Original Article

pISSN, eISSN 0125-5614
M Dent J 2026; 46 (2) : 140-148

Revisiting the incisor index for sex determination: development of cut-off values and validation of predictive accuracy

Disapong Youngcharoen[1], Tawepong Arayapisit [2], **Varita Tachasanskul**[1].

[1] *Dental Department, Police General Hospital, Bangkok, Thailand*
[2] *Department of Anatomy, Faculty of Dentistry, Mahidol University, Bangkok, Thailand*

Objective: Sex estimation is a fundamental step in forensic human identification. Teeth are highly resistant to postmortem degradation and therefore provide valuable biological markers for sex determination. Among odontometric methods, the incisor index has long been recognized as a simple tool for sex assessment; however, the absence of clearly defined cut-off values has limited its practical application. This study aimed to establish cut-off values for the incisor index and to evaluate its predictive accuracy for sex determination in a Thai population.

Materials and Methods: The study was conducted in two sequential phases. In the first phase, mesiodistal crown widths of maxillary and mandibular incisors were measured and used to calculate the incisor index. Receiver Operating Characteristic (ROC) curve analysis was applied to determine optimal cut-off values using both Youden's index and the Euclidean index. In the second phase, the predictive accuracy of these newly-derived cut-off values for sex classification was evaluated.

Results: Males exhibited greater mean mesiodistal tooth widths than females for all incisors, although statistically significant differences were observed in only four teeth. The highest predictive accuracy was obtained from the maxillary left incisor index with a cut-off value of 85.60, yielding an overall accuracy of 71.00%. The maxillary right incisor index demonstrated a similar performance with an accuracy of 70.00%. In contrast, mandibular incisor indices showed substantially lower predictive accuracies, all below 55%. These findings indicate that the discriminative potential of the incisor index depends primarily on the proportional relationship between central and lateral incisors rather than on their absolute dimensions.

Conclusion: The maxillary incisor index demonstrates moderate accuracy for sex estimation and may serve as a simple and practical tool for preliminary forensic assessment. However, the variability observed between dental arches highlights the importance of developing population-specific standards when applying incisor indices for forensic sex determination.

Keywords: forensic odontology, incisor index, incisor width, sex determination

How to cite: Youngcharoen D, Arayapisit T, **Tachasanskul V.** Revisiting the incisor index for sex determination: development of cut-off values and validation of predictive accuracy. M Dent J 2026;46(2): 140-148.

Introduction

Determination of sex constitutes a fundamental component of personal identification in forensic investigations. Establishing biological sex is widely regarded as an initial and indispensable step, as it substantially reduces the pool of potential matches and informs subsequent analyses of age and stature [1]. The importance of sex estimation becomes particularly pronounced in cases where only partial or fragmentary skeletal remains are recovered, such as in mass disasters, advanced decomposition, or skeletonized remains. In these situations, the absence of complete skeletal elements renders conventional osteological approaches more challenging and less reliable. Consequently, teeth, as alternative anatomical

Varita Tachasanskul
Dental Department, Police General Hospital, Bangkok, Thailand
Tel: +66868865111
E-mail: varita.tip@gmail.com
Received: 26 March 2026 **Revised:** 3 May 2026 **Accepted:** 11 May 2026

structures that demonstrate greater resistance to environmental and postmortem degradation, assume critical importance in the identification process [2].

Dental-based sex assessment has therefore emerged as a widely accepted and practical approach, given that teeth are the most durable structures in the human body [3]. Their high mineral content and dense crystalline architecture confer exceptional resistance to heat, mechanical trauma, and microbial activity, enabling them to remain relatively intact even when other skeletal components are fractured or destroyed [4,5]. Furthermore, numerous studies across diverse populations have documented consistent patterns of sexual dimorphism in tooth dimensions [6-8]. These differences are generally attributed to genetic influences during odontogenesis, which result in measurable size variations between males and females [9]. Although statistically significant at the population level, the magnitude of sexual dimorphism in tooth size is often too subtle to be reliably detected through visual inspection alone [2]. This limitation necessitates the application of quantitative and mathematical methods capable of objectively identifying and interpreting these dimensional differences with precision. Advances in mathematics and statistics over time have facilitated the application of increasingly sophisticated analytical models for sex estimation based on odontometric data. Methods such as discriminant analysis [6], logistic regression analysis [7], and various machine learning algorithms [8] have been employed to construct predictive models with the aim of maximizing classification accuracy. While these approaches have improved performance, the growing mathematical complexity of such models has introduced practical limitations such as requiring specialized expertise, advanced computational tools, or dedicated software for analysis. Consequently, their application may be constrained in real-world forensic settings, particularly at remote crime scenes or in mass fatality incidents, where access to specialized resources is limited [2]. In such contexts, highly complex analytical techniques may become impractical and, paradoxically, may hinder rather than facilitate the identification process. These challenges have prompted ongoing efforts to identify alternative methods that maintain acceptable levels of accuracy while reducing computational complexity, thereby enhancing feasibility and applicability in resource-limited or high-caseload scenarios. One such approach involves the use of simplified sex assessment indices derived from tooth measurements.

