ORIGINAL ARTICLE

Role of an Optimized Tomographic Biomechanical Index for Keratoconus Screening in Laser Vision Correction Candidates in Thailand

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Background: Corneal biomechanics differ among different ethnicities. The cTBI is a parameter adjusted from the tomographic biomechanical index (TBI) for the Chinese population to maintain high sensitivity and increase specificity for detecting keratoconus.

Objective: To determine the sensitivity and specificity of cTBI compared with those of TBI in screening for keratoconus, and subclinical keratoconus patients and to determine the optimal cutoff values of TBI and cTBI in patients who came to the corneal refractive surgery clinic in Thailand.

Materials and Methods: Patients were included from a single center at Thammasat University Hospital. All patients who presented between January 2023 and April 2024 were evaluated and divided into three categories: keratoconus patients, subclinical keratoconus patients, and normal individuals. The optimal cutoff points for TBI and cTBI, which maximized both sensitivity and specificity, were found using the area under the receiver operating characteristic (AUROC) curves.

Results: Five patients were diagnosed with keratoconus. All patients had early keratoconus. Thirty-three patients were considered to have subclinical keratoconus, and 272 patients had normal profiles. AUROC curves revealed AUCs of 0.861 (95% CI 0.812 to 0.910) for cTBI, 0.842 (95% CI 0.793 to 0.892) for TBI, 0.809 (95% CI 0.742 to 0.875) for cCBI, and 0.808 (95% CI 0.732 to 0.884) for CBI. These results revealed that cTBI had the highest diagnostic performance among the other three Corvis parameters in differentiating between normal populations and subclinical keratoconus or keratoconus populations, although the difference was not statistically significant (p=0.451). The best threshold value from the study for cTBI was 0.17, with 89.5% sensitivity and 75.4% specificity. For the TBI, a cutoff value of 0.47 provided the optimum result, with 81.6% sensitivity and 78.3% specificity.

Conclusion: From this study, TBI is a reliable parameter for detecting early keratoconus and at-risk patients. The cTBI could help reduce the false positive rate of diagnosing patients with keratoconus or at-risk patients, albeit with decreased sensitivity. It is still necessary to combine several parameters to diagnose patients with keratoconus and guide further management.

Keywords: Keratoconus; Subclinical keratoconus; Corvis ST; Corneal biomechanics; cTBI

Received 28 November 2025 | Revised 7 January 2026 | Accepted 20 January 2026

J Med Assoc Thai 2026;109(5):484-90

Website: http://www.jmatonline.com

Keratoconus is one of the ectatic corneal diseases caused by abnormalities in collagen fibers in the corneal stroma. The cornea loses its strength and changes its shape to be more prolate and thinning, resulting in decreased visual acuity. The prevalence of keratoconus is approximately 1.38 per 1,000 population[1]. Asian populations have a higher incidence of keratoconus than Caucasians[2].

Corneal laser vision correction makes the cornea thinner and directly leads to a reduction in corneal strength. The detection of mild or subclinical keratoconus has received increasing interest because these patients are at increased risk for developing iatrogenic corneal ectasia after corneal laser vision correction. In addition to elective refractive surgery, detecting mild or subclinical keratoconus is useful for monitoring progression closely and implementing treatment plans such as corneal crosslinking in a timely manner.

The definition and diagnostic criteria for subclinical keratoconus are still controversial. Slit lamp findings, corneal curvature, especially posterior corneal curvature, corneal thickness distribution,

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How to cite this article:

Teeyapant N, Phrueksaudomchai P. Role of an Optimized Tomographic Biomechanical Index for Keratoconus Screening in Laser Vision Correction Candidates in Thailand. J Med Assoc Thai 2026;109:484-90.

DOI: 10.35755/jmedassocthai.2026.5.03916

and several topographic/tomographic findings are the factors to be considered. Corneal biomechanical measurements have been developed to aid in detecting the abnormalities earlier.

