biomechanics in glaucoma among physicians, ophthalmologists, and glaucoma specialists

Avaliação do conhecimento sobre a importância da biomecânica da córnea no glaucoma entre médicos, oftalmologistas e especialistas em glaucoma

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ABSTRACT

Objective: To assess the knowledge of healthcare professionals about corneal biomechanics in glaucoma and identify knowledge gaps for educational focus.

Methods: A cross-sectional observational study involving an online questionnaire addressing knowledge and the importance of corneal biomechanics in glaucoma patients, completed by volunteer ophthalmologists, glaucoma specialists, and physicians from other specialties residing in Brazil. Data analysis was based on knowledge about the subject in these three groups, and the analyses were performed using the Statistical Package for Social Sciences, version 20.0.

Results: Out of 316 participants, 312 were analyzed after excluding 4 for incomplete responses. Glaucoma specialists showed superior knowledge in corneal biomechanics (99%) compared to non-specialists (90.3%) and other medical professionals (32.1%). Knowledge of specific devices like Ocular Response Analyzer and Corvis® ST was higher among specialists. However, even among specialists, detailed knowledge of the applicability of biomechanics in glaucoma was less common.

Conclusion: The study highlights the need for enhanced knowledge dissemination on corneal biomechanics in glaucoma across the medical community. Despite glaucoma specialists' deeper understanding, there is a general uncertainty about biomechanics' practical application. Addressing this through digital education tools and distance learning could bridge the knowledge gap, benefiting various medical specialties.

RESUMO

Objetivo: Avaliar o conhecimento dos profissionais de saúde sobre a biomecânica da córnea no glaucoma e identificar lacunas de conhecimento para focos educacionais.

Métodos: Estudo observacional transversal envolvendo um questionário online sobre o conhecimento e a importância da biomecânica da córnea em pacientes com glaucoma, respondido por oftalmologistas voluntários, especialistas em glaucoma e médicos de outras especialidades residentes no Brasil. A análise dos dados foi baseada no conhecimento sobre o tema nesses três grupos, e as análises foram realizadas utilizando o pacote estatístico Statistical Package for Social Sciences, versão 20.0.

Resultados: Dos 316 participantes, 312 foram analisados após a exclusão de 4 respostas incompletas. Especialistas em glaucoma mostraram maior conhecimento em biomecânica da córnea (99%) em comparação com não-especialistas (90,3%) e outros profissionais médicos (32,1%). O conhecimento sobre dispositivos específicos como o Ocular Response Analyzer e o Corvis® ST foi maior entre os especialistas. No entanto, mesmo entre os especialistas, o conhecimento detalhado da aplicabilidade da biomecânica no glaucoma era menos comum.

Conclusão: O estudo destaca a necessidade de uma maior disseminação de conhecimento sobre a biomecânica da córnea no glaucoma entre a comunidade médica. Apesar do entendimento mais aprofundado dos especialistas em glaucoma, há uma incerteza geral sobre a aplicação prática da biomecânica. Abordar essa questão por meio de ferramentas de educação digital e ensino à distância pode reduzir a lacuna de conhecimento, beneficiando várias especialidades médicas

INTRODUCTION

Glaucoma encompasses a range of conditions that result in permanent vision impairment, marked by a gradual decline in retinal ganglion cells.[1-3] Glaucoma is a leading cause of irreversible blindness worldwide, classified by the World Health Organization (WHO) as the second major cause of global blindness.[4] According to estimates, out of 2.2 billion people suffering from preventable visual impairments, approximately 6.9 million cases are caused by glaucoma.[5,6] While intraocular pressure (IOP) is no longer considered the sole criterion for diagnosing glaucoma and may not always be elevated, extensive clinical research has established it as the primary modifiable risk factor.[7]

The main limitation of current tonometry methods lies in the static nature of the measurements and the algorithms used. Numerous studies have shown that even minor increases in IOP can lead to visual field deterioration and glaucoma progression.[1,8] Furthermore, accurate IOP measurements are crucial tools for predicting and monitoring disease progression.[9]

Corneal biomechanics, a critical aspect of biophysics, has been a hot topic of research during the latest decades. One of the major applications of biomechanical analysis is the investigation of corneal ectatic diseases, especially the detection of early forms of keratoconus.[10] However, it also plays a pivotal role in glaucoma management by influencing the accuracy of IOP measurements and being linked to the risk of developing the disease.[11-13] Studies have demonstrated that the investigation of corneal biomechanics enhances the understanding of the pathogenesis of glaucoma, and improves patient diagnosis and monitoring.[14,15] By integrating biomechanical analysis from systems such as the Ocular Response Analyzer (ORA), and the Corvis® ST with tomographic data, such as that from Scheimpflug imaging, clinicians can better assess the unique biomechanical characteristics of each patient's eyes, thereby optimizing the diagnosis, monitoring, and treatment of glaucoma, including surgical interventions and IOP-lowering therapies.[16-21] Although the debate continues as to whether a more rigid eyeball contributes to glaucoma or is a consequence of the disease, increasing evidence supports an association between stiffer corneas and glaucoma, with patients possessing thin and rigid corneas at a higher risk for developing the condition.[22]

The study by Congdon et al. demonstrated that corneal hysteresis (CH), but not central corneal thickness (CCT), was predictive of glaucoma progression.[23] Another study suggested that CH and corneal resistance factor (CRF), alongside CCT, could be risk factors for glaucoma.[24] Susanna et al. further supported this by showing that a decrease in CH significantly increased the risk of developing glaucoma.[25] Additionally, the Ocular Hypertension Treatment Study (OHTS) indicated that individuals with greater CCT experienced less reduction in IOP from IOP-lowering treatments.[26] Thus, evaluation of corneal biomechanical parameters and other indicators can assist in diagnosing glaucoma, assessing its status and severity, and distinguishing between different disease subtypes.[13,27]

Thus, understanding the biomechanical properties of the eye can assist clinicians not only in the early detection of corneal ectasias but provide critical insights into the pathogenesis of glaucomatous damage. It also enhances the diagnosis of glaucoma suspects and aids in monitoring the efficacy of IOP-lowering therapies and surgical interventions.

