BMJ Open

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Journal:	*BMJ Open*
Manuscript ID	bmjopen-2019-034219
Article Type:	Original research
Date Submitted by the Author:	12-Sep-2019
Complete List of Authors:	Xu, Guihua; Huizhou Municipal Central Hospital; Aier School of Ophthalmology, Central South University Qi, Wei; Shanwei Eye Hospital Hu, Yijun; Aier School of Ophthalmology, Central South University , ; Aier Institute of Refractive Surgery, Aier Eye Hospital Group,
Keywords:	cataract, pterygium, corneal astigmatism, corneal curvature

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Distribution of Corneal Astigmatism in Eyes with Primary Pterygium before Cataract Surgery in Southern China

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Keywords: cataract; pterygium; corneal astigmatism; corneal curvature

Word Count: 2291 words

Abstract

Objectives: To investigate the distribution of corneal astigmatism in eyes with cataract and coexisting primary pterygium in a southern Chinese population.

Design: Clinic-based retrospective study.

Setting: A secondary hospital at southern China.

Participants: A group of 1689 eyes with primary pterygium (PT group) and the other group of 4062 eyes without pterygium (NPT group) were included.

Main outcome measures: Corneal power was measured by an autokeratorefractometer. Corneal astigmatism was calculated as the difference in corneal power between the steepest and flattest meridians. Distribution of corneal astigmatism was compared between eyes with pterygium and eyes without pterygium.

Results: Distribution of corneal astigmatism was different between PT group (Skewness=2.548, Kurtosis=8.237) and NPT group (Skewness=2.778, Kurtosis=15.52). Mean corneal astigmatism was significantly higher in the PT group (1.62±1.49D) compared to the NPT group (1.17±0.89D, P<0.0001). The prevalence of corneal astigmatism >1D (PT 52.3%, NPT 40.9%, P<0.0001), >2D (PT 22.4%, NPT 10.6%, P<0.0001) or >3D (PT 10.5%, NPT 3.2%, P<0.0001) was significantly higher in the PT group compared to the NPT group. Eyes in the PT group had significantly higher corneal astigmatism than the NPT group in almost every age group (all P<0.05), with the exception of patients ≥90 years. Moreover, eyes in the PT group had significantly higher with the rule (WTR, PT 1.72±1.59D, NPT 1.19±0.88D, P<0.0001) and against the rule (ATR, PT 1.63±1.46D, NPT

1.18±0.88D, *P*<0.0001) but similar OBL (PT 1.11±1.00D, NPT 0.999±0.8893D, *P*=0.065) corneal astigmatism compared to the NPT group. Power vector analysis indicated that the axis of corneal astigmatism was not significantly different between the two groups (J_0, PT -0.01±0.74D, NPT 0.01±0.52D, *P*=0.48; J_{45}, PT -0.03±0.82D, NPT -0.00±0.52D, *P*=0.54).

Conclusions: Distribution of corneal astigmatism in eyes with cataract and coexisting primary pterygium was different from eyes without pterygium. Pterygium is associated with higher magnitude but not different axis of corneal astigmatism.

Article Summary

Strengths and limitations of this study:

The present study investigated the distribution of corneal astigmatism in cataract eyes with primary pterygium in a rural Chinese population.

The study consisted of a large sample size to reveal the change of corneal astigmatism in eyes with primary pterygium.

The study was limited by its single-centre and retrospective design.

The timing of pterygium surgery in cataract eyes needs to be further investigated.

Introduction

Cataract surgery is the only effective treatment proven for age-related cataract. In cataract surgery, accurate assessment of axial length, corneal power and anterior chamber depth is crucial to achieve satisfactory visual function and reduce spectacle dependence postoperatively.[1,2] Corneal

astigmatism is also one of the major factors affecting postoperative visual function.[2,3] With the increasing demand of cataract patients and surgeons for better postoperative visual quality, proper and precise management of preoperative corneal astigmatism is one of the key issues for a successful and satisfactory cataract surgery. At tropical areas where people have long time exposure to ultraviolet light, eyes with age-related cataract are often accompanied by coexisting pterygium.[4] Pterygium have been shown to cause corneal irregularity and corneal astigmatism.[5,6] Proper management of corneal astigmatism in cataract eyes with coexisting pterygium may be challenging to cataract surgeons and it requires the knowledge about the distribution of corneal astigmatism in these eyes. The purpose of the present study was to investigate the distribution of corneal astigmatism in cataract eyes with primary pterygium in a southern Chinese population.

Materials and Methods

Participants

This is a retrospective study approved by the Institutional Review Board of Shanwei Eye Hospital and is in agreement with the Declaration of Helsinki. Medical records of eyes that were referred for cataract surgery between 2014 and 2016 were reviewed and eyes meeting inclusion criteria were included consecutively. A total of 1689 cataract eyes with pterygium and 4062 cataract eyes without pterygium were identified pre-operatively for analysis. Inclusion criteria were age-related cataract with or without coexisting primary pterygium. Exclusion criteria included eyes with pseudopterygium, recurrent pterygium, corneal dystrophy or corneal degeneration, history of

corneal infection, glaucoma, uveitis, ocular trauma or ocular surgery. Eyes with large pterygium in which keratometry could not be performed were also excluded. Since only review of medical records was conducted and no individual patient could be identified from the data, informed consent was waived.

Eyes were divided into two groups on the basis of with or without pterygium: pterygium group (PT) and no pterygium group (NPT), and they were further stratified into four groups based on age: 50-59 years, 60-69 years, 70-79 years, 80-89 years and 90 years and older.

Examination

A comprehensive ocular examination was performed on every patient, including best corrective visual acuity (BCVA), intraocular pressure with noncontact tonometry (CT-60; Topcon), slit lamp examination and dilated pupil for lens and fundus examination. Corneal power was measured by an autokeratorefractometer (KR-8900, Topcon, Tokyo, Japan) by experienced technicians. The patient's head was positioned in front of the autokeratorefractometer with the forehead and chin properly aligned and supported, and both lateral canthi aligned with the marks. The patient was asked to blink several times to have the tear film evenly distributed on the cornea. The patient was asked to open the eye and stare at the fixation target while the autokeratorefractometer was proceeded to the cornea. Once image of the pupil was clearly shown on the center of the display, the measurement button was pressed and three consecutive corneal curvature measurements were taken automatically. The procedure was performed again if the patient's eye blink during the

measurements or if agreement of the three measurement was poor. The average of three measurements with good agreement was recorded.

Corneal astigmatism was calculated as the difference in corneal power between the steepest and flattest meridians. Corneal astigmatism was defined as with-the-rule (WTR) when the steepest meridian was 90°±30°, as against-the-rule (ATR) when the steepest corneal meridian was between 1° and 30° or between 150° and 180°, and as oblique astigmatism (OBL) when the steepest meridian >30° and <60°, or >120° and <150°.[7]

Power vector analysis

Since corneal astigmatism is a vector consisting both magnitude and axis, power vector analysis was used to evaluate the corneal astigmatism in the eyes included, according to the following equations[8]:

$J_0 = -C/2 * \cos 2\alpha$

$J_{45} = -C/2 * \sin 2\alpha$

where C is minus astigmatism power and α is minus astigmatism axis. J_0 indicates orthogonal cylinder power set at 90° and 180°, and is a positive value in WTR astigmatism and a negative value in ATR astigmatism. J_{45} indicates oblique astigmatism at 45° and 135°, and is positive when the positive cylinder is closer to 135° and is negative when it is closer to 45°.[7]

Patient and public involvement

There was no patient or public involvement in the development and design of the study.

Statistical Analysis

Statistical analysis was performed using STATA software (version 15.0, stata, Inc.). Kolmogorov-Smirnov (KS) test was used to evaluate normality of all variables. Data of corneal astigmatism were presented as mean ± standard deviation (SD). Chi-square test or Fish's exact test was used to compare proportional data. Two-tailed Student's t-test was used for comparison of data with normal distribution and a Mann-Whitney test for other distributions. $P<0.05$ was considered to be statistically significant.

Results

The study included a group of 1689 eyes with primary pterygium (PT group) and the other group of 4062 eyes without pterygium (NPT group). Distribution of age groups and gender were not significantly different between the PT group and the NPT group (both $P>0.05$, Figure 1A, 1B). Distribution of corneal astigmatism was different between the PT group (Skewness=2.548, Kurtosis=8.237, Figure 2A) and the NPT group (Skewness=2.778, Kurtosis=15.52, Figure 2B). Corneal astigmatism distribution of the PT group was more positively skewed and strongly peaked than the NPT group. Mean corneal astigmatism was significantly higher in the PT group (1.62±1.49D) compared to the NPT group (1.17±0.89D, $P<0.0001$). In the PT group, corneal astigmatism was ≤1.0D in 47.7%, 1.0–2.0D in 29.8%, 2.0–3.0D in 11.9%, and >3.0D in 10.5% of eyes. In the NPT group, corneal astigmatism was ≤1.0D in 59.1%, 1.0–2.0D in 30.4%, 2.0–3.0D in 7.4%, and >3.0D in 3.2% of eyes ($P<0.001$ compared to the PT group). The prevalence of corneal astigmatism >1D (PT 52.3%, NPT 40.9%, $P<0.0001$), >2D (PT 22.4%, NPT 10.6%, $P<0.0001$) or >3D (PT 10.5%, NPT 3.2%, $P<0.0001$) was significantly higher in the PT group

compared to the NPT group. Moreover, eyes in the PT group had significantly higher corneal astigmatism than the NPT group in almost every age group (all $P<0.05$), with the exception of patients ≥90 years (Figure 3).

In the PT group, corneal astigmatism was WTR in 41.7%, ATR in 49.4%, and OBL in 8.9% of eyes. In the NPT group, corneal astigmatism was WTR in 41.8%, ATR in 50.4%, and OBL in 7.8% of eyes ($P=0.391$ compared to the PT group, Figure 4). Eyes in the PT group had significantly higher WTR (PT 1.72±1.59D, NPT 1.19±0.88D, $P<0.0001$) and ATR (PT 1.63±1.46D, NPT 1.18±0.88D, $P<0.0001$) but similar OBL (PT 1.11±1.00D, NPT 0.999±0.8893D, $P=0.065$) corneal astigmatism compared to the NPT group (Figure 5). Power vector analysis indicated that the axis of corneal astigmatism was not significantly different between the two groups (J_0, PT -0.01±0.74D, NPT 0.01±0.52D, $P=0.48$; J_{45}, PT -0.03±0.82D, NPT -0.00±0.52D, $P=0.54$, Figure 6).