The Corvis ST (OCULUS Optikgeräte GmbH, Wetzlar, Germany) instrument is used to assess corneal biomechanics by recording the reaction of the cornea to a defined air pulse via a high-speed Scheimpflug camera. The corneas in keratoconus are softer and deform more under air pressure with a longer deformation amplitude. The Corvis biomechanical index (CBI) is based on five dynamic corneal response parameters used to predict ectasia risk. The tomographic biomechanical index (TBI) is derived from the integration of Pentacam® data for a combined tomographic and biomechanical analysis [the sum of Belin/Ambrósio deviation (BAD-D) and CBI]. By combining data from two instruments, previous studies revealed that the TBI provided greater accuracy for detecting subclinical ectasia than did the CBI and BAD-D[3,4].

Reference values of the CBI for differentiating corneal ectasia from normal populations derived from a mixed South American and white population[5]. Studies have found that the deformation response parameters (DCRs) of the Chinese population differ significantly from those of white populations, particularly Ambrósio's relational thickness horizontal (ARTh) and stiffness parameter at first applanation (SP-A1)[6]. These parameters are parts of the CBI and indicate that Chinese individuals may have softer and thinner corneas than white individuals. Therefore, the reference value of the CBI for the Chinese population may differ and have to be adjusted. In that study conducted in China, logistic regression was used to optimize the values of the constants of the CBI based on Chinese populations, and a new version of the index, named the cCBI, was created[7]. They reported that cCBI was significantly better than CBI for separating healthy eyes from keratoconic eyes. The cCBI had a 93.4% specificity with a 95.5% sensitivity, whereas CBI had a 68.1% specificity with a 97.7% sensitivity. Since cTBI is calculated as the sum of BAD-D and cCBI, it is assumed that cTBI may also contribute to a more accurate diagnosis in certain populations. Recent study now supports this, demonstrating that the ethnicity-optimized cTBI index had good diagnostic efficiency for early ectasia in the Chinese population[8].

In Thai populations, the corneal properties and biomechanical characteristics are hypothesized to be more comparable to those observed in the Chinese populations than in the Caucasian individuals. To the authors' knowledge, no prior study in Thailand has evaluated the diagnostic accuracy or determined the cutoff values of the cCBI and cTBI indices.

The present study aimed to investigate whether cTBI, compared with TBI, has improved sensitivity and specificity in separating keratoconus, subclinical keratoconus, and healthy individuals and to determine the optimal cutoff values of TBI and cTBI in patients who visit the corneal refractive surgery clinic in Thailand.

Materials and Methods

Patients were included from a single refractive surgery clinic at Thammasat University Hospital. All patients who visited one refractive surgery specialist between January 2023 and April 2024 were evaluated and divided into three categories: keratoconus, subclinical keratoconus, and healthy individuals.

The research protocol was approved by the institutional review boards of the Faculty of Medicine, Thammasat University (283/2567). All patients underwent a complete ophthalmic examination, including the Pentacam® and Corvis ST examinations.

Keratoconus patients were defined on the basis of the 2015 Global Consensus on Keratoconus and Ectatic Diseases[9]. Individuals exhibiting abnormal posterior corneal elevation corresponding to the location of the thinnest corneal point, accompanied by abnormal corneal thickness distribution, were classified into the keratoconus group. Subclinical keratoconus was defined as having a normal-appearing cornea on slit-lamp biomicroscopy and at least one of the following tomographic signs: central corneal power greater than 47.2 diopters, inferior steepening (inferior minus superior power at 3-mm diameter greater than 1.4 D), skewed radial axis greater than 21°, or BAD-D at 1.6 or greater. Healthy individuals were those with normal-appearing corneas in both eyes on slit-lamp biomicroscopy and bilateral normal tomography. All patients in the keratoconus and subclinical keratoconus groups were reevaluated, and the diagnosis was confirmed by a cornea and refractive surgery specialist.

All examinations with the Pentacam® and Corvis ST with a quality score of "OK" were included in the analysis. All measurements were taken by one experienced technician. Only one eye per patient was randomly included to avoid bias in the relationship between bilateral eyes. The exclusion criteria were those aged younger than 18 years old, those who

had previously undergone ocular surgery or corneal crosslinking, those with corneal scar, glaucoma, or cataract, those wearing soft contact lenses within one week or hard contact lenses within three weeks before arriving, and those with missing data.