The availability of various parameters allows for a detailed analysis and identification of each patient's unique biomechanical characteristics. There is extensive literature on the significance of corneal biomechanics and its correlation with glaucoma. However, the practical knowledge among new doctors, ophthalmologists, and glaucoma specialists is still questionable. To our knowledge, this is the first cross-sectional study aimed at evaluating the medical professionals' understanding of corneal biomechanics in the assessment of patients with glaucoma.

METHODS

Study design

This observational, cross-sectional study was conducted by the Department of Ophthalmology at the *Hospital Universitário Gaffrée e Guinle*, affiliated with the *Universidade Federal do Estado do Rio de Janeiro* (UNIRIO). The study received approval from the Institutional Ethics and Research Committee and was registered with *Plataforma Brasil*, accepted under process number HUGG 6.211.542/2022. Participants were provided with the Informed Consent Form.

Literature review

A literature review was conducted focusing on corneal biomechanics and its applications; biomechanical studies related to glaucoma, including post-corneal and glaucoma surgeries, and the impact of glaucoma medications, such as prostaglandins, on corneal biomechanics.

Data collection

A virtual questionnaire comprising straightforward questions was administered to a diverse group of 316 participants. This group included general physicians, ophthalmologists, glaucoma specialists, and specialists from other medical fields. Participant anonymity was maintained throughout the study, with voluntary involvement and the option to withdraw at any time.

The survey consisted of three main sections: participant information data, knowledge of corneal biomechanics, and the role of biomechanics in glaucoma assessment, with responses organized as true or false and responses considered as relevant or not, validated or not, important or not and their level of graduation statements. Participants were categorized by medical specialty and sub-specialty, particularly in ophthalmology and glaucoma, and by the year and duration since graduation. A total of 20 questions were crafted to capture data from the responses (Table 1).

Table 1. Questionnaire

1. Are you an ophthalmologist?
2. Are you a glaucoma specialist?
3. What year did you graduate from medical school? (Please write in full, for example: 1998)
4. What year did you complete your medical residency? (Please write in full, for example: 2001).
5. Are you familiar with the term corneal biomechanics?
6. Are you familiar with the Ocular Response Analyzer (ORA)?
7. Are you familiar with the Corvis® ST non-contact tonometer?
8. The most indicated exam to assess ocular rigidity is:
9. What is the best exam to evaluate corneal hysteresis?
10. Which exam is indicated to assess biomechanically corrected pressure (bIOP)?
11. Do you know the difference between ocular hypertension and glaucoma?
12. Do you routinely perform pachymetry in the evaluation of your patients with glaucoma?
13. In your opinion, the correlation between corneal biomechanics and glaucoma is:
14. In your assessment, exams like Pentacam, ORA, Corvis® ST in some specific cases of patients with glaucoma (such as keratoconus and pre and post refractive surgeries) are:
15. Do you routinely evaluate corneal biomechanics parameters in patients with glaucoma?
16. Do you consider correlating corneal biomechanics with glaucoma progression?
17. Is evaluating corneal biomechanics in patients who have used or are currently using prostaglandins:
18. Do you consider evaluating corneal biomechanics pre- and post-operatively in glaucoma surgery?
19. Do you analyze the measurement of axial length in patients with glaucoma or in those suspected of having glaucoma?
20. Could corneal biomechanics change your treatment strategy in patients suspected of having glaucoma or in those with glaucoma?

The questionnaire was disseminated digitally through platforms like Telegram, WhatsApp, and email between July and September 2023, ensuring a diverse and stratified sample. The study aimed to inform physicians for better clinical decision-making without advocating for specific surgical interventions.

Statistical analysis

Data from the questionnaire, collected via Google Forms, were exported to Microsoft Excel 2016 for analysis. Participants were categorized by medical specialty and sub-specialty, particularly in ophthalmology and glaucoma, and by graduation year and time. Descriptive analysis was conducted using absolute and relative frequencies. Associations between categorical variables were tested using the Chi-squared test or Fisher's exact test for small samples. Adjusted standardized residuals were used to identify local differences, with absolute values above 1.96 indicating significant associations. A significance level of 5% was applied for all statistical tests conducted using Statistical Package for Social Sciences, version 20.0.

RESULTS

In this study, data from 312 respondents were analyzed after excluding 4 participants for inconsistent responses, comprising 106 (34.0%) glaucoma specialist ophthalmologists, 178 (57.1%) ophthalmologists from other subspecialties, and 28 (9%) physicians from various other medical specialties.