Sex assessment indices based on odontometric parameters offer the advantage of conceptual simplicity and rapid calculation, without requiring sophisticated analytical tools [10]. Nonetheless, their principal limitation lies in concerns regarding predictive accuracy. Among the most widely recognized odontometric indices is the incisor index, introduced by Aitchison J in 1963 [11]. Since its inception, the incisor index has been repeatedly cited in textbooks [12-13] and review articles [10,14] addressing sex estimation from tooth size. However, a critical limitation of this index is the absence of a clearly defined cut-off value for classifying individuals as male or female. Without an established threshold, it is not possible to evaluate the diagnostic performance or accuracy of the index, which in turn has restricted its practical implementation. Therefore, the present study aims to develop an evidence-based cut-off value for the incisor index for use in sex estimation within a Thai population and to assess the diagnostic accuracy of sex classification based on this newly established threshold.

Materials and methods

To achieve the objectives of the present study, the research was structured into two sequential phases. The first phase focused on the development of a cut-off value for the incisor index using Receiver Operating Characteristic (ROC) curve analysis. The second phase aimed to evaluate the predictive accuracy of the newly established cut-off value. The study protocol was reviewed and approved by the Institutional Review Board of the Faculty of Dentistry and the Faculty of Pharmacy, Mahidol University (COE No. MU-DT/PY-IRB 2026/008.1203). All statistical analyses were performed using IBM SPSS Statistics for Windows, Version 27.0 (IBM Corp., Armonk, NY, USA).

Phase 1: Development of the Cut-off Value for the Incisor Index Using ROC Curve Analysis

Cast Selection and Tooth Measurement

A total of 100 pairs of pre-orthodontic dental casts were retrospectively selected from the Orthodontic Clinic at the Dental Hospital, Faculty of Dentistry, Mahidol University. The sample comprised 50 male and 50 female subjects, with an age range of 18–32 years. Eligible casts were required to demonstrate fully erupted and morphologically normal anterior teeth, including the maxillary central incisors, maxillary lateral incisors, mandibular central incisors, and mandibular lateral incisors, without evidence of dental caries, proximal restorations, morphological anomalies, or structural defects affecting the mesiodistal surfaces. The mesiodistal tooth width was measured as the maximum dimension perpendicular to the long axis of each tooth using a digital vernier caliper (Mitutoyo, Japan) with a resolution of 0.01 mm, (Figure 1) To ensure a high level of measurement precision, all measurements were performed independently by two investigators. Inter-examiner reliability was assessed using the intraclass correlation coefficient (ICC), which ranged from 0.85 to 0.96, and the mean of the two measurements was used for analysis. In addition, the Kolmogorov–Smirnov test was used to assess normality. As the data were normally distributed, an independent samples t-test was performed to compare the mean mesiodistal widths of each incisor between male and female subjects. Statistical significance was set at $p < 0.05$ ($\alpha = 0.05$).