The present study aimed to compare the performance of Corvis parameters (TBI, cTBI, CBI, and cCBI) and the optimal cutoff point for differentiating keratoconus and subclinical keratoconus patients from the normal population in patients coming to the corneal refractive surgery clinic in Thailand. Moreover, the authors also investigated cTBI and TBI with a cutoff value of 0.29 to compare accuracy in this specific population. In a previous study, they reported that an optimized TBI cutoff value of 0.29 provided 90.4% sensitivity with 96% specificity for detecting patients who had one eye with normal topography, whereas the other eyes of these patients showed clinical ectasia[3]. Since keratoconus is a bilateral disease, both eyes are usually affected eventually, although the severity may differ between them. The TBI with this cutoff in the present study showed promising results for detecting subclinical ectasia among eyes that are prone to developing keratoconus in the future.

Statistical analysis

All the statistical analyses were performed with Stata, version 17 (StataCorp LP, College Station, TX, USA). Continuous data were summarized as means ± standard deviations and medians (25th and 75th percentiles) for normally distributed and nonnormally distributed continuous variables. Categorical data were presented as frequencies and percentages. The chi-square test and Fisher's exact test were used to compare categorical variables, while one-way ANOVA and the Kruskal-Wallis test were used to assess continuous variables with normal and skewed distributions, respectively. The receiver operating characteristic (ROC) curves were used to determine the appropriate cutoff levels (based on maximization of the Youden index) for each cTBI, TBI, cCBI, and CBI for discriminating between keratoconus and subclinical keratoconus. DeLong's test was used to compare the area under the ROC (AUROC) curve between the models. The information was reported as the AUROC curve, sensitivity, specificity, positive and negative predictive values, and positive and negative likelihood ratios with 95% confidence intervals. A p-value of 0.05 was considered statistically significant.

Table 1. Demographic and clinical characteristics of the patients

Variables	Value
Sex; n (%)	
Female	199 (64.2)
Male	111 (35.8)
Age (years); mean±SD	30.67±8.36
Race; n (%)	
Thai	307 (99.0)
Others	3 (1.0)
K1 (D); mean±SD	43.11±1.45
K2 (D); mean±SD	44.68±1.66
Astigmatism (D); mean±SD	1.56±0.81
Kmax (D); mean±SD	45.25±1.71
CCT (μm); mean±SD	541.22±30.42
Thinnest point thickness (μm); mean±SD	537.4±30.23
PI; mean±SD	0.98±0.14
ARTmax; mean±SD	439.76±76.56
BAD-D; mean±SD	1.07±0.65
ARC (mm); mean±SD	7.68±0.27
PRC (mm); mean±SD	6.28±0.26
CBI; mean±SD	0.50±0.28
cCBI; mean±SD	0.34±0.35
TBI; mean±SD	0.31±0.24
cTBI; mean±SD	0.14±0.15
A1v; mean±SD	0.13±0.02
DA ratio; mean±SD	8.35±1.72
SP-A1; median (IQR)	4.4 (4.1 to 4.8)
ARTh; median (IQR)	103.75 (88.65 to 121.55)
IR; mean±SD	472.68±158.97

SD=standard deviation; IQR=interquartile range; CCT=central corneal thickness; PI=peripheral iridotomy; ARTmax=maximum Ambrósio relational thickness; BAD-D=Belin/Ambrósio deviation; ARC=average radius of curvature; PRC=posterior radius of curvature; CBI=Corvis Biomechanical Index; cCBI=CBI for Chinese population; TBI=tomographic biomechanical index; cTBI=TBI for Chinese population; A1v=applanation 1 velocity; DA=deformation amplitude; SP-A1=stiffness parameter at first applanation; ARTh=Ambrósio's relational thickness horizontal; IR=integrated radius

K1, K2, astigmatism, Kmax, CCT, thinnest point thickness, PI, ARTmax, BAD-D, ARC, and PRC were parameters from Pentacam®.