According to data described on table 2, significant differences in the understanding of corneal biomechanics ($p < 0.001$), ORA ($p < 0.001$), and Corvis® ST systems ($p < 0.001$) were observed. Glaucoma specialists among ophthalmologists demonstrated a higher awareness of corneal biomechanics, the ORA, and the Corvis® ST non-contact tonometers compared to general ophthalmologists and physicians from other specialties. Specifically, 99% of glaucoma specialists were familiar with corneal biomechanics, significantly higher than physicians from other fields (32.1%). For knowledge regarding the ORA system, 95.3% of glaucoma specialists were knowledgeable, exceeding the awareness levels of general ophthalmologists (61.6%) and other specialists (17.9%). Similarly, 66% of glaucoma specialists knew about the Corvis® ST system, compared to 25% of physicians from other specialties.

Table 3 reveals distinct distributions in the selection of exams for ocular rigidity ($p < 0.001$), CH ($p < 0.001$), biomechanically corrected IOP (bIOP) ($p < 0.001$), understanding the difference between ocular hypertension and glaucoma ($p < 0.001$), and the use of pachymetry in glaucoma patients ($p < 0.001$). Glaucoma specialists showed a preference for using both Corvis® ST and ORA to assess ocular rigidity (34%), a percentage higher than that of other specialists (10.7%), who had a greater tendency to respond "Don't know" (78.6% *versus* 23.6% for specialists). For CH, "ORA" was the preferred response for 62.3% of glaucoma specialists, exceeding the rate among general ophthalmologists (36.2%) and other specialists (7.1%), with the latter group again showing a higher "Don't know" answer rate (85.7% *versus* 17.0% for specialists).

When assessing bIOP, glaucoma specialists had the highest response rates for ORA (25.5%), Corvis® ST (35.8%), and Pascal (23.6%) compared to other groups, with general ophthalmologists favoring "Pascal" more than other specialists (10% *versus* 0%), who had the highest "Don't know" answer rate (82.1%). Both specialist and non-specialist ophthalmologists had similar and higher percentages than other specialists in differentiating between ocular hypertension and glaucoma and in performing pachymetry in glaucoma patients.

Table 2. Distribution of medical school graduation and residency completion years and general knowledge by medical specialty

	Physician				
	Glaucoma specialist ophthalmologist	General ophthalmologist	Other specialties	Total	p-value
Year of medical school graduation					0.277
≤ 2000	45 (42.5)	88 (49.4)	9 (32.1)	142 (45.5)	
2001 a 2005	29 (27.4)	36 (20.2)	10 (35.7)	75 (24.0)	
> 2005	32 (30.2)	54 (30.3)	9 (32.1)	95 (30.4)	
Year of medical residency completion					0.221
≤ 2000	32 (30.2)	71 (39.9)	8 (28.6)	111 (35.6)	
2001 a 2005	26 (24.5)	27 (15.2)	5 (17.9)	58 (18.6)	
> 2005	48 (45.3)	80 (44.9)	15 (53.6)	143 (45.8)	
Familiar with the term Corneal Biomechanics?					< 0.001
No	1 (1.0)	17 (9.7)	19 (67.9)	37 (12.0)	
Yes	104 (99.0)	159 (90.3)	9 (32.1)	272 (88.0)	
Familiar with the Ocular Response Analyzer (ORA)?					< 0.001
No	5 (4.7)	68 (38.4)	23 (82.1)	96 (30.9)	
Yes	101 (95.3)	109 (61.6)	5 (17.9)	215 (69.1)	
Familiar with the Corvis® ST non-contact tonometer?					< 0.001
No	36 (34.0)	77 (43.3)	21 (75.0)	134 (42.9)	
Yes	70 (66.0)	101 (56.7)	7 (25.0)	178 (57.1)	

p - descriptive level of the Chi-Square test.
The sum of the percentages for the levels of a variable may not be equal to 100% due to rounding.

Table 3. Distribution of knowledge of the most recommended tests, the difference between ocular hypertension and glaucoma, and routine care by medical specialty

	Physician				
	Glaucoma specialist ophthalmologist	General ophthalmologist	Other specialties	Total	p-value
The most indicated exam to evaluate ocular rigidity is:					< 0.001*
Corvis® ST	20 (18.9)	23 (13.1)	2 (7.1)	45 (14.5)	
ORA	21 (19.8)	30 (17.0)	1 (3.6)	52 (16.8)	
Both	36 (34.0)	39 (22.2)	3 (10.7)	78 (25.2)	
None of the above	4 (3.8)	4 (2.3)	0 (0.0)	8 (2.6)	
I don't know the answer	25 (23.6)	80 (45.5)	22 (78.6)	127 (41.0)	
The best exam to evaluate corneal hysteresis is:					< 0.001*
Pentacam	1 (0.9)	7 (4.0)	1 (3.6)	9 (2.9)	
Corvis® ST	21 (19.8)	33 (19.0)	1 (3.6)	55 (17.9)	
Anterior Segment OCT	0 (0.0)	5 (2.9)	0 (0.0)	5 (1.6)	
ORA	66 (62.3)	63 (36.2)	2 (7.1)	131 (42.5)	
I don't know the answer	18 (17.0)	66 (37.9)	24 (85.7)	108 (35.1)	
The exam suggested to evaluate biomechanically corrected intraocular pressure (bIOP) is:					< 0.001*
ORA	27 (25.5)	30 (17.0)	3 (10.7)	60 (19.4)	
Icare	1 (0.9)	1 (0.6)	0 (0.0)	2 (0.6)	
Corvis® ST	38 (35.8)	49 (27.8)	2 (7.1)	89 (28.7)	
Pascal	25 (23.6)	19 (10.8)	0 (0.0)	44 (14.2)	
I don't know the answer	15 (14.2)	77 (43.8)	23 (82.1)	115 (37.1)	
Do you know the difference between ocular hypertension and glaucoma?					< 0.001†
No	0 (0.0)	0 (0.0)	15 (53.6)	15 (4.8)	
Yes	106 (100.0)	178 (100.0)	13 (46.4)	297 (95.2)	
Do you perform pachymetry in your routine evaluation of your patients with glaucoma?					<0.001†
No	1 (0.9)	5 (2.8)	21 (75.0)	27 (8.7)	
Yes	105 (99.1)	173 (97.2)	7 (25.0)	285 (91.3)	