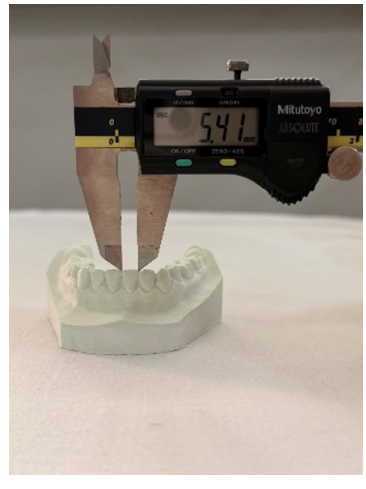


Figure 1 Measurement of the mesiodistal width of anterior tooth using a digital vernier caliper

Cut-off Value Determination Using ROC Curve Analysis

Sexual dimorphism for each incisor was calculated based on tooth width using the following formula [15]:

Sexual dimorphism (%) = [(Xm / Xf) - 1] × 100

where *Xm* represents the mean mesiodistal width of the specified incisor in males and *Xf* represents the corresponding mean value in females.

The maxillary and mandibular incisor indices were calculated separately according to the formula [11]:

Incisor index = (I2 / I1) × 100

where I2 represents the mesiodistal width of the lateral incisor and I1 represents the mesiodistal width of the central incisor within the same dental arch.

Sex discrimination performance metrics derived from the incisor index, including sensitivity and specificity, were calculated and subsequently analyzed using ROC curve methodology. To further develop of cut-off value, both Youden's index and the Euclidean index were applied. Youden's index quantifies the vertical distance of a point on the ROC curve above the diagonal line extending from (0,0) to (1,1) with a slope of 1. In contrast, the Euclidean index represents the straight-line distance between a point on the ROC curve and the top-left corner of the plot at (0,1). The optimal cut-off value for each incisor index was determined by either maximizing Youden's index or minimizing the Euclidean index, thereby identifying the threshold that most effectively distinguished between male and female individuals.

Youden's index was calculated as [16]:

Youden's index = Sen + Spec – 1

Euclidean index was calculated as [17]:

$$\text{Euclidean index} = \sqrt{[(1 - Sen)^2 + (1 - Spec)^2]}$$

where Sen represents the sensitivity of the incisor index and Spec represents the specificity of the incisor index.

Phase 2: Evaluation of the Predictive Accuracy of the Newly Established Cut-off Value

In the second phase, an independent set of 100 pairs of pre-orthodontic dental casts was recruited, comprising 50 male and 50 female subjects with an age range of 18–31 years. The inclusion and exclusion criteria were identical to those applied in Phase 1 to ensure methodological consistency and comparability between datasets.

The mesiodistal widths of all incisors were measured using the same protocol and instrumentation described in Phase 1. The recorded tooth widths were subsequently used to calculate the incisor index for each dental arch. These index values were then classified according to the newly established cut-off value to determine sex both from the Youden's index and the Euclidean index. Predictive accuracy was analyzed using the following formula:

Predictive accuracy (%) = (Tr / To) × 100

where Tr represents the number of casts correctly classified by the incisor index, and To represents the total number of casts evaluated.

Results

The mesiodistal width of each incisor for male and female participants was summarized as mean values with their corresponding standard deviations in Table 1. Overall, males exhibited greater mean tooth widths than females for all examined incisors. Comparative analysis between the sexes revealed statistically significant

differences in four teeth: the maxillary right central incisor ($p = 0.011$), the maxillary left central incisor ($p = 0.001$), the mandibular right central incisor ($p = 0.033$), and the mandibular right lateral incisor ($p = 0.011$). In contrast, the remaining teeth, the maxillary right lateral incisor, the maxillary left lateral incisor, the mandibular left central incisor, and the mandibular left lateral incisor, did not demonstrate statistically significant differences between the sexes ($p > 0.05$). When the magnitude of sexual dimorphism was evaluated across all incisors, the highest degree of sexual dimorphism was observed in the maxillary left central incisor (4.82%), followed by the mandibular right lateral incisor (3.85%), the mandibular right central incisor (3.78%), and the maxillary right central incisor (3.76%), as shown in Table 1.

Left and right, as well as maxillary and mandibular, incisor indices were calculated from the mesiodistal widths of the incisors. The descriptive statistics of each incisor index and the predictive accuracy of the cut-off values derived from both Youden's index and the Euclidean index were presented in Table 2. Overall, the maxillary incisor indices demonstrated higher classification accuracy than the mandibular incisor indices for sex determination. The highest predictive accuracy based on both Youden's index and the Euclidean index was observed for the maxillary left incisor index at a cut-off value of 85.60, which yielded an overall accuracy of 71.00%. The second highest predictive accuracy, also based on both Youden's index and the Euclidean index, was obtained from the maxillary right incisor index at a cut-off value of 85.24, resulting in an overall accuracy of 70.00%. In contrast, the incisor indices derived from the mandibular teeth produced predictive accuracies of less than 55.00%, as seen in Table 2.