Discussions

Pterygium is an ocular surface disorder involving a wing-like fibrovascular growth of the bulbar conjunctiva and underlying subconjunctival tissue onto the cornea.[9] It is commonly seen in areas within the 'pterygium zone' – a geographical latitude 40 degrees north and south of the equator,[10] and in people with outdoor occupations or hobbies, [9,10] implicating the role of UV radiation in the pathogenesis of pterygium. Besides, chronic irritation and/or inflammation in the peripheral cornea and limbus caused by dust, low humidity, microtrauma from smoke or sand, human papilloma virus infection and genetic factors have also been suggested as risk factors for the development of pterygium.[11] Pterygium has been found to have a significant impact on the corneal surface,

reducing corneal surface regularity index while increasing astigmatism and the surface asymmetry index.[5,12] It has been shown that corneal astigmatism is significantly higher in eyes with pterygium compared to eyes without pterygium,[13] and that pterygium-induced astigmatism is associated with size and vascularity index of the pterygiam.[5] Mohammad-Salih et al analyzed corneal astigmatism in 77 patients with unilateral primary pterygium and showed that the mean difference in corneal astigmatism between pterygium-affected eyes and control eyes was 0.60±0.7D. They also found a positive linear correlation between pterygium size and corneal astigmatism.[13] In a consecutive series of 163 eyes undergoing primary pterygium removal surgery, percent pterygium extension was positively correlated with preoperative corneal astigmatism and postoperative change in corneal astigmatism.[14] In our study cataract eyes with pterygium were also found to have significant higher corneal astigmatism (1.62±1.49D) than those without pterygium (1.17±0.89D, P<0.001). Mean corneal astigmatism in the PT group was also significantly higher than the corneal astigmatism reported in eyes without pterygium from other Chinese populations.[15-17] The difference in mean corneal astigmatism between the PT group and NPT group was 0.45D. This was consistent with what had been reported in the literature.[5,13,14]

In the era of precision medicine, proper management of corneal astigmatism has become increasingly important in cataract surgery. With the increasing demand of postoperative visual quality, accurate preoperative evaluation of corneal astigmatism and precise intraoperative astigmatism correction are crucial in patients undergoing cataract surgery,[18] especially for patients with pterygium, in whom the pterygium may affect the corneal astigmatism and its management

strategy. A fundamental basis of precision astigmatism management in cataract eyes with pterygium is the knowledge about distribution and change of corneal astigmatism in these eyes. In the present study, we showed that the distribution of corneal astigmatism in cataract eyes with pterygium was different from eyes without pterygium. The distribution curve of corneal astigmatism in the PT group was less positively skewed and lower peaked than the NPT group. It meant that higher prevalence of larger corneal astigmatism was present in the PT group compared to the NPT group. In our study, the mean WTR and ART corneal astigmatism were significantly higher in cataract eyes with pterygium compared to eyes without pterygium. The corneal astigmatism was also significantly higher in cataract eyes with pterygium than eyes without pterygium in all the age groups, with the exception of patients ≥90 years. Careful evaluation and management of the higher corneal astigmatism in cataract eyes with coexisting pterygium is crucial to having satisfactory visual outcomes after cataract surgery, especially in eyes with ATR corneal astigmatism.

In contrary to the common belief that pterygium could flatten the cornea on the horizontal axis and cause WTR, our study showed that the proportions of WTR, ART and OBL were not significantly different between the PT and NPT groups. Besides, mean ART corneal astigmatism was significantly higher in the PT group than the NPT group. These findings could be explained by the diversity of pterygium characteristics in our study, considering a large number of eyes with pterygium were included. Various characteristics of pterygium might have diverse effects on corneal astigmatism and subepithelial irregularities.[19]

Due to the corneal astigmatism caused by pterygium, eyes with cataract and co-existing pterygium usually need to undergo pterygium removal before cataract surgery can be performed, if the pterygium cause significant change in corneal astigmatism. Pujol et al showed that the best threshold of preoperative corneal astigmatism of indicating astigmatism reduction after pterygium surgery was 1.05D, with 82.5% sensitivity and 80.5% specificity.[20] After pterygium removal, the timing of cataract surgery also needs to be considered. Tomidokoro et al showed that refractive status of the cornea was markedly modified but stabilize 1 month after pterygium surgery, and have suggested cataract surgery to be performed 1 month or more after pterygium surgery.[14] After pterygium surgery, the residual corneal astigmatism can be managed by limbal relaxing incisions, femtosecond laser-assisted astigmatic keratotomy, or toric intraocular lens (IOL) implantation during cataract surgery.[21,22] One of the key issues to a sustainable visual outcome after subsequent cataract surgery is the prevention of pterygium recurrence. Surgical methods such as conjunctival autografting and conjunctive mitomycin C have been wildly used in pterygium surgery to minimize recurrence.[23,24] In some settings simultaneous pterygium excision and cataract surgery may be recommended to the patients to provide faster visual recovery while reducing hospital visits and overall cost.[25,26] In these patients, a postoperative myopic shift should be taken into account when deciding the IOL power when the pterygium is large.[25,26]

The study was limited by its single-centre and retrospective design. Since we only included eyes referred for cataract surgery, most of our patients were aged people. Many young patients with primary pterygium and eyes with pterygium but without cataract were not included. Therefore, the

results of the study only reflected the effect of primary pterygium on corneal astigmatism observed in eyes with age-related cataract. Moreover, this is a cross-sectional study, the cutoffs of corneal astigmatism and pterygium characteristics parameters indicating the benefit of pterygium removal in cataract eyes could not be determined. A prospective cohort study is needed to address these issues.

In conclusion, our study provides previously unavailable information regarding the details in distribution of corneal astigmatism in cataract eyes with coexisting pterygium. Change of corneal astigmatism in these eyes is an important clinical issue which cannot be overlooked during planning of cataract surgery.

Author Contributions

GX and YH designed the study. WQ and YH collected the dada. GX and YH analyzed and interpreted the data. GX and YH wrote the article. WQ and YH made critical revision to the article. All authors have read and approved the final manuscript.

Funding

This work was supported by the Science Research Foundation of Aier Eye Hospital Group (AF2018003) and the Science and Technology Planning Project of Shanwei City (2017C015). The study was designed, analyzed and interpreted independent of funding sources.

Competing interests

None declared.

Patient consent

Since only review of medical records was conducted and no individual patient could be identified from the data, informed consent was waived.

Ethics approval

The study was in agreement with the Declaration of Helsinki and approved by the Institutional Review Board of Shanwei Eye Hospital.

Data sharing statement

No additional data are available.

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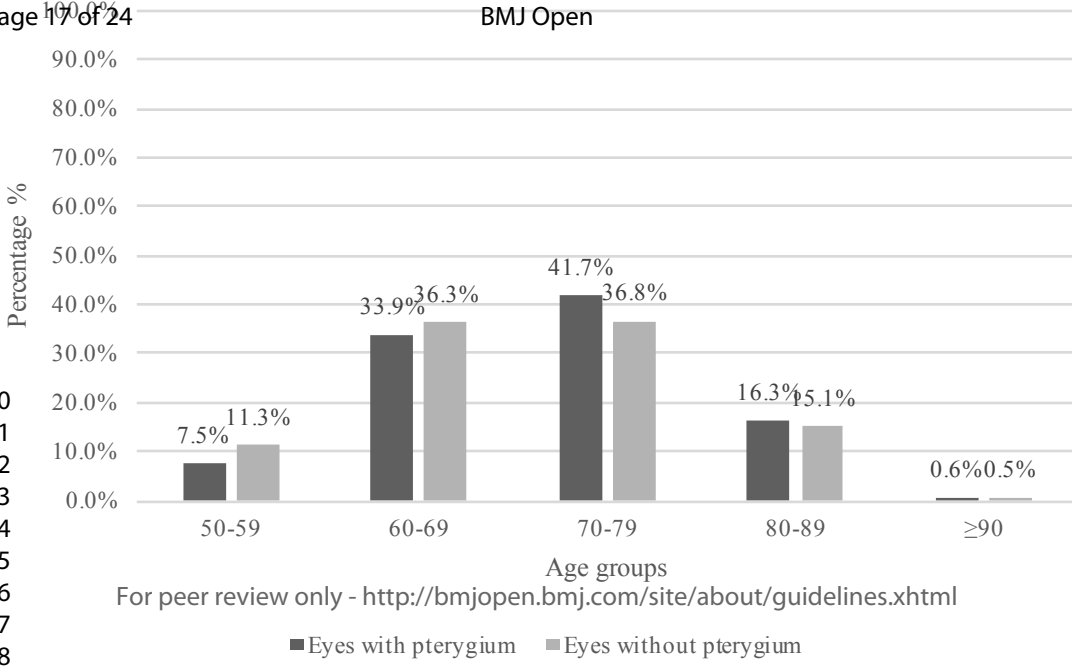