The sum of the percentages for the levels of a variable may not be equal to 100% due to rounding.
p-value: descriptive level of *Fisher's Exact test and the †Chi-squared test.
ORA: Ocular Response Analyzer; OCT: Optical coherence tomography; bIOP: biomechanically corrected intraocular pressure.

According to table 4, distinct response distributions were observed among medical specialties regarding the correlation between corneal biomechanics and glaucoma (p = 0.031), the use of Pentacam, ORA, Corvis® ST in specific glaucoma cases (p < 0.001), the consideration of corneal biomechanics in the progression of glaucoma (p = 0.002), the practice of measuring axial length in patients with or suspected of having glaucoma (p = 0.037), and the impact of corneal biomechanics on treatment strategy changes in suspected or confirmed glaucoma patients (p < 0.001). Both glaucoma-specialized and non-specialized ophthalmologists shared similar views on the correlation between corneal biomechanics and glaucoma and the application of Pentacam, ORA, Corvis® ST in certain glaucoma cases, differing from other medical specialists who often provided unclear responses. Glaucoma specialists were significantly more likely to acknowledge the importance of corneal biomechanics in glaucoma progression, with 81.1% affirming this correlation compared to 48.1% from other specialties. Other specialists were less inclined to perform axial length measurements in glaucoma or glaucoma-suspect patients, with only 7.4% affirming they do so, versus over 24.0% among ophthalmologists. Furthermore, when considering the role of corneal biomechanics in altering treatment strategies for glaucoma, a higher percentage of non-ophthalmology specialists responded negatively (29.6%) compared to ophthalmologists, highlighting a discrepancy in the

Table 4. Distribution of items on corneal biomechanics by medical specialty

	Physician				
	Glaucoma specialist ophthalmologist	General ophthalmologist	Other specialties	Total	p-value
In your opinion, how important is the correlation between corneal biomechanics and glaucoma?					0.031*
Little important	7 (6.6)	9 (5.1)	0 (0.0)	16 (5.1)	
Important	38 (35.8)	70 (39.3)	8 (29.6)	116 (37.3)	
Without validity	0 (0.0)	2 (1.1)	4 (14.8)	6 (1.9)	
Very important	38 (35.8)	55 (30.9)	10 (37.0)	103 (33.1)	
Extremely important	23 (21.7)	42 (23.6)	5 (18.5)	70 (22.5)	
In your assessment, do exams like Pentacam, ORA, and Corvis® ST hold significance in specific cases of patients with glaucoma?					< 0.001*
Irrelevant	3 (2.8)	0 (0.0)	1 (3.7)	4 (1.3)	
Little relevant	5 (4.7)	9 (5.1)	0 (0.0)	14 (4.5)	
Neutral	6 (5.7)	3 (1.7)	7 (25.9)	16 (5.1)	
Relevant	44 (41.5)	76 (42.7)	13 (48.1)	133 (42.8)	
Quite relevant	48 (45.3)	90 (50.6)	6 (22.2)	144 (46.3)	
Do you routinely evaluate corneal biomechanics parameters in patients with glaucoma?					0.612†
No	85 (80.2)	137 (77.8)	24 (85.7)	246 (79.4)	
Yes	21 (19.8)	39 (22.2)	4 (14.3)	64 (20.6)	
Do you consider correlating corneal biomechanics with glaucoma progression?					0.002†
No	20 (18.9)	56 (31.5)	14 (51.9)	90 (28.9)	
Yes	86 (81.1)	122 (68.5)	13 (48.1)	221 (71.1)	
Do you consider evaluating corneal biomechanics in patients who use or have used prostaglandins?					0.092*
Invalid	4 (3.8)	3 (1.7)	0 (0.0)	7 (2.3)	
Little valid	8 (7.5)	15 (8.5)	0 (0.0)	23 (7.4)	
Neutral	34 (32.1)	56 (31.8)	13 (48.1)	103 (33.3)	
Valid	57 (53.8)	85 (48.3)	10 (37.0)	152 (49.2)	
Extremely valid	3 (2.8)	17 (9.7)	4 (14.8)	24 (7.8)	
Do you consider evaluating corneal biomechanics in the pre- and post-operative stages of glaucoma surgery?					0.261†
No	50 (47.2)	69 (38.8)	9 (33.3)	128 (41.2)	
Yes	56 (52.8)	109 (61.2)	18 (66.7)	183 (58.8)	
Do you analyze axial length in patients with glaucoma or those suspected of having glaucoma?					0.037†
No	73 (68.9)	134 (75.7)	25 (92.6)	232 (74.8)	
Yes	33 (31.1)	43 (24.3)	2 (7.4)	78 (25.2)	
Could corneal biomechanics influence your treatment strategy for patients with suspected glaucoma or those with glaucoma?					< 0.001†
No	3 (2.8)	8 (4.5)	8 (29.6)	19 (6.1)	
Only in selected cases	44 (41.5)	61 (34.3)	8 (29.6)	113 (36.3)	
Yes	59 (55.7)	109 (61.2)	11 (40.7)	179 (57.6)	

p-value: descriptive level of *Fisher's Exact test and the †Chi-squared test.
The sum of the percentages for the levels of a variable may not be equal to 100% due to rounding.
ORA: Ocular Response Analyzer

perceived relevance of corneal biomechanics across different medical fields.