Table 1 Mean and standard deviation of tooth width (mm) and sexual dimorphism (%) for each incisor used to determine the cut-off value of the incisor index.

Tooth	Tooth width in male	Tooth width in female	*p*-value of t-test	Sexual dimorphism
11	8.59±0.64	8.28±0.55	0.011*	3.76
12	7.13±0.62	7.07±0.61	0.581	0.97
21	8.68±0.69	8.28±0.52	0.011*	4.82
22	7.15±0.67	7.13±0.60	0.845	0.35
31	5.47±0.48	5.32±0.40	0.084	2.92
32	6.00±0.48	5.85±0.42	0.096	2.59
41	5.48±0.50	5.28±0.42	0.033*	3.78
42	5.99±0.47	5.77±0.38	0.011*	3.85

*$p < 0.05$ was considered statistically significant.

Table 2 Mean and standard deviation of incisor index, 95% confident interval (CI) of Area under the ROC curve (AUC), cut-off value, and accuracy (%) of each incisor index.

Incisor index	Mean incisor index in males	Mean incisor index in females	AUC (95%CI)	Youden's index		Euclidean index	
				Cut-off value	Accuracy	Cut-off value	Accuracy
Maxillary Left incisor index	82.56±6.26	86.11±5.15	0.738 (0.628-0.848)	85.60	71.00	85.60	71.00
Maxillary right incisor index	83.07±4.37	85.35±5.06	0.723 (0.617-0.829)	85.24	70.00	85.24	70.00
Mandibular left incisor index	109.88±5.47	110.22±6.08	0.577 (0.463-0.691)	111.18	54.00	111.18	54.00
Mandibular right incisor index	109.61±6.50	109.68±7.06	0.468 (0.352-0.584)	116.25	48.00	111.02	52.00

Discussion

Aitchison J [11] proposed the maxillary incisor index and reported that its value was greater in males than in females. Similar findings were reported by Pereira C *et al*. [18], who likewise demonstrated that both the left and right maxillary incisor indices were higher in males than in females, thereby supporting the potential application of this index for sex discrimination. In contrast, Prasanna S *et al*. [19] reported different results, revealing that the maxillary incisor index was higher in females than in males, whereas the mandibular incisor index was greater in males. Another study by Rani ST [20] found that the mandibular incisor index was greater in males, while no statistically significant sex difference was observed in the maxillary incisor index. In the present study, both the maxillary and mandibular incisor indices were higher in females than in males. These contrasting findings highlight the complex and population-specific nature of odontometric sexual dimorphism. The inconsistencies observed among studies may largely be attributed to differences in study populations. Odontometric characteristics, including mesiodistal crown width, are known to vary across ethnic and geographic groups [15]. Moreover, the incisor index is derived from the proportional relationship between the mesiodistal widths of the lateral and central incisors. Since the lateral incisor is typically smaller than the central incisor, the index reflects the relative proportional difference between these teeth rather than their absolute dimensions. Consequently, the relationship between the central and lateral incisors may not exhibit a consistent pattern of sexual dimorphism across different populations. In certain populations, males may display a greater proportional difference between the central and lateral incisor widths, whereas in others, females may demonstrate a different pattern of inter-tooth proportionality. Such population-specific variation can substantially influence ratio-based measurements, including the incisor index.

Another important observation from the present findings concerns the relationship between individual tooth dimensions and the predictive accuracy of the incisor index. In the maxillary arch, only the mesiodistal width of the