CBI, cCBI, TBI, cTBI, A1v, DA ratio, SP-A1, ARTh, and IR were parameters from Corvis ST.

Results

There were 322 patients who visited the refractive surgery clinic of one cornea and refractive surgery specialist at Thammasat University Hospital between January 2023 and April 2024. Five patients were excluded due to cataract, one patient due to corneal scar, and six patients due to incomplete data. Three hundred ten patients remained to be evaluated. The demographic and clinical characteristics of all patients are shown in Table 1.

Table 2 shows the demographic and clinical characteristics of patients categorized according

Table 2. Demographic and clinical characteristics of patients according to keratoconus status

Variables	Normal (n=272)	Subclinical KC (n=33)	KC (n=5)	p-value
All patients; n (%)	272 (87.7)	33 (10.6)	5 (1.6)	
Sex; n (%)				0.806
Female	173 (63.6)	22 (66.7)	4 (80.0)	
Male	99 (36.4)	11 (33.3)	1 (20.0)	
Age (years); mean±SD	30.83±8.45	29.30±7.54	31.20±9.23	0.608
Race; n (%)				1.000
Thai	269 (98.9)	33 100)	5 (100)	
Others	3 (1.1)	0 (0.0)	0 (0.0)	
K1 (D); mean±SD	42.95±1.36	44.29±1.64	44.08±1.46	<0.001
K2 (D); mean±SD	44.46±1.49	46.31±2.02	45.88±1.37	<0.001
Astigmatism (D); mean±SD	1.51±0.75	1.98±1.11	1.80±0.58	0.005
Kmax (D); mean±SD	45.02±1.56	46.92±1.99	46.60±1.41	<0.001
CCT (μm); mean±SD	544.13±28.88	516.06±32.41	549.2±26.24	<0.001
Thinnest point thickness (μm); mean±SD	540.51±28.43	510.91±32.74	544.8±26.41	<0.001
PI; mean±SD	0.96±0.13	1.14±0.10	1.08±0.16	<0.001
ART max; mean±SD	449.93±72.9	357.24±49.23	430.8±100.17	<0.001
BAD-D; mean±SD	0.93±0.55	2.04±0.38	2.14±0.59	<0.001
ARC (mm); mean±SD	7.71±0.25	7.44±0.27	7.47±0.23	<0.001
PRC (mm); mean±SD	6.32±0.23	6.02±0.30	6.04±0.23	<0.001
CBI; mean±SD	0.46±0.27	0.80±0.20	0.59±0.32	<0.001
cCBI; mean±SD	0.29±0.32	0.73±0.28	0.54±0.43	<0.001
TBI; mean±SD	0.26±0.22	0.62±0.19	0.65±0.15	<0.001
cTBI; mean±SD	0.11±0.12	0.35±0.16	0.41±0.19	<0.001
A1v; mean±SD	0.13±0.02	0.15±0.02	0.13±0.02	<0.001
DA ratio; mean±SD	8.20±1.68	9.63±1.62	8.26±0.50	<0.001
SP-A1; median (IQR)	4.4 (4.1 to 4.7)	4.9 (4.6 to 5.1)	4.2 (4.0 to 4.5)	<0.001
ARTh; median (IQR)	104.95 (90.60 to 122.55)	88.00 (71.30 to 101.70)	101.70 (4.70 to 119.60)	<0.001
IR; mean±SD	483.13±164.19	396.13±87.82	417.86±79.9	0.009

SD=standard deviation; IQR=interquartile range; CCT=central corneal thickness; PI=peripheral iridotomy; ARTmax=maximum Ambrósio relational thickness; BAD-D=Belin/Ambrósio deviation; ARC=average radius of curvature; PRC=posterior radius of curvature; CBI=Corvis biomechanical index; cCBI=CBI for Chinese population; TBI=tomographic biomechanical index; cTBI=TBI for Chinese population; A1v=applanation 1 velocity; DA=deformation amplitude; SP-A1=stiffness parameter at first applanation; ARTh=Ambrósio's relational thickness horizontal; IR=integrated radius; KC=keratoconus

to the different keratoconus groups. There were 272 patients in the normal group, 33 patients in the subclinical keratoconus group, and five patients in the keratoconus group.