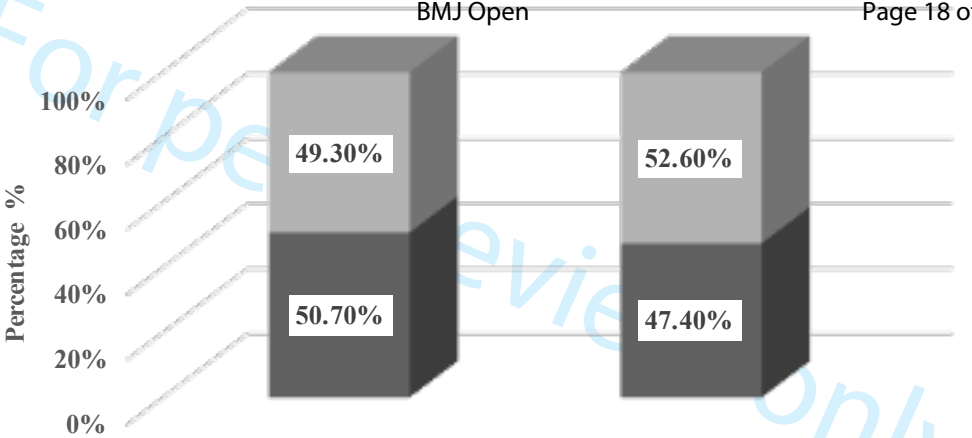

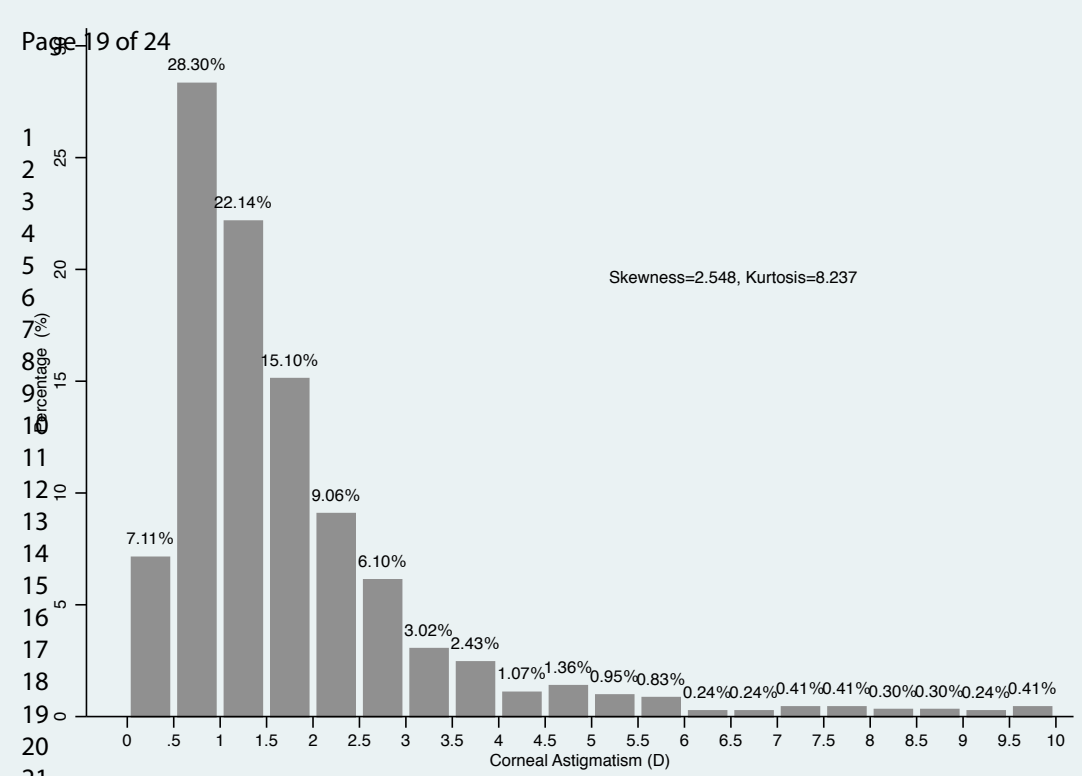

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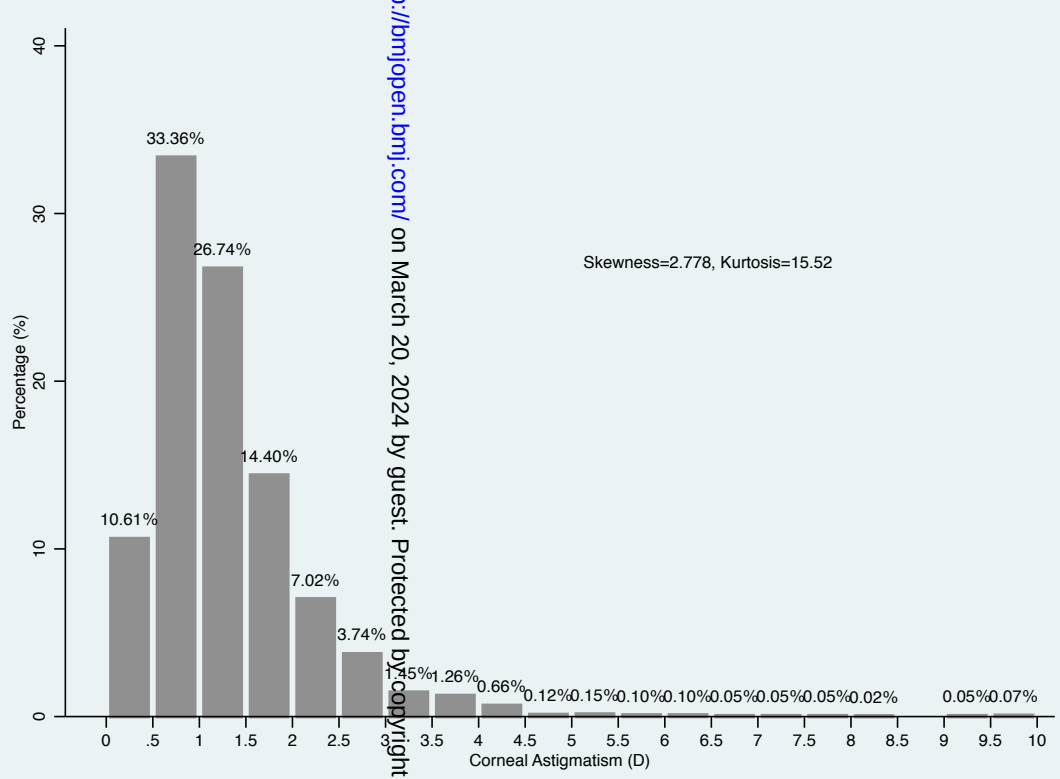

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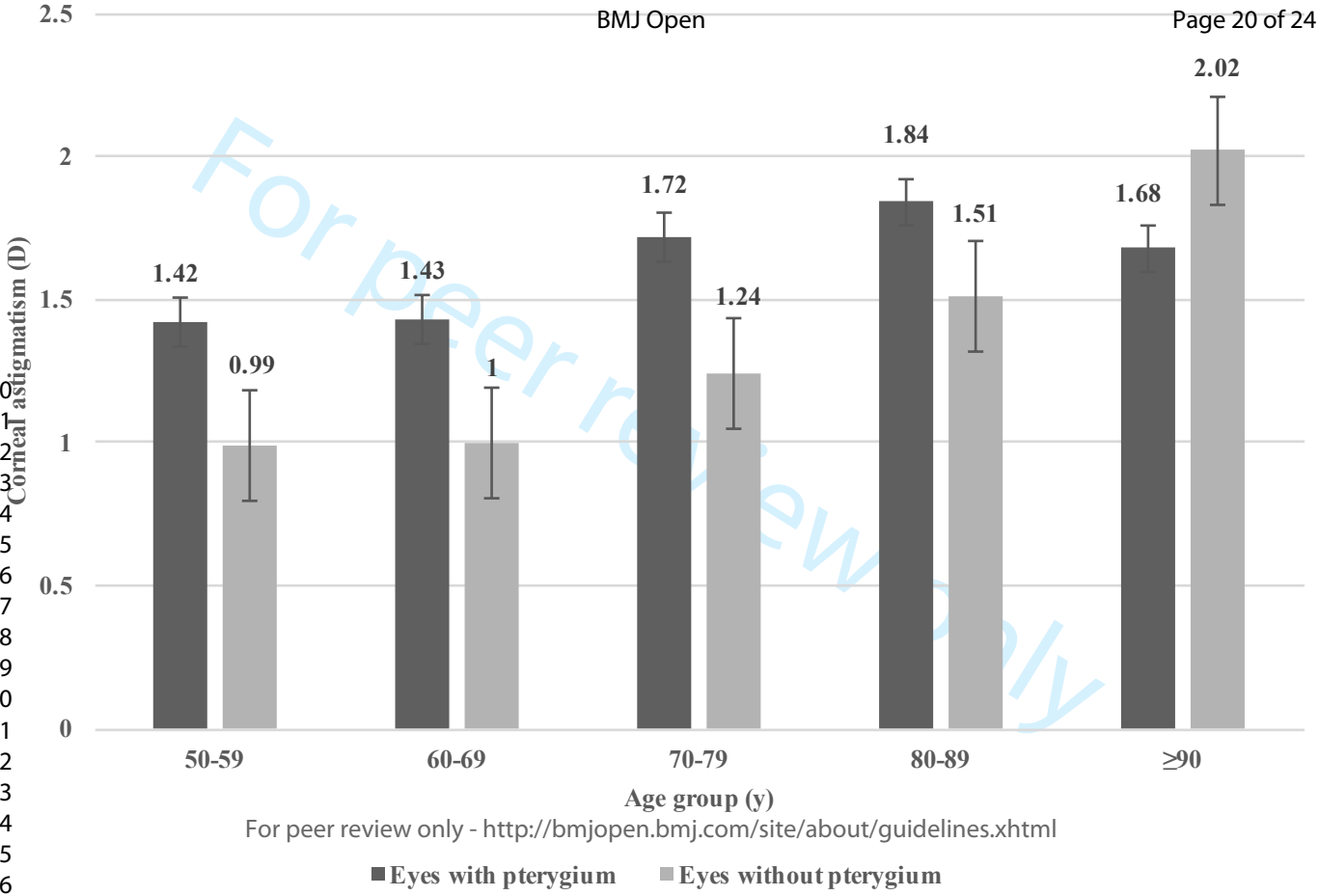