According to table 5, there were no observed differences in the distribution of knowledge items by year of residency completion among glaucoma specialist ophthalmologists. Similarly, table 6 indicates no significant variations in knowledge items based on the year of residency completion among non-specialist ophthalmologists.

Table 5. Distribution of knowledge items by year of completion of residency in ophthalmologists specialized in glaucoma

	Year of completion of medical residency			Total	p-value
	≤ 2000	2001 to 2005	> 2005		
Do you know the term corneal biomechanics?					1.000*
No	0 (0.0)	0 (0.0)	1 (2.1)	1 (1.0)	
Yes	31 (100.0)	26 (100.0)	47 (97.9)	104 (99.0)	
Do you know the Ocular Response Analyzer (ORA) device?					0.602*
No	2 (6.3)	0 (0.0)	3 (6.3)	5 (4.7)	
Yes	30 (93.8)	26 (100.0)	45 (93.8)	101 (95.3)	
Do you know the Corvis® ST breath tonometer?					0.403†
No	12 (37.5)	6 (23.1)	18 (37.5)	36 (34.0)	
Yes	20 (62.5)	20 (76.9)	30 (62.5)	70 (66.0)	
The most suitable test to assess ocular stiffness is					0.745*
Corvis® ST	6 (18.8)	5 (19.2)	9 (18.8)	20 (18.9)	
ORA	4 (12.5)	7 (26.9)	10 (20.8)	21 (19.8)	
Both	13 (40.6)	10 (38.5)	13 (27.1)	36 (34.0)	
None of the previous answers	1 (3.1)	0 (0.0)	3 (6.3)	4 (3.8)	
I don't know	8 (25.0)	4 (15.4)	13 (27.1)	25 (23.6)	
What is the best test to evaluate corneal hysteresis?					0.347*
Pentacam	0 (0.0)	0 (0.0)	1 (2.1)	1 (0.9)	
Corvis® ST	6 (18.8)	7 (26.9)	8 (16.7)	21 (19.8)	
Anterior segment OCT	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
ORA	17 (53.1)	17 (65.4)	32 (66.7)	66 (62.3)	
I don't know	9 (28.1)	2 (7.7)	7 (14.6)	18 (17.0)	
What is the recommended test to assess biomechanically corrected pressure (bIOP)?					0.201*
ORA	9 (28.1)	9 (34.6)	9 (18.8)	27 (25.5)	
Icare	1 (3.1)	0 (0.0)	0 (0.0)	1 (0.9)	
Corvis® ST	8 (25.0)	8 (30.8)	22 (45.8)	38 (35.8)	
Pascal	6 (18.8)	7 (26.9)	12 (25.0)	25 (23.6)	
I don't know	8 (25.0)	2 (7.7)	5 (10.4)	15 (14.2)	
Do you know the difference between ocular hypertension and glaucoma?					-
No	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Yes	32 (100.0)	26 (100.0)	48 (100.0)	106 (100.0)	
Do you routinely perform pachymetry when evaluating your glaucoma patients?					0.543*
No	1 (3.1)	0 (0.0)	0 (0.0)	1 (0.9)	
Yes	31 (96.9)	26 (100.0)	48 (100.0)	105 (99.1)	
In your opinion, the correlation between corneal biomechanics and glaucoma is					0.121*
Little important	3 (9.4)	0 (0.0)	4 (8.3)	7 (6.6)	
Important	11 (34.4)	14 (53.8)	13 (27.1)	38 (35.8)	
NULL	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Very important	9 (28.1)	10 (38.5)	19 (39.6)	38 (35.8)	
Extremely important	9 (28.1)	2 (7.7)	12 (25.0)	23 (21.7)	
In your evaluation, tests such as Pentacam, ORA, Corvis® ST in some specific cases of patients with Glaucoma are:					0.823*
Irrelevant	1 (3.1)	0 (0.0)	2 (4.2)	3 (2.8)	
Not very relevant	1 (3.1)	1 (3.8)	3 (6.3)	5 (4.7)	
Neutral	2 (6.3)	0 (0.0)	4 (8.3)	6 (5.7)	
Relevant	15 (46.9)	10 (38.5)	19 (39.6)	44 (41.5)	
Quite relevant	13 (40.6)	15 (57.7)	20 (41.7)	48 (45.3)	
Do you routinely evaluate corneal biomechanics parameters in patients with glaucoma?					0.728†
No	26 (81.3)	22 (84.6)	37 (77.1)	85 (80.2)	
Yes	6 (18.8)	4 (15.4)	11 (22.9)	21 (19.8)	
Do you consider correlating corneal biomechanics and glaucoma progression?					0.999†
No	6 (18.8)	5 (19.2)	9 (18.8)	20 (18.9)	
Yes	26 (81.3)	21 (80.8)	39 (81.3)	86 (81.1)	

Continue...

Continuation.