Table 3 shows the Corvis biomechanical parameters compared between the normal population and patients in the keratoconus or subclinical keratoconus group. The ROC curve and AUROC curve shown in Figure 1 and Table 4 revealed an AUC of 0.861 (95% CI 0.812 to 0.910) for cTBI, 0.842 (95% CI 0.793 to 0.892) for TBI, 0.809 (95% CI 0.742 to 0.875) for cCBI, and 0.808 (95% CI 0.732 to 0.884) for CBI. These results revealed that cTBI had the highest diagnostic performance among the other three Corvis parameters in differentiating between normal populations and subclinical keratoconus or keratoconus populations, although the difference was not statistically significant (p=0.451).

Table 3. Corvis biomechanical index and tomographic biomechanical index of patients according to the categorized groups

Variables	Normal (n=272) mean±SD	Subclinical KC or KC (n=38) mean±SD	p-value
CBI	0.46±0.27	0.77±0.22	<0.001
cCBI	0.29±0.32	0.70±0.30	<0.001
TBI	0.26±0.22	0.62±0.18	<0.001
cTBI	0.11±0.12	0.36±0.16	<0.001

SD=standard deviation; CBI=Corvis biomechanical index; cCBI=CBI for Chinese population; TBI=tomographic biomechanical index; cTBI=TBI for Chinese population; KC=keratoconus

The best threshold value from this study was determined using Youden's index. Table 5 shows that the resulting cutoff value for cTBI was 0.17 with

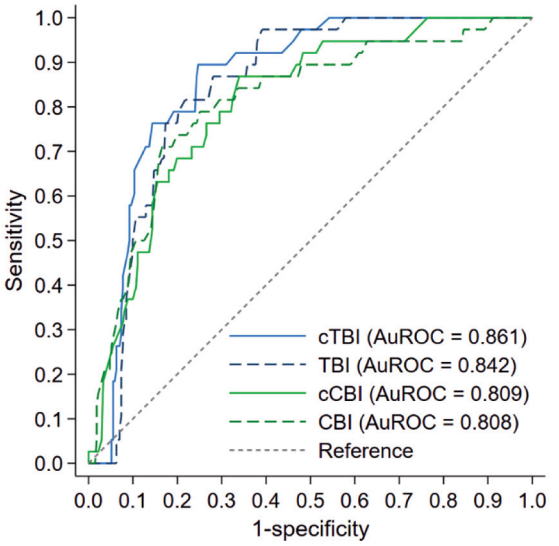

Figure 1. ROC curve for Corvis biomechanical index and tomographic biomechanical index for the prediction of KC and subclinical KC vs. healthy individuals.

Table 4. Area under the ROC (AUROC) curve for Corvis biomechanical index and tomographic biomechanical index for the prediction of KC and subclinical KC vs. healthy individuals

Variables	AUROC (95% CI)	p-value
cTBI	0.861 (0.812 to 0.910)	0.451
TBI	0.842 (0.793 to 0.892)	
cCBI	0.809 (0.742 to 0.875)	
CBI	0.808 (0.732 to 0.884)	

CBI=Corvis biomechanical index; cCBI=CBI for Chinese population; TBI=tomographic biomechanical index; cTBI=TBI for Chinese population; CI=confidence interval

89.5% sensitivity and 75.4% specificity. For the TBI, a cutoff value of 0.47 provided the optimum result, with 81.6% sensitivity and 78.3% specificity.

Further evaluation of the TBI and cTBI cutoff values of 0.29 in laser vision correction candidates in Thailand was performed. In this study, a TBI value of 0.29 provided 97.4% sensitivity and 58.1% specificity for differentiating clinical and subclinical keratoconus patients from normal individuals, while a cTBI value of 0.29 provided 65.8% sensitivity and 89.7% specificity (Table 5).