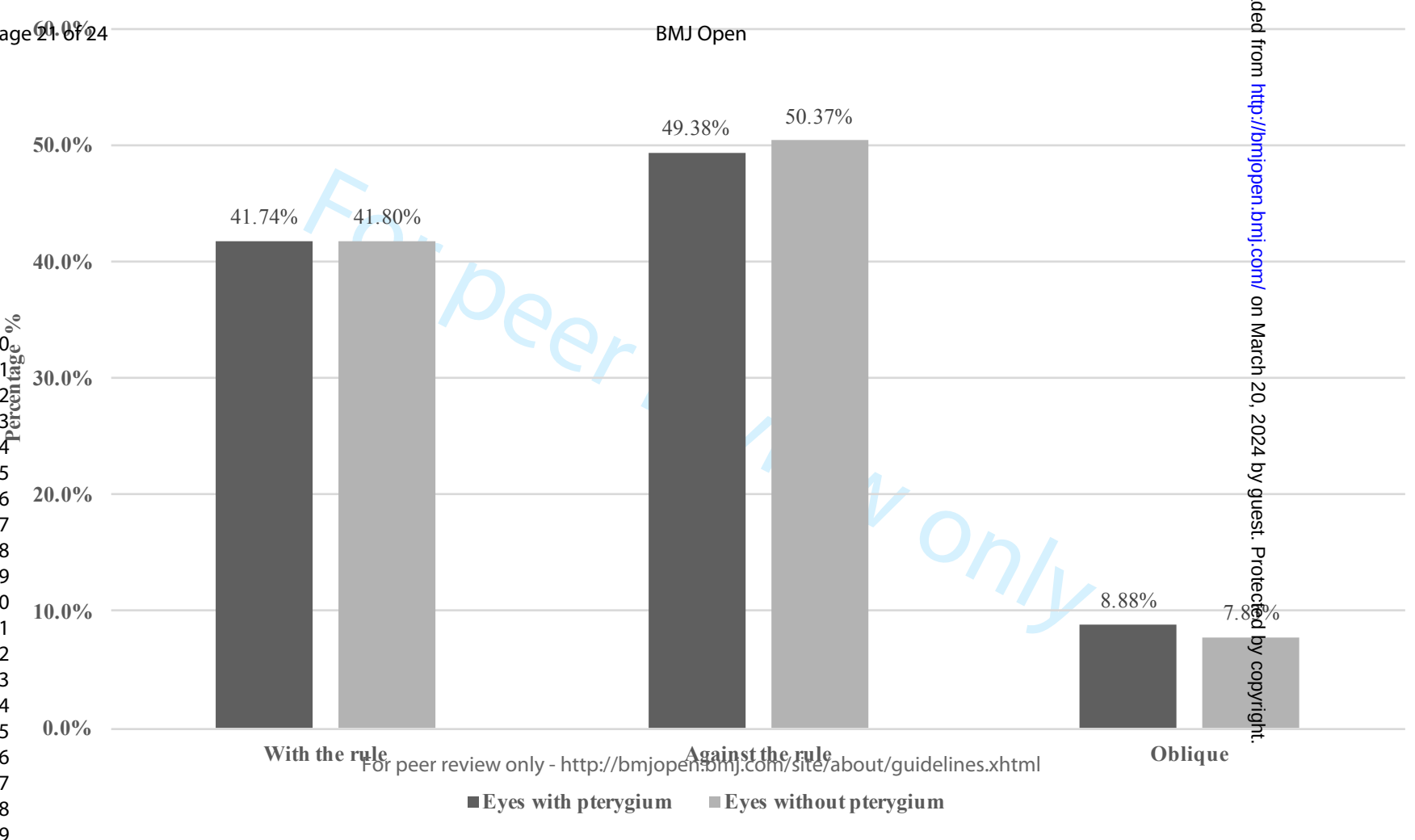

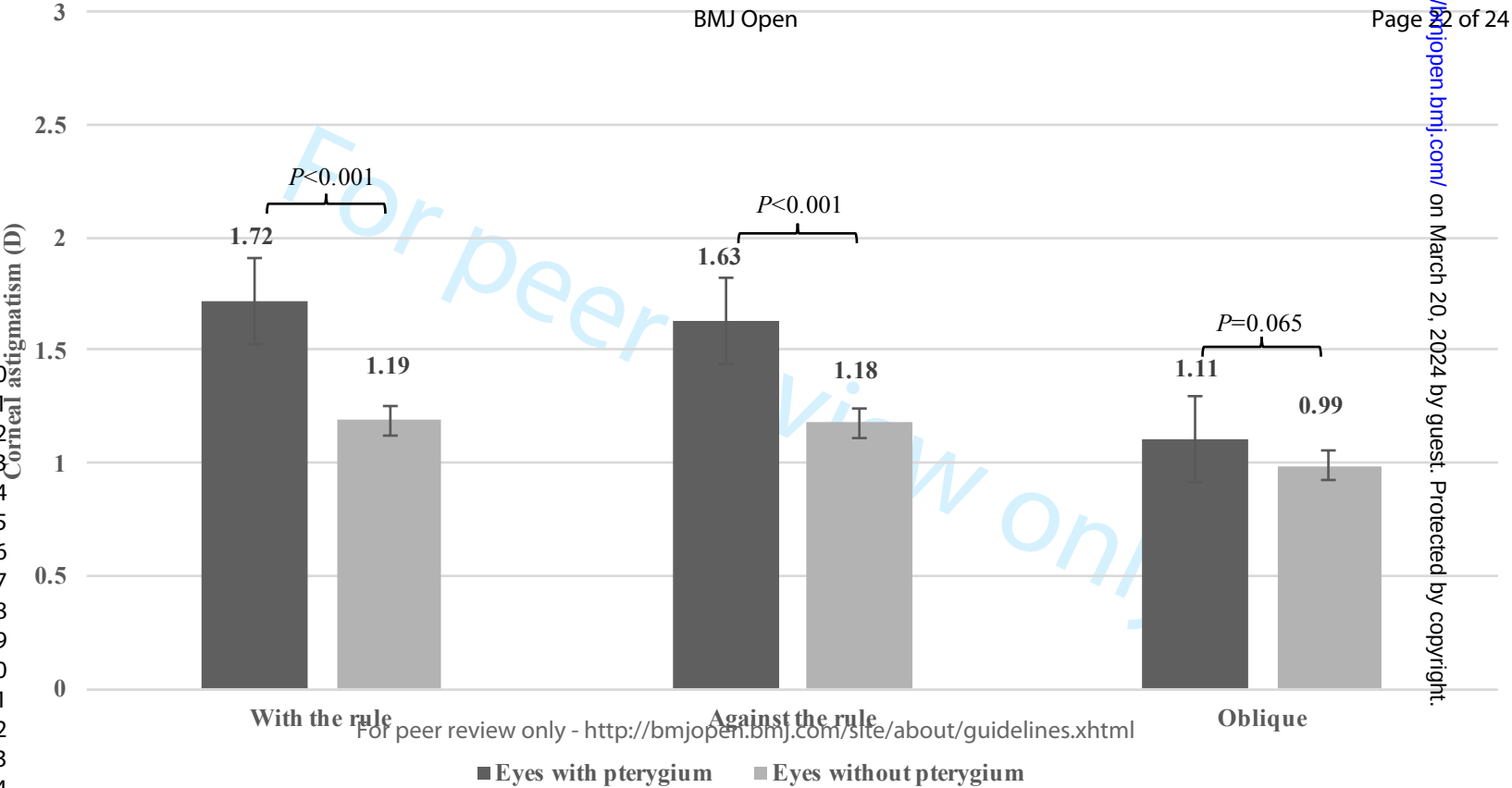

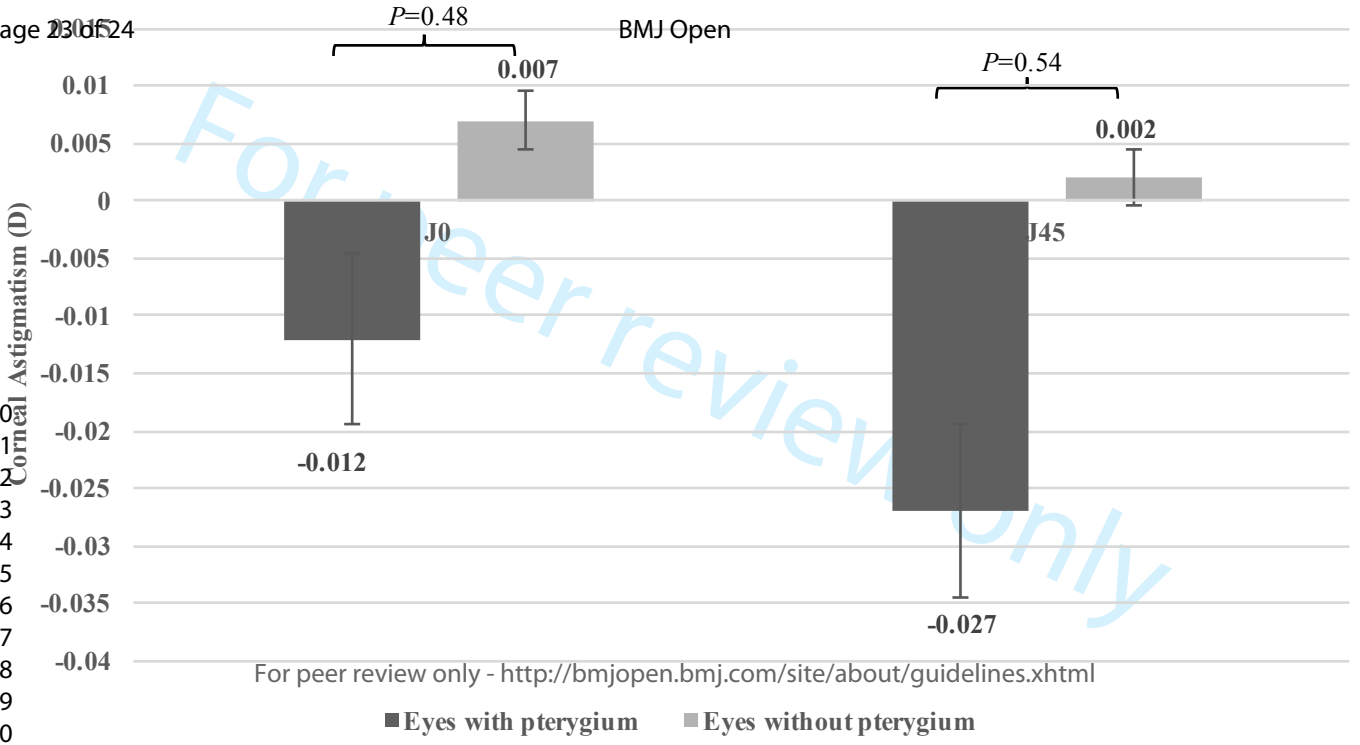

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-4
Objectives	3	State specific objectives, including any prespecified hypotheses	3-4
Methods			
Study design	4	Present key elements of study design early in the paper	4-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4-6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4-6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4-6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4-6
Bias	9	Describe any efforts to address potential sources of bias	*n/a*
Study size	10	Explain how the study size was arrived at	4-6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4-6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6-7
		(*b*) Describe any methods used to examine subgroups and interactions	6-7
		(*c*) Explain how missing data were addressed	6-7
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	6-7
		(*e*) Describe any sensitivity analyses	6-7
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	7
		(c) Consider use of a flow diagram	7
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7
		(b) Indicate number of participants with missing data for each variable of interest	7
Outcome data	15*	Report numbers of outcome events or summary measures	7-8
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7-8
		(*b*) Report category boundaries when continuous variables were categorized	7-8
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	7-8
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	n/a
Discussion			
Key results	18	Summarise key results with reference to study objectives	8-12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	8-12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8-12
Generalisability	21	Discuss the generalisability (external validity) of the study results	8-12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	12

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

A cross-sectional study of pattern of corneal astigmatism induced by primary pterygium in cataract patients in a secondary hospital in Southern China

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2019-034219.R1
Article Type:	Original research
Date Submitted by the Author:	06-Nov-2019
Complete List of Authors:	Xu, Guihua; Huizhou Municipal Central Hospital; Aier School of Ophthalmology, Central South University Qi, Wei; Shanwei Eye Hospital Hu, Yijun; Aier School of Ophthalmology, Central South University , ; Aier Institute of Refractive Surgery, Aier Eye Hospital Group,
Primary Subject Heading:	Ophthalmology
Secondary Subject Heading:	Ophthalmology
Keywords:	cataract, pterygium, corneal astigmatism, corneal curvature

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A cross-sectional study of pattern of corneal astigmatism induced by primary pterygium in cataract patients in a secondary hospital in Southern China

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Keywords: cataract; pterygium; corneal astigmatism; corneal curvature

Word Count: 2503 words

Abstract

Objectives: To review the pattern of primary pterygium induced corneal astigmatism in cataract patients in a southern Chinese population.

Design: Clinic-based cross-sectional retrospective study.

Setting: A secondary hospital at southern China.

Participants: A group of 1689 eyes with primary pterygium (PT group) and the other group of 4062 eyes without pterygium (NPT group) were included.

Main outcome measures: Corneal power was measured by an autokeratorefractometer. Corneal astigmatism was calculated as the difference in corneal power between the steepest and flattest meridians. Distribution of corneal astigmatism was compared between eyes with pterygium and eyes without pterygium.