	Year of completion of medical residency			Total	p-value
	≤ 2000	2001 to 2005	> 2005		
How do you consider evaluating corneal biomechanics in patients who use or have used prostaglandins?					0.704*
Not valid	1 (3.1)	1 (3.8)	2 (4.2)	4 (3.8)	
Slightly valid	4 (12.5)	1 (3.8)	3 (6.3)	8 (7.5)	
Neutral	10 (31.3)	7 (26.9)	17 (35.4)	34 (32.1)	
Valid	15 (46.9)	16 (61.5)	26 (54.2)	57 (53.8)	
Extremely valid	2 (6.3)	1 (3.8)	0 (0.0)	3 (2.8)	
Do you consider evaluating corneal biomechanics pre- and post-operatively after glaucoma surgery?					0.419†
No	13 (40.6)	15 (57.7)	22 (45.8)	50 (47.2)	
Yes	19 (59.4)	11 (42.3)	26 (54.2)	56 (52.8)	
Do you analyze the measurement of axial length in patients with glaucoma or those with suspected glaucoma?					0.188†
No	26 (81.3)	17 (65.4)	30 (62.5)	73 (68.9)	
Yes	6 (18.8)	9 (34.6)	18 (37.5)	33 (31.1)	
Could corneal biomechanics change your treatment strategy in your patients with suspected glaucoma or in patients with glaucoma?					0.594*
No	1 (3.1)	1 (3.8)	1 (2.1)	3 (2.8)	
Only in selected cases	10 (31.3)	11 (42.3)	23 (47.9)	44 (41.5)	
Yes	21 (65.6)	14 (53.8)	24 (50.0)	59 (55.7)	

p-value: descriptive level of *Fisher's Exact test and the †Chi-squared test.
The sum of the percentages of the levels of a variable may not be equal to 100% due to rounding.

Table 6. Distribution of knowledge items by year of completion of a residency in ophthalmologists who are not glaucoma specialists

	Year of completion of medical residency			Total	p-value
	≤ 2000	2001 to 2005	> 2005		
Do you know the term corneal biomechanics?					0.544*
No	7 (10.0)	4 (14.8)	6 (7.6)	17 (9.7)	
Yes	63 (90.0)	23 (85.2)	73 (92.4)	159 (90.3)	
Do you know the Ocular Response Analyzer (ORA) device?					0.766*
No	29 (40.8)	11 (40.7)	28 (35.4)	68 (38.4)	
Yes	42 (59.2)	16 (59.3)	51 (64.6)	109 (61.6)	
Do you know the Corvis® ST breath tonometer?					0.596*
No	34 (47.9)	11 (40.7)	32 (40.0)	77 (43.3)	
Yes	37 (52.1)	16 (59.3)	48 (60.0)	101 (56.7)	
The most suitable test to assess ocular stiffness is					0.261†
Corvis® ST	6 (8.6)	2 (7.4)	15 (19.0)	23 (13.1)	
ORA	8 (11.4)	7 (25.9)	15 (19.0)	30 (17.0)	
Both	15 (21.4)	6 (22.2)	18 (22.8)	39 (22.2)	
None of the previous answers	2 (2.9)	0 (0.0)	2 (2.5)	4 (2.3)	
I don't know the answer	39 (55.7)	12 (44.4)	29 (36.7)	80 (45.5)	
What is the best test to evaluate corneal hysteresis?					0.150†
Pentacam	3 (4.3)	1 (3.8)	3 (3.8)	7 (4.0)	
Corvis® ST	8 (11.6)	2 (7.7)	23 (29.1)	33 (19.0)	
Anterior segment OCT	3 (4.3)	0 (0.0)	2 (2.5)	5 (2.9)	
ORA	25 (36.2)	11 (42.3)	27 (34.2)	63 (36.2)	
I don't know the answer	30 (43.5)	12 (46.2)	24 (30.4)	66 (37.9)	
What is the recommended test to assess biomechanically corrected pressure (bIOP)?					0.196†
ORA	9 (12.9)	6 (22.2)	15 (19.0)	30 (17.0)	
Icare	0 (0.0)	0 (0.0)	1 (1.3)	1 (0.6)	
Corvis® ST	16 (22.9)	7 (25.9)	26 (32.9)	49 (27.8)	
Pascal	13 (18.6)	1 (3.7)	5 (6.3)	19 (10.8)	
I don't know the answer	32 (45.7)	13 (48.1)	32 (40.5)	77 (43.8)	
Do you know the difference between ocular hypertension and glaucoma?					-
No	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Yes	71 (100.0)	27 (100.0)	80 (100.0)	178 (100.0)	
Do you routinely perform pachymetry when evaluating your glaucoma patients?					0.299†
No	1 (1.4)	2 (7.4)	2 (2.5)	5 (2.8)	
Yes	70 (98.6)	25 (92.6)	78 (97.5)	173 (97.2)	

Continue...

Continuation.