Discussion

In the present study, the authors investigate whether cTBI has better sensitivity and specificity than TBI in detecting keratoconus and subclinical keratoconus in the Thai population. The study's result with the AuROC curve between TBI, cTBI, CBI, and cCBI shows no statistically significant difference in diagnostic performance. At the cutoff value of 0.29, this study shows that cTBI has increased specificity when compared with TBI, but sensitivity drops prominently. This is compatible with what the authors have hypothesized that cTBI would have increased specificity, according to the previous study conducted in China that showed cCBI had improved specificity while sensitivity remained high in that study[7]. Considering the best threshold value in terms of sensitivity and specificity, cTBI and TBI in this study yield comparable outcomes at different cutoff values. cTBI demonstrates a trend toward increased specificity at the expense of reduced sensitivity when compared to the same value in TBI. However, the optimal balance of these parameters may vary in clinical practice, depending on the intended diagnostic or therapeutic goals. When using cTBI, TBI, cCBI, and CBI in clinical practice, different cutoff values may be required to achieve optimal results.

In this study, it is found that the mean central corneal thickness (CCT) is highest in the keratoconus group and lowest in the subclinical keratoconus group, which does not correlate with the natural history of the keratoconus disease. This may be due to the keratoconus diagnostic criteria, which do not include CCT or thinnest point thickness into consideration. Many parameters, such as the ARTmax, ARC, PRC, CBI, cCBI, PI, Kmax, and degree of astigmatism, also tend to be more severe in the subclinical keratoconus group than in the clinical keratoconus group. These results emphasize that keratoconus and subclinical keratoconus cannot be reliably diagnosed using a single parameter but require a multiparametric approach. Another limitation of the present study is the small sample size, which may affect the generalizability of the findings. Further studies with larger sample sizes are recommended to confirm and strengthen these results.

When analyzing patients who are not suitable for refractive surgery due to the increased risk of developing keratoconus, several parameters from corneal tomography and corneal biomechanical measurements must be considered together to accurately detect the right patients. cTBI, when applied with a cutoff value favoring higher specificity, may additionally help identify patients with low-risk tomographic profiles that are safe to proceed with refractive surgery.

In conclusion, this study suggests that the TBI and cTBI cutoff value of 0.29 may be used together to increase the accuracy of subclinical keratoconus and

Table 5. Diagnostic performance of the Corvis biomechanical index and tomographic biomechanical index for prediction of KC or subclinical KC vs. healthy individuals