Results: Distribution of corneal astigmatism was different between PT group (Skewness=2.548, Kurtosis=8.237) and NPT group (Skewness=2.778, Kurtosis=15.52). Mean corneal astigmatism was significantly higher in the PT group (1.62±1.49D) compared to the NPT group (1.17±0.89D, P<0.0001). The prevalence of corneal astigmatism >1D (PT 52.3%, NPT 40.9%, P<0.0001), >2D (PT 22.4%, NPT 10.6%, P<0.0001) or >3D (PT 10.5%, NPT 3.2%, P<0.0001) was significantly higher in the PT group compared to the NPT group. Eyes in the PT group had significantly higher corneal astigmatism than the NPT group in almost every age group (all P<0.05), with the exception of patients ≥90 years. Moreover, eyes in the PT group had significantly higher with the rule (WTR, PT 1.72±1.59D, NPT 1.19±0.88D, P<0.0001) and against the rule (ATR, PT 1.63±1.46D, NPT

1.18±0.88D, *P*<0.0001) but similar OBL (PT 1.11±1.00D, NPT 1.00±0.89D, *P*=0.065) corneal astigmatism compared to the NPT group. Power vector analysis indicated that the axis of corneal astigmatism was not significantly different between the two groups (J_0, PT -0.01±0.74D, NPT 0.01±0.52D, *P*=0.48; J_{45}, PT -0.03±0.82D, NPT -0.00±0.52D, *P*=0.54).

Conclusions: Pattern of corneal astigmatism in eyes with cataract and coexisting primary pterygium was different from eyes without pterygium. Pterygium is associated with higher magnitude but not different axis of corneal astigmatism.

Article Summary

Strengths and limitations of this study:

The present study investigated the distribution of corneal astigmatism in cataract eyes with primary pterygium in a rural Chinese population.

The study consisted of a large sample size to reveal the change of corneal astigmatism in eyes with primary pterygium.

The study was limited by its single-centre and retrospective design.

The timing of pterygium surgery in cataract eyes needs to be further investigated.

Introduction

Cataract surgery is the only effective treatment proven for age-related cataract. In cataract surgery, accurate assessment of axial length, corneal power and anterior chamber depth is crucial to achieve satisfactory visual function and reduce spectacle dependence postoperatively.[1,2] Corneal

astigmatism is also one of the major factors affecting postoperative visual function.[2,3] With the increasing demand of cataract patients and surgeons for better postoperative visual quality, proper and precise management of preoperative corneal astigmatism is one of the key issues for a successful and satisfactory cataract surgery. At tropical areas where people have long time exposure to ultraviolet light, eyes with age-related cataract are often accompanied by coexisting pterygium.[4] Pterygium have been shown to cause corneal irregularity and corneal astigmatism.[5,6] Proper management of corneal astigmatism in cataract eyes with coexisting pterygium may be challenging to cataract surgeons and it requires the knowledge about the distribution of corneal astigmatism in these eyes. The purpose of the present study was to investigate the distribution of corneal astigmatism in cataract eyes with primary pterygium in a southern Chinese population.

Materials and Methods

Participants

This is a retrospective study approved by the Institutional Review Board of Shanwei Eye Hospital and is in agreement with the Declaration of Helsinki. Medical records of eyes referred for cataract surgery between 2014 and 2016 were reviewed and eyes meeting inclusion criteria were included consecutively. A total of 1689 cataract eyes with pterygium and 4062 cataract eyes without pterygium were identified pre-operatively for analysis. Inclusion criteria were age-related cataract with or without coexisting primary pterygium. Exclusion criteria included eyes with pseudopterygium, recurrent pterygium, corneal dystrophy or corneal degeneration, history of

corneal infection, glaucoma, uveitis, ocular trauma or ocular surgery. Eyes with large pterygium (exceeded 3mm into the cornea) and/or in which keratometry could not be performed were also excluded. Since only review of medical records was conducted and no individual patient could be identified from the data, informed consent was waived.

Eyes were divided into two groups on the basis of with or without pterygium: pterygium group (PT) and no pterygium group (NPT), and they were further stratified into four groups based on age: 50-59 years, 60-69 years, 70-79 years, 80-89 years and 90 years and older. All of the eyes underwent cataract surgery (cataract surgery alone, simultaneous/sequel pterygium and cataract surgery) after thorough preoperative examination.

Examination

A comprehensive ocular examination was performed on every patient, including best corrective visual acuity (BCVA), intraocular pressure with noncontact tonometry (CT-60; Topcon), slit lamp examination and dilated pupil for lens and fundus examination. Corneal power was measured by an autokeratorefractometer (KR-8900, Topcon, Tokyo, Japan) by experienced technicians. The patient's head was positioned in front of the autokeratorefractometer with the forehead and chin properly aligned and supported, and both lateral canthi aligned with the marks. The patient was asked to blink several times to have the tear film evenly distributed on the cornea. The patient was asked to open the eye and stare at the fixation target while the autokeratorefractometer was proceeded to the cornea. Once image of the pupil was clearly shown on the center of the display, the measurement button was pressed and three consecutive corneal curvature measurements were

taken automatically. The procedure was performed again if the patient's eye blink during the measurements or if agreement of the three measurement was poor. The average of three measurements with good agreement was recorded.

Corneal astigmatism was calculated as the difference in corneal power between the steepest and flattest meridians. Corneal astigmatism was defined as with-the-rule (WTR) when the steepest meridian was 90°±30°, as against-the-rule (ATR) when the steepest corneal meridian was between 1° and 30° or between 150° and 180°, and as oblique astigmatism (OBL) when the steepest meridian >30° and <60°, or >120° and <150°.[7]

Power vector analysis

Since corneal astigmatism is a vector consisting both magnitude and axis, power vector analysis was used to evaluate the corneal astigmatism in the eyes included, according to the following equations[8]:

$J_0 = -C/2 * \cos 2\alpha$

$J_{45} = -C/2 * \sin 2\alpha$

where C is minus astigmatism power and α is minus astigmatism axis. J_0 indicates orthogonal cylinder power set at 90° and 180°, and is a positive value in WTR astigmatism and a negative value in ATR astigmatism. J_{45} indicates oblique astigmatism at 45° and 135°, and is positive when the positive cylinder is closer to 135° and is negative when it is closer to 45°.[7]

Patient and public involvement

There was no patient or public involvement in the development and design of the study.

Statistical Analysis

Statistical analysis was performed using STATA software (version 15.0, stata, Inc.). Kolmogorov-Smirnov (KS) test was used to evaluate normality of all variables. Data of corneal astigmatism were presented as mean ± standard deviation (SD). Chi-square test or Fish's exact test was used to compare proportional data. Two-tailed Student's t-test was used for comparison of data with normal distribution and a Mann-Whitney test for other distributions. $P<0.05$ was considered to be statistically significant.

Results

The study included a group of 1689 eyes with primary pterygium (PT group) and the other group of 4062 eyes without pterygium (NPT group). The basic characteristics and spectrum of corneal astigmatism in the PT group and NPT group were presented in Table 1.

Table 1 The frequency and demographic characteristic between patients with and without pterygium (mean ± standard deviation)

Parameter	Eyes with pterygium	Eyes without pterygium	*P*
Number of eyes	1689	4062	/
WTR, eyes (%)	705 (41.7%)	1698 (41.8%)	0.966⁺
ATR, eyes (%)	834 (49.4%)	2046 (50.4%)	0.494⁺
OBL, eyes (%)	150 (8.9%)	318 (7.8%)	0.184⁺
Age (years)	71.4±8.1	70.3±8.5	<0.001*
Male/female sex (%)	47.4%/52.6%	50.6%/49.4%	0.023⁺
Corneal astigmatism (D)	1.62±1.49	1.17±0.89	<0.001*
WTR (D)	1.72±1.59	1.19±0.88	<0.001*
ATR (D)	1.63±1.46	1.18±0.88	<0.001*
OBL (D)	1.11±1.00	1.00±0.89	0.065*
J0 (D)	-0.01±0.74	0.01±0.52	0.480
J45 (D)	-0.03±0.82	0.00±0.52	0.540

* Mann-Whitney test, $P<0.05$ was considered to be statistically significant.

⁺ Chi-square test, $P<0.05$ was considered to be statistically significant.

WTR: with-the-rule; ATR: against-the-rule; OBL: oblique astigmatism; D: diopter

Distribution of age groups and gender were not significantly different between the PT group and the NPT group (both $P>0.05$, Figure 1A, 1B). Distribution of corneal astigmatism was different between the PT group (Skewness=2.548, Kurtosis=8.237, Figure 2A) and the NPT group (Skewness=2.778, Kurtosis=15.52, Figure 2B). Corneal astigmatism distribution of the PT group was more positively skewed and strongly peaked than the NPT group. Mean corneal astigmatism was significantly higher in the PT group (1.62±1.49D) compared to the NPT group (1.17±0.89D, $P<0.0001$). In the PT group, corneal astigmatism was ≤1.0D in 47.7%, 1.0–2.0D in 29.8%, 2.0–3.0D in 11.9%, and >3.0D in 10.5% of eyes. In the NPT group, corneal astigmatism was ≤1.0D in

59.1%, 1.0–2.0D in 30.4%, 2.0–3.0D in 7.4%, and >3.0D in 3.2% of eyes (P<0.001 compared to the PT group). The prevalence of corneal astigmatism >1D (PT 52.3%, NPT 40.9%, P<0.0001), >2D (PT 22.4%, NPT 10.6%, P<0.0001) or >3D (PT 10.5%, NPT 3.2%, P<0.0001) was significantly higher in the PT group compared to the NPT group. Moreover, eyes in the PT group had significantly higher corneal astigmatism than the NPT group in almost every age group (all P<0.05), with the exception of patients ≥90 years (Figure 3).

In the PT group, corneal astigmatism was WTR in 41.7%, ATR in 49.4%, and OBL in 8.9% of eyes. In the NPT group, corneal astigmatism was WTR in 41.8%, ATR in 50.4%, and OBL in 7.8% of eyes (P=0.391 compared to the PT group, Figure 4). Eyes in the PT group had significantly higher WTR (PT 1.72±1.59D, NPT 1.19±0.88D, P<0.0001) and ATR (PT 1.63±1.46D, NPT 1.18±0.88D, P<0.0001) but similar OBL (PT 1.11±1.00D, NPT 1.00±0.89D, P=0.065) corneal astigmatism compared to the NPT group (Figure 5). Power vector analysis indicated that the axis of corneal astigmatism was not significantly different between the two groups (J_0, PT -0.01±0.74D, NPT 0.01±0.52D, P=0.48; J_{45}, PT -0.03±0.82D, NPT -0.00±0.52D, P=0.54, Figure 6).