	Year of completion of medical residency			Total	p-value
	≤ 2000	2001 to 2005	> 2005		
In your opinion, the correlation between corneal biomechanics and glaucoma is					0.986†
Little important	5 (7.0)	1 (3.7)	3 (3.8)	9 (5.1)	
Important	27 (38.0)	12 (44.4)	31 (38.8)	70 (39.3)	
Null	1 (1.4)	0 (0.0)	1 (1.3)	2 (1.1)	
Very important	23 (32.4)	8 (29.6)	24 (30.0)	55 (30.9)	
Extremely important	15 (21.1)	6 (22.2)	21 (26.3)	42 (23.6)	
In your evaluation, tests such as Pentacam, ORA, Corvis® ST in some specific cases of patients with Glaucoma are:					0.261b
Irrelevant	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Not very relevant	5 (7.0)	2 (7.4)	2 (2.5)	9 (5.1)	
Neutral	0 (0.0)	1 (3.7)	2 (2.5)	3 (1.7)	
Relevant	31 (43.7)	14 (51.9)	31 (38.8)	76 (42.7)	
Quite relevant	35 (49.3)	10 (37.0)	45 (56.3)	90 (50.6)	
Do you routinely evaluate corneal biomechanics parameters in patients with glaucoma?					0.642*
No	52 (74.3)	22 (81.5)	63 (79.7)	137 (77.8)	
Yes	18 (25.7)	5 (18.5)	16 (20.3)	39 (22.2)	
Do you consider correlating corneal biomechanics and glaucoma progression?					0.269†
No	18 (25.4)	8 (29.6)	30 (37.5)	56 (31.5)	
Yes	53 (74.6)	19 (70.4)	50 (62.5)	122 (68.5)	
How do you consider evaluating corneal biomechanics in patients who use or have used prostaglandins?					0.776*
Not valid	1 (1.4)	0 (0.0)	2 (2.5)	3 (1.7)	
Not valid	6 (8.7)	2 (7.4)	7 (8.8)	15 (8.5)	
Neutral	21 (30.4)	9 (33.3)	26 (32.5)	56 (31.8)	
Valid	33 (47.8)	16 (59.3)	36 (45.0)	85 (48.3)	
Extremely valid	8 (11.6)	0 (0.0)	9 (11.3)	17 (9.7)	
Do you consider evaluating corneal biomechanics pre- and post-operatively after glaucoma surgery?					0.095†
No	22 (31.0)	9 (33.3)	38 (47.5)	69 (38.8)	
Yes	49 (69.0)	18 (66.7)	42 (52.5)	109 (61.2)	
Do you analyze the measurement of axial length in patients with glaucoma or those suspected of glaucoma?					0.771*
No	54 (76.1)	19 (70.4)	61 (77.2)	134 (75.7)	
Yes	17 (23.9)	8 (29.6)	18 (22.8)	43 (24.3)	
Could corneal biomechanics change your treatment strategy in your patients with suspected glaucoma or in patients with glaucoma?					0.534†
No	1 (1.4)	1 (3.7)	6 (7.5)	8 (4.5)	
Only in selected cases	25 (35.2)	9 (33.3)	27 (33.8)	61 (34.3)	
Yes	45 (63.4)	17 (63.0)	47 (58.8)	109 (61.2)	

p-value: descriptive level of the *Chi-squared test and †Fisher's exact test.
The sum of the percentages of the levels of a variable may not be equal to 100% due to rounding.

DISCUSSION

The significance of medical knowledge extends beyond mere diagnostic and treatment capabilities, as it is crucial for fostering a healthier and more knowledgeable society. With technological advancements, the assessment of this knowledge through online questionnaires has become invaluable.[28,29] These questionnaires enable the evaluation of healthcare professionals' understanding of the latest medical innovations and practices while also educating the public on critical health issues. They provide an accessible and efficient platform for disseminating updated medical information, promoting self-education and awareness. Moreover, the analysis of responses in real-time facilitates the identification of knowledge gaps, thus guiding the development of more targeted and effective continuing education programs.[30-32]

To our knowledge, this is the first study that analyzed responses from 312 medical professionals, including glaucoma specialist ophthalmologists, general ophthalmologists, and physicians from various other specialties, to assess their knowledge and practices regarding corneal biomechanics and its relevance to glaucoma. Key findings revealed significant differences in awareness and application of corneal biomechanics, with glaucoma specialists demonstrating a higher level of knowledge and utilization of specific diagnostic tools such as the ORA and Corvis® ST non-contact tonometers compared to their peers. The study also highlighted a notable preference among glaucoma specialists for using these tools to assess ocular rigidity, CH, and bIOP, underscoring the perceived importance of corneal biomechanics in diagnosing and managing glaucoma. Furthermore, the research

indicated a consensus among ophthalmologists on the correlation between corneal biomechanics and glaucoma progression and the utility of specific exams in certain glaucoma cases, contrasting with more ambiguous responses from other medical specialists.

It was found that glaucoma specialists possess a higher degree of knowledge regarding corneal biomechanics than their peers in other ophthalmology subspecialties. This trend can be attributed to the active pursuit by glaucoma specialists to improve the accuracy of IOP measurement. As part of this effort, there is a focus on utilizing current devices, particularly non-contact tonometers, that are capable of measuring biomechanical properties.[33] Despite this, there is a significant gap in knowledge about newer non-contact tonometry technologies like the ORA and Corvis® ST, with a percentage of glaucoma specialists (66%) aware of the Corvis® ST. This gap may be attributed to factors such as the high cost of these technologies, the limited availability of educational services in Brazil, and the minimal coverage of corneal biomechanics in glaucoma at conferences.[33]

The survey also highlighted a lack of understanding regarding the basic principles of corneal biomechanics and the specific indexes provided by devices like the ORA and Corvis® ST. Although a large percentage of respondents claimed familiarity with corneal biomechanics, only 34% of glaucoma specialists recognized that both devices assess ocular rigidity, indicating a superficial understanding of the subject. Furthermore, there is a significant lack of awareness about the CH index provided by the ORA, with 17% of glaucoma specialists and 37.9% of non-specialists unfamiliar with it.