Test	Cutoff	Sensitivity (%) (95% CI)	Specificity (%) (95% CI)	PPV (%) (95% CI)	NPV (%) (95% CI)	LR+ (95% CI)	LR– (95% CI)	Youden's index (J)
cTBI	≥0.17†	89.5 (75.2 to 97.1)	75.4 (69.8 to 80.4)	33.7 (24.6 to 43.8)	98.1 (95.2 to 99.5)	3.63 (2.87 to 4.59)	0.14 (0.06 to 0.35)	0.65
	≥0.20	78.9 (62.7 to 90.4)	76.8 (71.4 to 81.7)	32.3 (22.9 to 42.7)	96.3 (92.9 to 98.4)	3.41 (2.6 to 4.47)	0.27 (0.15 to 0.51)	0.56
	≥0.25	76.3 (59.8 to 88.6)	84.2 (79.3 to 88.3)	40.3 (28.9 to 52.5)	96.2 (92.9 to 98.3)	4.83 (3.48 to 6.69)	0.28 (0.16 to 0.5)	0.61
	≥0.29	65.8 (48.6 to 80.4)	89.7 (85.5 to 93)	47.2 (33.3 to 61.4)	94.9 (91.5 to 97.3)	6.39 (4.2 to 9.72)	0.38 (0.25 to 0.59)	0.56
	≥0.30	65.8 (48.6 to 80.4)	89.7 (85.5 to 93)	47.2 (33.3 to 61.4)	94.9 (91.5 to 97.3)	6.39 (4.2 to 9.72)	0.38 (0.25 to 0.59)	0.56
	≥0.35	50.0 (33.4 to 66.6)	90.8 (86.7 to 94)	43.2 (28.3 to 59)	92.9 (89.1 to 95.6)	5.44 (3.33 to 8.88)	0.55 (0.4 to 0.76)	0.41
	≥0.40	39.5 (24 to 56.6)	92.3 (88.4 to 95.2)	41.7 (25.5 to 59.2)	91.6 (87.7 to 94.6)	5.11 (2.89 to 9.03)	0.66 (0.51 to 0.85)	0.32
TBI	≥0.29	97.4 (86.2 to 99.9)	58.1 (52 to 64)	24.5 (17.9 to 32.2)	99.4 (96.5 to 100)	2.32 (2 to 2.7)	0.05 (0.01 to 0.31)	0.56
	≥0.47†	81.6 (65.7 to 92.3)	78.3 (72.9 to 83.1)	34.4 (24.7 to 45.2)	96.8 (93.6 to 98.7)	3.76 (2.87 to 4.93)	0.24 (0.12 to 0.46)	0.60
	≥0.50	76.3 (59.8 to 88.6)	80.1 (74.9 to 84.7)	34.9 (24.8 to 46.2)	96.0 (92.6 to 98.2)	3.84 (2.86 to 5.17)	0.30 (0.17 to 0.53)	0.56
	≥0.55	65.8 (48.6 to 80.4)	84.6 (79.7 to 88.6)	37.3 (25.8 to 50)	94.7 (91 to 9,700)	4.26 (2.97 to 6.11)	0.41 (0.26 to 0.63)	0.50
	≥0.60	55.3 (38.3 to 71.4)	87.1 (82.6 to 90.9)	37.5 (24.9 to 51.5)	93.3 (89.5 to 96.1)	4.29 (2.82 to 6.54)	0.51 (0.36 to 0.73)	0.42
	≥0.65	50.0 (33.4 to 66.6)	90.1 (85.9 to 93.4)	41.3 (27 to 56.8)	92.8 (89 to 95.6)	5.04 (3.12 to 8.13)	0.56 (0.4 to 0.77)	0.40
	≥0.70	36.8 (21.8 to 54)	91.5 (87.6 to 94.6)	37.8 (22.5 to 55.2)	91.2 (87.2 to 94.3)	4.36 (2.46 to 7.71)	0.69 (0.54 to 0.88)	0.28
cCBI	≥0.29	86.8 (71.9 to 95.6)	60.3 (54.2 to 66.2)	23.4 (16.7 to 31.3)	97.0 (93.2 to 99)	2.19 (1.81 to 2.65)	0.22 (0.1 to 0.5)	0.47
	≥0.38†	86.8 (71.9 to 95.6)	66.2 (60.2 to 71.8)	26.4 (18.9 to 35)	97.3 (93.8 to 99.1)	2.57 (2.09 to 3.16)	0.20 (0.09 to 0.45)	0.53
	≥0.50	76.3 (59.8 to 88.6)	72.8 (67.1 to 78)	28.2 (19.7 to 37.9)	95.7 (91.9 to 98)	2.81 (2.16 to 3.65)	0.33 (0.18 to 0.58)	0.49
	≥0.60	71.1 (54.1 to 84.6)	76.1 (70.6 to 81)	29.3 (20.3 to 39.8)	95.0 (91.2 to 97.5)	2.97 (2.22 to 3.99)	0.38 (0.23 to 0.63)	0.47
	≥0.70	65.8 (48.6 to 80.4)	81.3 (76.1 to 85.7)	32.9 (22.5 to 44.6)	94.4 (90.7 to 97)	3.51 (2.5 to 4.92)	0.42 (0.27 to 0.66)	0.47
	≥0.80	52.6 (35.8 to 69)	85.7 (80.9 to 89.6)	33.9 (22.1 to 47.4)	92.8 (88.9 to 95.7)	3.67 (2.41 to 5.58)	0.55 (0.39 to 0.78)	0.38
	≥0.90	36.8 (21.8 to 54)	91.2 (87.2 to 94.3)	36.8 (21.8 to 54)	91.2 (87.2 to 94.3)	4.18 (2.37 to 7.35)	0.69 (0.54 to 0.89)	0.28
CBI	≥0.29	94.7 (82.3 to 99.4)	33.5 (27.9 to 39.4)	16.6 (11.9 to 22.2)	97.8 (92.4 to 99.7)	1.42 (1.27 to 1.59)	0.16 (0.04 to 0.61)	0.28
	≥0.75	73.7 (56.9 to 86.6)	80.1 (74.9 to 84.7)	34.1 (24 to 45.4)	95.6 (92.1 to 97.9)	3.71 (2.74 to 5.04)	0.33 (0.19 to 0.56)	0.54
	≥0.78†	71.1 (54.1 to 84.6)	83.5 (78.5 to 87.7)	37.5 (26.4 to 49.7)	95.4 (91.9 to 97.7)	4.29 (3.07 to 6.01)	0.35 (0.21 to 0.57)	0.55
	≥0.80	57.9 (40.8 to 73.7)	85.3 (80.5 to 89.3)	35.5 (23.7 to 48.7)	93.5 (89.7 to 96.3)	3.94 (2.65 to 5.84)	0.49 (0.34 to 0.72)	0.43
	≥0.85	47.4 (31 to 64.2)	90.4 (86.3 to 93.7)	40.9 (26.3 to 56.8)	92.5 (88.6 to 95.3)	4.96 (3.02 to 8.14)	0.58 (0.43 to 0.79)	0.38
	≥0.90	31.6 (17.5 to 48.7)	93.8 (90.2 to 96.3)	41.4 (23.5 to 61.1)	90.7 (86.7 to 93.9)	5.05 (2.62 to 9.74)	0.73 (0.59 to 0.91)	0.25
	≥0.95	21.1 (9.6 to 37.3)	96.3 (93.3 to 98.2)	44.4 (21.5 to 69.2)	89.7 (85.7 to 93)	5.73 (2.41 to 13.6)	0.82 (0.69 to 0.97)	0.17