Discussions

Pterygium is an ocular surface disorder involving a wing-like fibrovascular growth of the bulbar conjunctiva and underlying subconjunctival tissue onto the cornea.[9] It is commonly seen in areas within the 'pterygium zone' – a geographical latitude 40 degrees north and south of the equator,[10] and in people with outdoor occupations or hobbies, [9,10] implicating the role of UV radiation in the pathogenesis of pterygium. Besides, chronic irritation and/or inflammation in the peripheral cornea

and limbus caused by dust, low humidity, microtrauma from smoke or sand, human papilloma virus infection and genetic factors have also been suggested as risk factors for the development of pterygium.[11] Pterygium has been found to have a significant impact on the corneal surface, reducing corneal surface regularity index while increasing astigmatism and the surface asymmetry index.[5,12] It has been shown that corneal astigmatism is significantly higher in eyes with pterygium compared to eyes without pterygium,[13] and that pterygium-induced astigmatism is associated with size and vascularity index of the pterygiam.[5] Mohammad-Salih et al analyzed corneal astigmatism in 77 patients with unilateral primary pterygium and showed that the mean difference in corneal astigmatism between pterygium-affected eyes and control eyes was 0.60±0.7D. They also found a positive linear correlation between pterygium size and corneal astigmatism.[13] In a consecutive series of 163 eyes undergoing primary pterygium removal surgery, percent pterygium extension was positively correlated with preoperative corneal astigmatism and postoperative change in corneal astigmatism.[14] In our study cataract eyes with pterygium were found to have significant higher corneal astigmatism (1.62±1.49D) than those without pterygium (1.17±0.89D, P<0.001). Mean corneal astigmatism in the PT group was also significantly higher than the corneal astigmatism reported in eyes without pterygium from other Chinese populations.[15-17] The difference in mean corneal astigmatism between the PT group and NPT group was 0.45D. This was consistent with what had been reported in the literature.[5,13,14]

In the era of precision medicine, proper management of corneal astigmatism has become increasingly important in cataract surgery. With the increasing demand of postoperative visual

quality, accurate preoperative evaluation of corneal astigmatism and precise intraoperative astigmatism correction are crucial in patients undergoing cataract surgery,[18] especially for patients with pterygium, in whom the pterygium may affect the corneal astigmatism and its management strategy. A fundamental basis of precision astigmatism management in cataract eyes with pterygium is the knowledge about distribution and change of corneal astigmatism in these eyes. In the present study, we showed that the distribution of corneal astigmatism in cataract eyes with pterygium was different from eyes without pterygium. The distribution curve of corneal astigmatism in the PT group was less positively skewed and lower peaked than the NPT group. It meant that higher prevalence of larger corneal astigmatism was present in the PT group compared to the NPT group. In our study, the mean WTR and ART corneal astigmatism were significantly higher in cataract eyes with pterygium compared to eyes without pterygium. These findings indicate that corneal astigmatism is higher in cataract eyes with primary pterygium and a high magnitude of astigmatism correction is needed to be considered in these eyes. Moreover, in patients having simultaneous pterygium and cataract surgery, the extra corneal astigmatism induced by the pterygium may need to be taken into account when deciding the intraocular lens (IOL) power. The corneal astigmatism was also significantly higher in cataract eyes with pterygium than eyes without pterygium in all the age groups, with the exception of patients ≥90 years. The exception might be due to the small sample size in this age group. However, the trend of corneal astigmatism change in our study was consistent with a recent study by Shao et al that showed a non-linear trend of increased corneal astigmatism with aging.[19] Careful evaluation and

management of the higher corneal astigmatism in cataract eyes with coexisting pterygium is crucial to having satisfactory visual outcomes after cataract surgery, especially in eyes with ATR corneal astigmatism.

In contrary to the common belief that pterygium could flatten the cornea on the horizontal axis and cause WTR, our study showed that the proportions of WTR, ATR and OBL were not significantly different between the PT and NPT groups. Power vector analysis also indicated that the axis of corneal astigmatism was not significantly different between the two groups. These findings suggest that in our population the pterygium may not be associated with change of corneal astigmatism axis in cataract eyes. Therefore, adjustment of target corneal astigmatism in these eyes should focus more on the magnitude but less on the orientation of the corneal astigmatism. Besides, mean ATR corneal astigmatism was significantly higher in the PT group than the NPT group. These findings could be explained by the diversity of pterygium characteristics in our study, considering a large number of eyes with pterygium were included. Various characteristics of pterygium might have diverse effects on corneal astigmatism and subepithelial irregularities.[20]

Due to the corneal astigmatism caused by pterygium, eyes with cataract and co-existing pterygium usually need to undergo pterygium removal before cataract surgery can be performed, if the pterygium cause significant change in corneal astigmatism. Pujol et al showed that the best threshold of preoperative corneal astigmatism of indicating astigmatism reduction after pterygium surgery was 1.05D, with 82.5% sensitivity and 80.5% specificity.[21] After pterygium removal, the timing of cataract surgery also needs to be considered. Tomidokoro et al showed that refractive

status of the cornea was markedly modified but stabilize 1 month after pterygium surgery, and have suggested cataract surgery to be performed 1 month or more after pterygium surgery.[14] After pterygium surgery, the residual corneal astigmatism can be managed by limbal relaxing incisions, femtosecond laser-assisted astigmatic keratotomy, or toric intraocular lens (IOL) implantation during cataract surgery.[22,23] One of the key issues to a sustainable visual outcome after subsequent cataract surgery is the prevention of pterygium recurrence. Surgical methods such as conjunctival autografting and conjunctive mitomycin C have been wildly used in pterygium surgery to minimize recurrence.[24,25] In some settings simultaneous pterygium excision and cataract surgery may be recommended to the patients to provide faster visual recovery while reducing hospital visits and overall cost.[26,27] In these patients, a postoperative myopic shift should be taken into account when deciding the IOL power when the pterygium is large.[26,27]

The study was limited by its single-centre and retrospective design. Since we only included eyes referred for cataract surgery, most of our patients were aged people. Many young patients with primary pterygium and eyes with pterygium but without cataract were not included. Therefore, the results of the study only reflected the effect of primary pterygium on corneal astigmatism observed in eyes with age-related cataract. Moreover, this is a cross-sectional study, the cutoffs of corneal astigmatism and pterygium characteristics parameters indicating the benefit of pterygium removal in cataract eyes could not be determined. A prospective cohort study is needed to address these issues.

In conclusion, our study provides previously unavailable information regarding the details in distribution of corneal astigmatism in cataract eyes with coexisting pterygium. Change of corneal astigmatism in these eyes is an important clinical issue which cannot be overlooked during planning of cataract surgery.

Author Contributions

GX and YH designed the study. WQ and YH collected the dada. GX and YH analyzed and interpreted the data. GX and YH wrote the article. WQ and YH made critical revision to the article. All authors have read and approved the final manuscript.

Funding

This work was supported by the Science Research Foundation of Aier Eye Hospital Group (AF2018003) and the Science and Technology Planning Project of Shanwei City (2017C015). The study was designed, analyzed and interpreted independent of funding sources.

Competing interests

None declared.

Patient consent

Since only review of medical records was conducted and no individual patient could be identified from the data, informed consent was waived.

Ethics approval

The study was in agreement with the Declaration of Helsinki and approved by the Institutional Review Board of Shanwei Eye Hospital.

Data sharing statement

Data are available upon reasonable request.

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Figure legend

Figure1 Frequency distribution (%) of eyes with or without pterygium by age group (A) and frequency distribution (%) of eyes with or without pterygium by gender group (B).

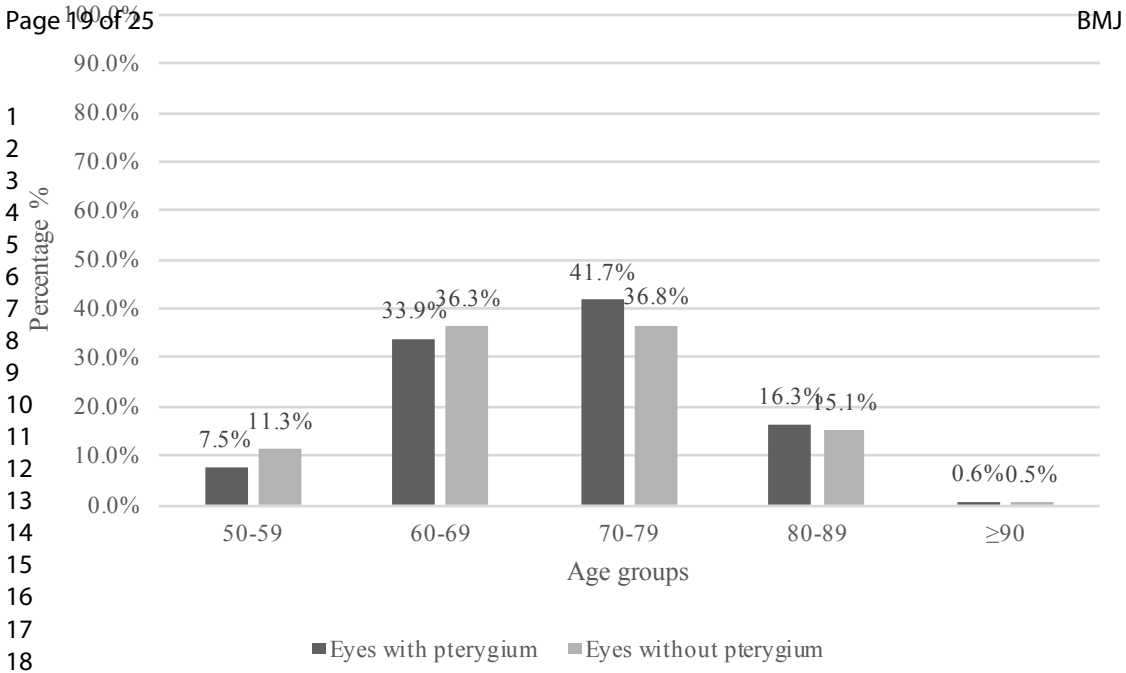
Figure 2 Frequency distribution (%) of corneal astigmatism in eyes with pterygium (A) and eyes without pterygium (B).

Figure 3 Magnitude of corneal astigmatism (D) in 5 age groups.

Figure 4 Frequency distribution (%) of with the rule, against the rule and oblique astigmatism in eyes with or without pterygium.

Figure 5 Magnitude of with the rule, against the rule and oblique corneal astigmatism (D) in eyes with or without pterygium.

Figure 6 Power vector analysis of corneal astigmatism (D) in eyes with or without pterygium.