Despite recognizing the relevance of correlating corneal biomechanics with glaucoma, about 80% of specialists do not routinely evaluate biomechanics in their medical practice. This discrepancy might be due to the high cost of technology and uncertainty about its practical application.[19,22,33] Additionally, while the ORA and Corvis® ST are acknowledged for their utility in explaining patients who progress with lower pressures, there is no established protocol for correlating or predicting progression based on biomechanical indices.[22,33]

Lastly, the survey revealed a lack of knowledge or consensus on the significance of corneal biomechanics, glaucoma, and associated risk factors, as evidenced by the response to calculating axial length in glaucoma patients, with a majority considering it unimportant despite recent studies highlighting its relevance.[34-36] The findings suggest a need for improved dissemination of knowledge on corneal biomechanics and its application in glaucoma management across all ophthalmology groups.

Previous research has consistently highlighted the importance of corneal biomechanics in both diagnosing and managing glaucoma.[37,38] A study by Wang et al. using the Corvis® ST highlights the potential predictive role of corneal biomechanics in structural and functional progression in primary open-angle glaucoma.[39] Qassim et al. found that glaucoma suspect eyes with elevated corneal stiffness parameters and reduced CCT, indicating thin and rigid corneas, have a higher risk of progression.[13] Additionally, Zarei et al. demonstrated that corneal biomechanical parameters, along with other indicators, aid in diagnosing glaucoma, assessing its severity, and distinguishing between disease subtypes.[27] Thus, previous studies underscore the potential of corneal biomechanics as a valuable tool in glaucoma care.[13,27,40-43] The importance of corneal biomechanics lies in its ability to provide insights into the structural integrity of the cornea, which can influence the accuracy of IOP measurements. Therefore, a better understanding of corneal biomechanics can lead to more accurate diagnoses, personalized treatment plans, and potentially better outcomes for patients with glaucoma.[22,44]

To address the knowledge gap in the understanding and application of corneal biomechanics in glaucoma management, several strategies can be implemented. Firstly, enhancing the curriculum of medical education and residency programs to include comprehensive coverage of corneal biomechanics and its significance in glaucoma could be beneficial. This enhancement could involve the creation of specialized courses, workshops, and continuing medical education programs.[37] Secondly, fostering interdisciplinary collaboration among glaucoma specialists, general ophthalmologists, and other medical professionals is crucial for sharing knowledge and best practices related to corneal biomechanics. Thirdly, supporting research initiatives focused on the clinical applications of corneal biomechanics in glaucoma management, including the development of new diagnostic tools and treatment modalities, is essential.[43] Additionally, developing and disseminating clinical guidelines that incorporate corneal biomechanics assessments into standard care protocols for glaucoma patients can help standardize care.[41] Promoting the use of advanced diagnostic devices, such as the ORA and Corvis® ST, in routine clinical practice can enhance the accuracy and reliability of corneal biomechanics assessment. Lastly, educating patients about the role of corneal biomechanics in their glaucoma

care can increase their engagement and adherence to treatment plans.[22] By implementing these strategies, the medical community can significantly improve the quality of care for patients with glaucoma, leveraging the potential of corneal biomechanics in glaucoma management.

LIMITATIONS

Our study has several limitations that could impact its findings. Firstly, the voluntary nature of participant selection may introduce selection bias, as those opting in could inherently possess a different level of interest or expertise in corneal biomechanics than those who abstain. Additionally, the research's focus on medical professionals within Brazil potentially restricts the applicability of its conclusions to other geographical areas with distinct medical education frameworks and technological accessibility. There's a potential bias in our study when we group cornea specialists with specialists from other medical fields. Cornea specialists have an advanced understanding of corneal biomechanics, crucial for managing conditions like keratoconus, refractive surgeries, and corneal crosslinking. This grouping could skew the results. The reliance on self-reported data further subjects the study to bias, as participants might overstate their knowledge or lean towards socially acceptable responses. Moreover, while the study evaluates awareness of corneal biomechanics, it may not adequately measure the depth of understanding or the practical application of this knowledge in a clinical setting. These inferred limitations underscore the need for a cautious interpretation of the study's results and point towards areas for future research to enhance the robustness of findings.

CONCLUSION

To our knowledge, this is the first study that has illuminated the critical need for disseminating knowledge on the interplay between corneal biomechanics and glaucoma among medical professionals. It was noted that glaucoma specialists are more knowledgeable about this topic compared to their peers in other ophthalmic sub-specialties. However, a significant information gap persists among these specialists regarding the instruments that measure biomechanical properties, particularly the indices these instruments provide, and the fundamental concepts tied to this intricate and consequential subject. Moreover, there is a notable uncertainty concerning the practical application of biomechanics in the clinical practice of the three groups studied, including the specialists.

Therefore, there is an opportunity not only to clarify the connection between corneal biomechanics and glaucoma but also to educate on its clinical relevance across various medical disciplines, leveraging digital education tools and distance learning as potential strategies to mitigate the identified knowledge gap. This could enhance early glaucoma diagnosis, improve management and treatment in special cases such as post-corneal surgery, crosslinking, corneal ring implantation, and keratoconus, and provide tools for early detection of glaucoma progression, thereby helping to prevent vision loss from this leading cause of irreversible blindness globally.

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