central incisor demonstrated a statistically significant difference between males and females on both sides, whereas the lateral incisor did not exhibit significant sexual dimorphism. Despite this, the maxillary incisor indices yielded relatively high predictive accuracies, reaching approximately 70–71%. In contrast, the mandibular arch displayed a different pattern. On the left side, neither the central nor the lateral incisor showed a statistically significant sex difference in mesiodistal width, whereas on the right side both incisors demonstrated significant differences between males and females. Nevertheless, both mandibular incisor indices produced relatively low overall accuracies, all below 55%. These findings suggest that the predictive performance of the incisor index is not determined solely by sex differences in the absolute size of either the central or the lateral incisor independently. As a proportional measurement, the value of the incisor index is directly influenced by the magnitude of the difference between the mesiodistal widths of the central and lateral incisors. When the dimensional difference between the two teeth increases, the ratio of lateral to central incisor width decreases. Conversely, when the difference becomes smaller, the ratio increases. Therefore, even when only one tooth demonstrates statistically significant sexual dimorphism, as observed in the maxillary incisors in the present study, the proportional relationship between the two teeth may still generate measurable discriminatory potential. In contrast, when the proportional relationship between the central and lateral incisors remains similar between males and females, the resulting index may exhibit limited discriminatory ability regardless of whether statistically significant differences exist in the individual tooth widths. These observations suggest that sexual dimorphism in the incisor index is influenced less by generalized tooth size differences and more by sex-related variation in the proportional relationship between the central and lateral incisors. When this proportional difference consistently varies between sexes within a given population, the incisor index may serve as a useful parameter for sex estimation. However, when the proportional patterns overlap substantially between males and females, the discriminatory capacity of the index is reduced.

Compared with more complex methods such as logistic regression (reported accuracy 71–100%) [7] and discriminant analysis (up to 90%) [6], the incisor index in the present study demonstrated moderate accuracy (70–71%). However, the incisor index offers notable advantages in terms of simplicity, ease of application, and minimal statistical requirements, making it practical for rapid or preliminary assessments. While there is a trade-off between simplicity and accuracy, the method remains forensically useful as an initial screening tool, particularly in situations where advanced statistical analysis is not feasible.

Nevertheless, the limitations of the present study should also be considered. First, the relatively small sample size may limit the generalizability of the findings and may influence the stability of the derived cut-off values. Future studies involving larger sample sizes would therefore be beneficial to improve the robustness and external validity of the results. Second, the study sample was derived from a single population group, which may restrict the applicability of the findings to other populations with different genetic or environmental backgrounds. Additionally, only mesiodistal crown widths were evaluated in the present study; incorporating other odontometric parameters or combining multiple dental indices may further enhance the accuracy of sex estimation in future investigations. Although, measurements on dental casts are accessible and highly

reproducible under standardized conditions, minor errors may arise from impression and cast fabrication processes, which could affect dimensional accuracy compared to direct measurements on natural teeth.

In summary, the present findings suggest that sexual dimorphism in incisor proportions does not follow a uniform pattern across populations or between dental arches. Instead, its expression appears to be influenced by biological variability and population-specific morphological characteristics. These observations highlight the importance of developing arch-specific and population-based standards when applying the incisor index in forensic sex estimation. Consequently, the forensic applicability of the incisor index should be evaluated within each population group, and the establishment of population-specific reference data remains essential to ensure the accuracy and reliability of sex determination.

Conclusion

The present study established population-specific cut-off values for the incisor index and evaluated their diagnostic performance for sex estimation in a Thai population. The results demonstrated that the maxillary incisor index achieved moderate predictive accuracy (approximately 70–71%), whereas the mandibular incisor index showed limited discriminative ability with accuracies below 55%. These findings indicate that the maxillary incisor index may serve as a simple and practical parameter for preliminary sex estimation in forensic contexts. However, due to population-specific variation and the relatively small sample size of the present study, further research with larger samples is required to validate and refine these cut-off values.