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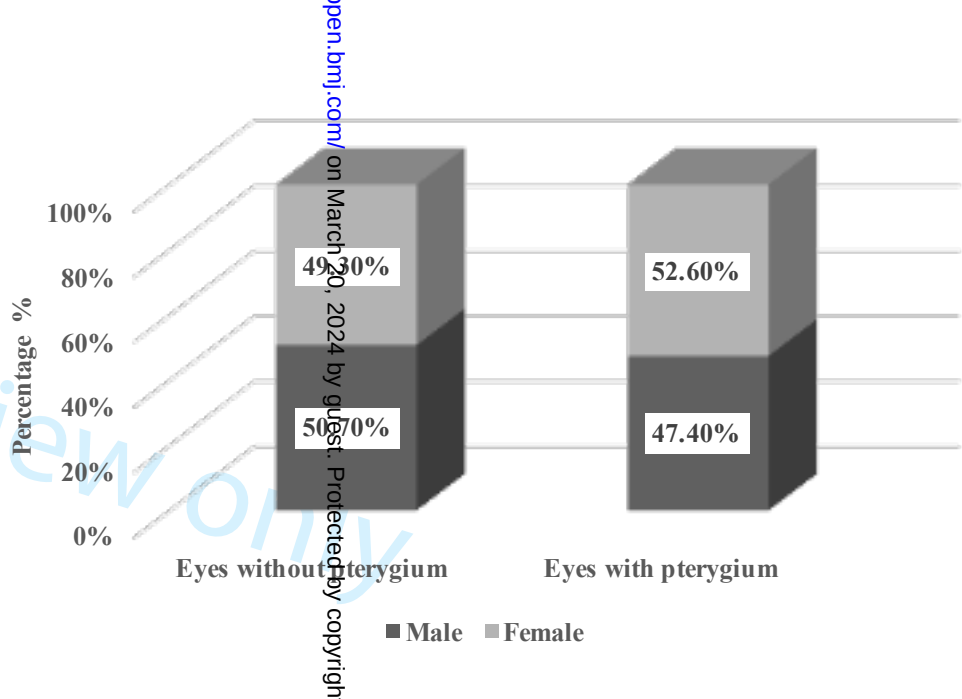

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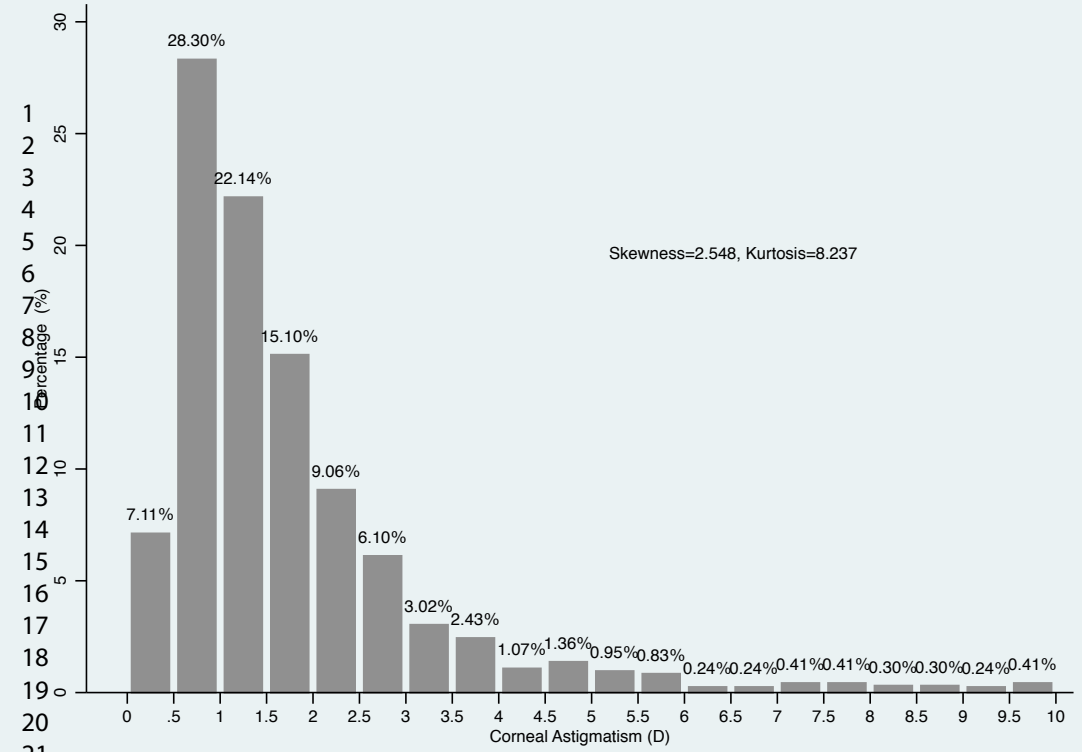

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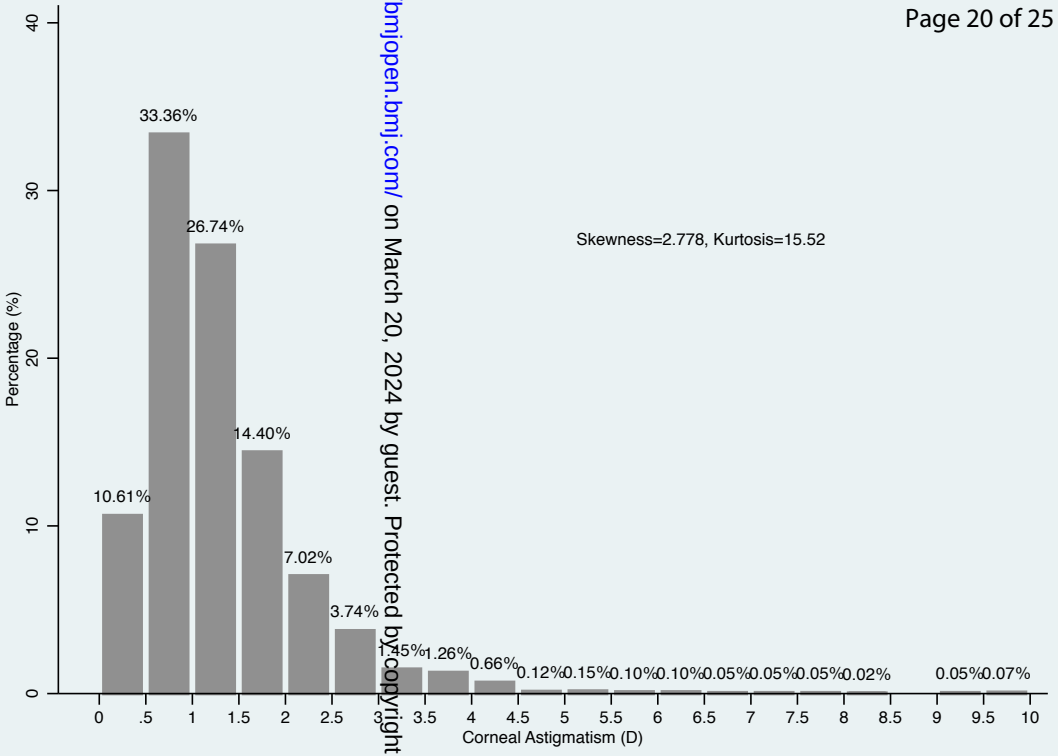

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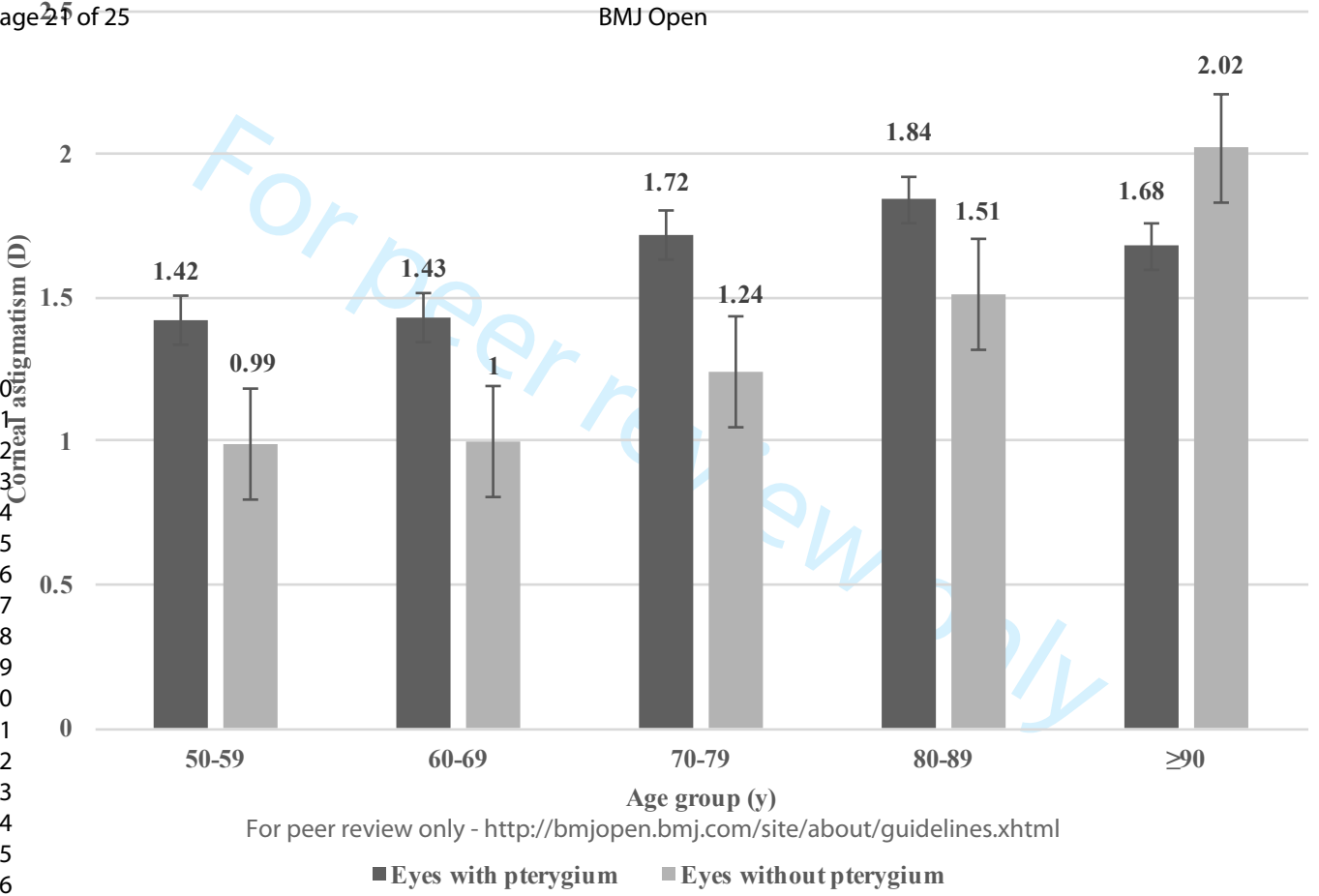