CBI=Corvis biomechanical index; cCBI=CBI for Chinese population; TBI=tomographic biomechanical index; cTBI=TBI for Chinese population; CI=confidence interval; PPV=positive predictive value; NPV=negative predictive value; LR=likelihood ratio

† The best threshold value was determined using Youden's index [Youden's index (J) = Sensitivity + Specificity – 1].

clinical keratoconus detection in the Thai population, considering refractive surgery. Additionally, the authors introduce a new cutoff value for the TBI, cTBI, CBI, and cCBI with different values to yield the best result for early keratoconus detection.

What is already known about this topic?

The cTBI has better sensitivity and specificity than TBI in detecting keratoconus and subclinical keratoconus in the Chinese population.

What does this study add?

This study suggests that the TBI and cTBI cutoff value of 0.29 may be used together to increase the accuracy of subclinical keratoconus and clinical keratoconus detection in the Thai population, considering refractive surgery.

Acknowledgement

The authors would like to thanks the Thammasat Cataract & Lasik Center (TCLC) for provided data used in this research.

Authors' contributions

NT and PP contributed to the study conception and design. Data collection, data analysis, and drafting of the initial manuscript were performed by NT. All authors read and approved the final manuscript.

Data availability statement

The data that support the findings of this study

are available upon reasonable request from the corresponding author. The data are not publicly available due to their containing information that could compromise the privacy of research participants.

Ethics approval and consent to participate

All the procedures were performed in accordance with the guidelines of the Declaration of Helsinki. The research protocol was approved by the institutional review boards of the Faculty of Medicine, Thammasat University (Number of COA: 283/2567).

As this study involves retrospective data collection from medical records, which were obtained as part of standard medical care, informed consent was not obtained from the participants and the Research Ethics Subcommittee of the Faculty of Medicine, Thammasat University approved this.

Clinical trial registration

Not applicable. This study was not a clinical trial.

Use of artificial intelligence

GPT-5.2 and GPT-5.3 (OpenAI) were utilized in this research solely for grammatical correction and sentence refinement, and not for generating original content.

Conflicts of interest

The authors declare no conflict of interest.

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