References

1. Nagare SP, Chaudhari RS, Birangane RS, Parkarwar PC. Sex determination in forensic identification: a review. *J Forensic Dent Sci*. 2018 May-Aug;10(2):61-66. doi: 10.4103/jfo.jfds_55_17.
2. Chunhabundit P, Arayapisit T, Srimaneekarn N. Sex prediction from human tooth dimension by ROC curve analysis: a preliminary study. *Sci Rep.* 2025 Feb;15(1):6627. doi: 10.1038/s41598-025-90801-x.
3. Lacasella GV, Signorini L, Ballini A, Bizzoca ME, Musella G, Lo Muzio E, *et al*. Forensic odontology: a comprehensive review of advances and applications in dental forensic medicine. *Minerva Dent Oral Sci.* 2025 Aug;74(4):273-290. doi: 10.23736/S2724-6329.25.05187-3.
4. Smitha T, Sheethal HS, Hema KN, Franklin R. Forensic odontology as a humanitarian tool. *J Oral Maxillofac Pathol.* 2019 Jan-Apr;23(1):164. doi: 10.4103/jomfp.JOMFP_249_18.
5. Rothwell BR. Principles of dental identification. *Dent Clin North Am.* 2001 Apr;45(2):253-270.
6. Anuthama K, Shankar S, Ilayaraja V, Kumar GS, Rajmohan M, Vignesh. Determining dental sex dimorphism in South Indians using discriminant function analysis. *Forensic Sci Int.* 2011 Oct;212(1-3):86-89. doi: 10.1016/j.forsciint.2011.05.018.
7. Acharya AB, Prabhu S, Muddapur MV. Odontometric sex assessment from logistic regression analysis. *Int J Legal Med.* 2011 Mar;125(2):199-204. doi: 10.1007/s00414-010-0417-9.
8. Senol D, Secgin Y, Duman BS, Toy S, Oner Z. Sex and age estimation with machine learning algorithms using parameters obtained from cone beam computed tomography images of maxillary first molar and canine teeth. *Egypt J Forensic Sci.* 2023 June;13(1):27. doi: 10.1186/s41935-023-00346-1.
9. Nakayama M, Kondo O, Pesonen P, Alvesalo L, Lähdesmäki R. Influence of long and short arms of X chromosome on maxillary molar crown morphology. *PLoS One.* 2018 Nov;13(11):e0207070. doi: 10.1371/journal.pone.0207070.
10. Nagare SP, Chaudhari RS, Birangane RS, Parkarwar PC. Sex determination in forensic identification: a review. *J Forensic Dent Sci.* 2018 May-Aug;10(2):61-66. doi: 10.4103/jfo.jfds_55_17.

11. Aitchison J. Sex differences in teeth, jaws, and skulls. ***Dent Pract.*** 1963;14:52-57.
12. Rai B, Kaur J. Sex determination methods in forensic odontology; In: Rai B, Kaur J, editors. Evidence-based forensic dentistry. Berlin: Springer-Verlag, 2012; p.73-79.
13. Hemanth M, Pandey A. Forensic odontology and its applications; In: Jain N, editor. Textbook of forensic odontology. New Delhi: Jaypee Brothers Medical Publishers, 2013; p.10-42.
14. Heng D, Manica S, Franco A. Forensic dentistry as an analysis tool for sex estimation: a review of current techniques. ***Res Rep Forensic Med Sci.*** 2022 Dec;12:25-39. doi: 10.2147/RRFMS.S334796.
15. Garn SM, Lewis AB, Swindler DR, Kerewsky RS. Genetic control of sexual dimorphism in tooth size. ***J Dent Res***. 1967 Sep-Oct;46(5):963-972. doi: 10.1177/00220345670460055801.
16. Youden WJ. Index for rating diagnostic tests. ***Cancer.*** 1950 Jan;3(1):32-35. doi: 10.1002/1097-0142(1950)3:1<32::aid-cncr2820030106>3.0.co;2-3.
17. Perkins NJ, Schisterman EF. The inconsistency of "optimal" cutpoints obtained using two criteria based on the receiver operating characteristics curve. ***Am J Epidemiol.*** 2006 Apr;163(7):670-675. doi: 10.1093/aje/kwj063.
18. Pereira C, Bernardo M, Pestana D, Santos JC, Mendonça MC. Contribution of teeth in human forensic identification--discriminant function sexing odontometrical techniques in Portuguese population. ***J Forensic Leg Med.*** 2010 Feb;17(2):105-110. doi: 10.1016/j.jflm.2009.09.001.
19. Prasanna S, Raj LSM, Krishna PS, Manikandan VJS, Srikant N. Evaluation of incisor index as a forensic tool in genderal dimorphism: a study in South Indian population. ***Indian J Forensic Med Toxicol.*** 2021 Aug;15(4):2319-2323. doi: 10.37506/ijfmt.v15i4.17053.
20. Rani ST. Applicability of odontometric dimensions and indices in sexual dimorphism among Nalgonda population. ***J Forensic Dent Sci***. 2017 Sep-Dec;9(3):175. doi: 10.4103/jfo.jfds_42_16.