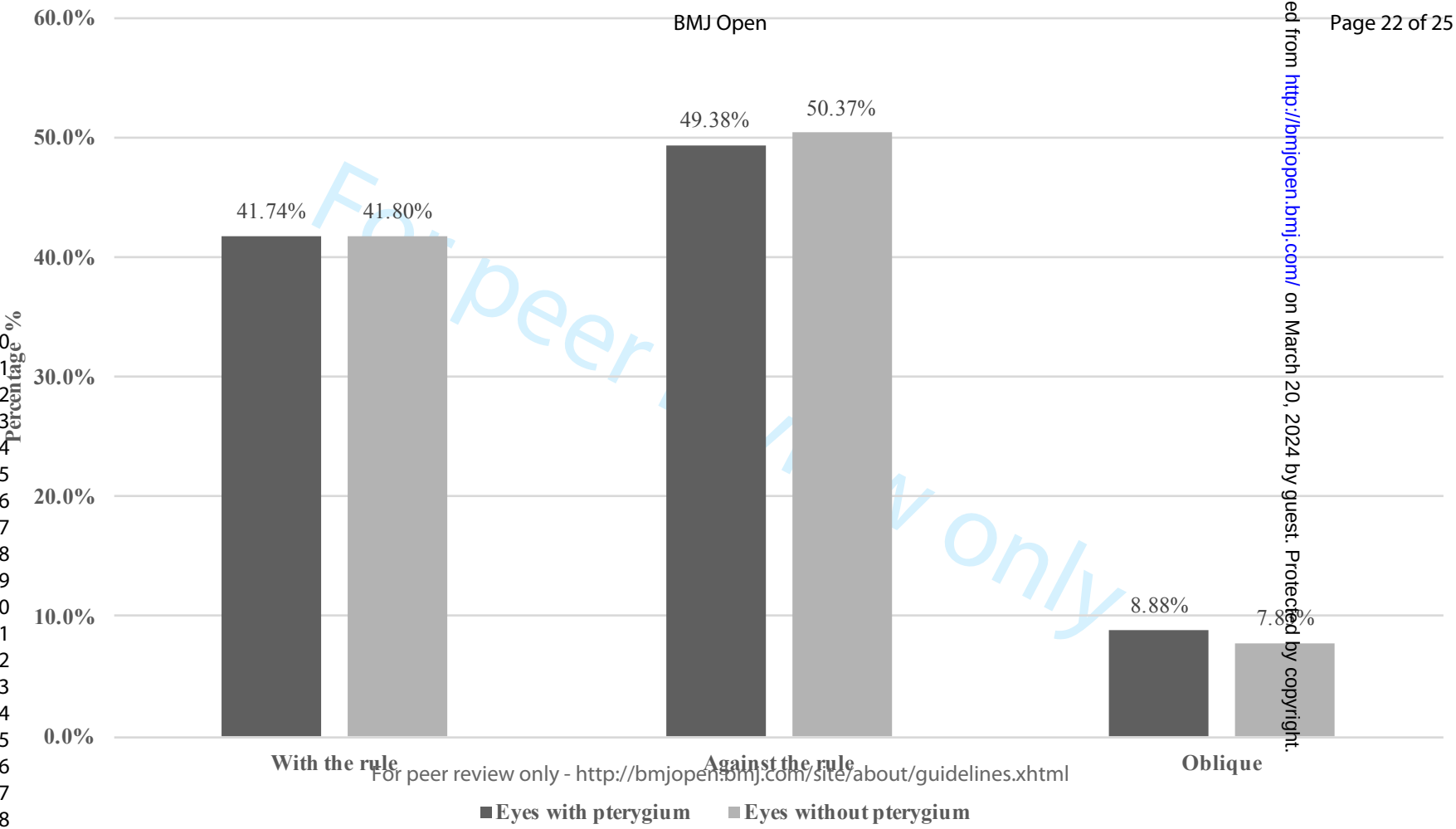

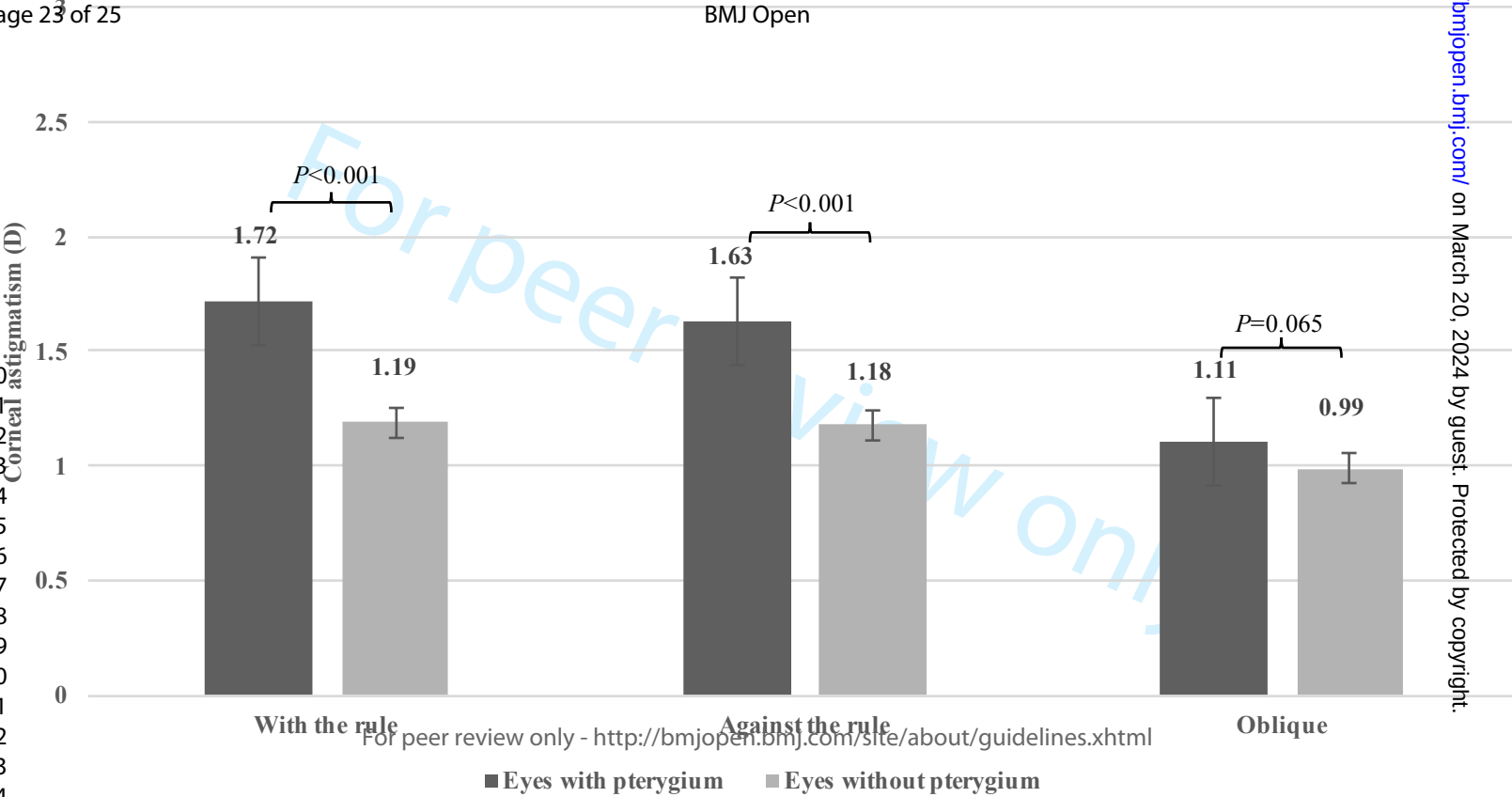

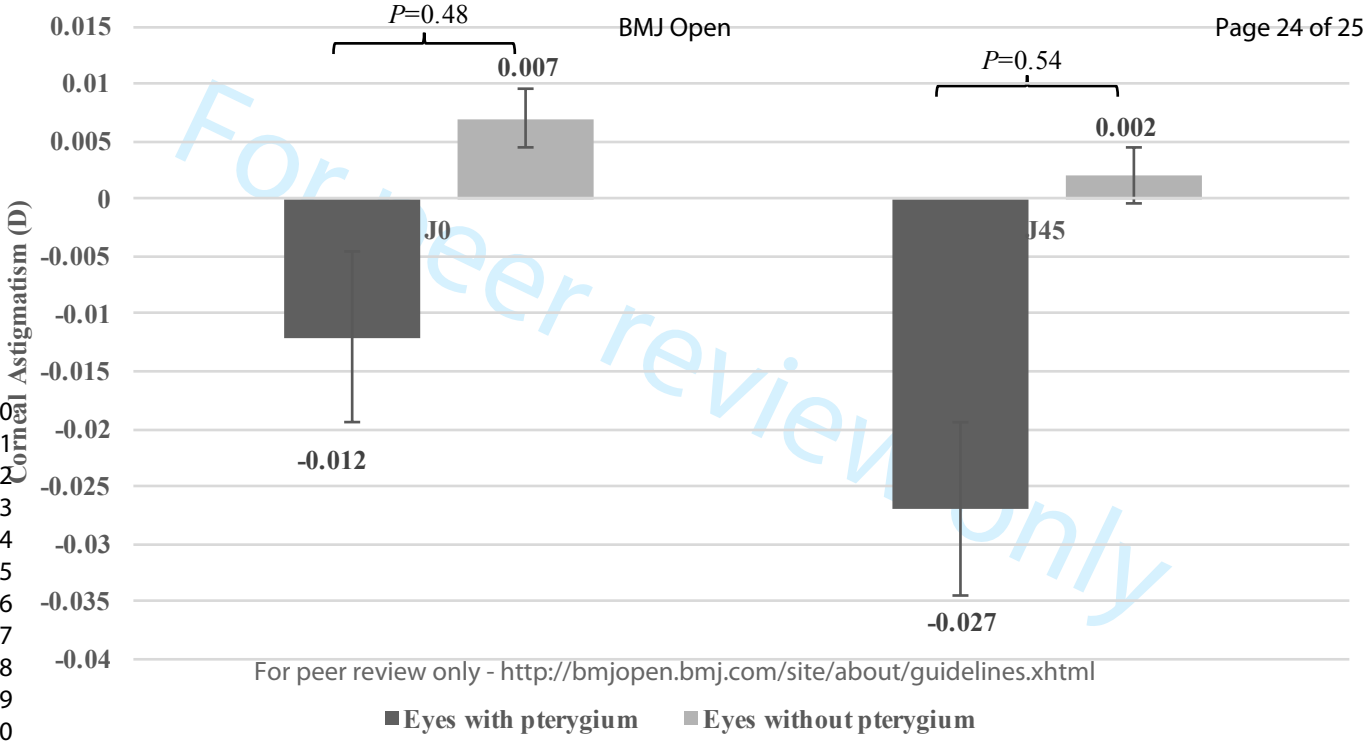

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-4
Objectives	3	State specific objectives, including any prespecified hypotheses	3-4
Methods			
Study design	4	Present key elements of study design early in the paper	4-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4-6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4-6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4-6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4-6
Bias	9	Describe any efforts to address potential sources of bias	*n/a*
Study size	10	Explain how the study size was arrived at	4-6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4-6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6-7
		(*b*) Describe any methods used to examine subgroups and interactions	6-7
		(*c*) Explain how missing data were addressed	6-7
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	6-7
		(*e*) Describe any sensitivity analyses	6-7
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	7
		(c) Consider use of a flow diagram	7
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7
		(b) Indicate number of participants with missing data for each variable of interest	7
Outcome data	15*	Report numbers of outcome events or summary measures	7-8
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7-8
		(*b*) Report category boundaries when continuous variables were categorized	7-8
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	7-8
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	n/a
Discussion			
Key results	18	Summarise key results with reference to study objectives	8-12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	8-12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8-12
Generalisability	21	Discuss the generalisability (external validity) of the study results	8-12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	12

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.