Predicting age in the age group of 16–21 years using tooth–coronal index-Benindra method: a comparison with Kvaal and Schour and Massler methods

S Farahyati, N Soedarsono*, M Yuniastuti and B Nehemia

Department of Oral Biology, Faculty of Dentistry, Universitas Indonesia, Jakarta, 10430, Indonesia

*Email: drtamy@gmail.com

Abstract. Age estimation is critical for the identification of human trafficking practices or struggles for the rights of legal heirs in justice cases in the age group of 16–21 years. This study aims to test the tooth–coronal index (TCI) by Benindra (TCI-Benindra) method and compare the results to those obtained with Kvaal as well as Schour and Massler methods. TCI-Benindra method was used to estimate age and then compared the results to those obtained with Kvaal as well as Schour and Massler methods. The results obtained with TCI-Benindra method exhibited a significant difference with those obtained with Kvaal method ($P < 0.05$), but exhibited no significant difference with those obtained with Schour and Massler method ($P > 0.05$). In conclusion, age estimation using TCI-Benindra and Schour and Massler methods gave results that were closest to the actual age; furthermore, significant differences were observed between TCI-Benindra and Kvaal method in these results.

1. Introduction
Similar to human rights violations, human trafficking is a global public health issue. Human trafficking has been associated with several health-related risks, such as psychological trauma and violent injury. Broadly, human trafficking is defined as the recruitment, transfer, concealment, or acceptance of persons by threat or use of force or acceptance of profits to obtain the consent of persons in control over others for exploitation. While various statistics suggest that 600,000–800,000 people are trafficked around the globe every year, the United Nations International Children’s Emergency Fund estimates that more than 1.2 million children are trafficked annually [1].

The Law on Placement and Protection of Indonesian Workers Abroad (Law No. 39/2004) states that the age of a prospective worker must be between 18 and 39 years. Incidentally, Law No. 13/2003 on Employment states that a child is any person aged <18 years. The law prompts trafficking organisations to remove the evidence of identity documents from victims of illegal trafficking, such as underage victims who have posed a problem in Indonesia. Thus, the role of forensic science in determining and predicting the age of such victims is imperative.

One of the methods that can be used to predict age is dental examination performed by dentists. Typically, the identification of age through teeth can be done using four methods, namely clinical, radiological, histological, and biochemical examination. Gustafson investigated the clinical examination method in 1950. The radiological examination was performed by Schour and Massler.
(1944), Demirjian (1973), Ubelaker (1989), Kvaal (1994), Ikeda (1985), Drusini (2005), Al-Qahtani (2008), Thevissen (2009) and Blenkin and Taylor (2012). The histological examination was performed by Murray (2006), and the biochemical examination was performed by Helfman and Bada (1975) and Yekalla. While the clinical, histological and biochemical methods require tooth extraction, the radiological method is a non-invasive method that does not require tooth extraction [2].

Recently, age estimation methods based on radiographic analysis of teeth have been widely practised. Ikeda (1985) investigated dental radiographs using the tooth–coronal index (TCI) method; this investigation was continued by Drusini (2005) using the second premolar and lower second molars in the age group of 20–80 years with a panoramic radiograph to estimate the age [3]. In addition, Benindra (2012) used TCI method for the age group of 16–21 years and proposed an age calculation formula. However, this formula has never been compared with other methods. Hence, this study aims to calibrate TCI formula with previously discovered methods, namely Kvaal (1995) and Schour and Massler (1944) methods.

2. Methods
Age estimation test was performed using the intraoral periapical radiographs of first premolars of the mandible and panoramic radiograph from 34 patients. Another 25 intraoral periapical, panoramic and lateral cephalometric radiographs were also used in this study. All of the radiographs were obtained from patients of Teaching Dental Hospital, Faculty of Dentistry, Universitas Indonesia. Age estimation analysis using TCI by Benindra (TCI-Benindra) method was performed by evaluating the height of the crown (CH) and height of the pulp chamber of the crown (CPCH) of the mandibular first premolar tooth; the results thus obtained were compared with those obtained using the age estimation formula of Kvaal and age index on Schour and Massler atlas.

Using a digital caliper, CH and CPCH were measured. Then, the size of the dental crown from the cervical line to the highest cusp was measured as reported by Moss et al., and the crown pulp height was measured vertically from the cervical line to the highest point of the pulp horn, as reported by Ikeda et al. (Figure 1). TCI is calculated using the following formula [4]: $\text{TCI} = \text{CPCH} \times \left(\frac{100}{\text{CH}}\right)$. The calculated TCI value is then put into the Benindra formula: Age prediction = 29.16 + (−0.4) TCI.

![Figure 1. Schematic representation of measurements on radiographic images.](image)

Using Kvaal method, the measurements that were obtained included: the maximum tooth length; pulp length; root length on the mesial side; pulp width at the a level [cementoenamel junction (CEJ) level], c level (mid-root level) and b level (in between c and a levels) and the root width at the a, c and b level. Then, the following ratios were calculated: root length/tooth length (T), pulp length/tooth length (R), pulp length/root length (P), pulp width/root width at level a (A), pulp width/root width at level b (B), pulp width/root width at level c (C), the mean value of the entire ratio (M), the mean of the width ratio from level b and c (W), the value of the ratio of length P and R (L) and the difference between W and L (W-L).
In contrast, Schour and Massler described 21 sequences of dental development starting from the age of 5 months in utero to 21 years of age. Using Schour and Massler method, the developmental comparison of a person’s teeth with the age index on Schour and Massler atlas was performed to estimate the age. Schour and Massler divided the development of one’s teeth into six stages.

3. Results
Table 1 presents a comparison between the results of the age estimation study using TCI-Benindra method on intraoral periapical radiographs and Kvaal method on panoramic radiographs.

Table 1. Comparison of age estimation between TCI-Benindra and Kvaal methods.

| Paired t-Test                  | N   | Mean ± SD   | Mean Difference ± SD | IK 95%       | P     |
|-------------------------------|-----|-------------|----------------------|--------------|-------|
| Age estimation using Dental TCI| 34  | 18.84 ± 1.67| 4.15 ± 1.66          | 3.57–4.73    | <0.05 |
| Age estimation using Kvaal     | 34  | 22.99 ± 0.21| 4.15 ± 1.66          | 3.57–4.73    | <0.05 |

A significant difference was observed between age estimation results obtained using TCI-Benindra and Kvaal methods (P < 0.05; Table 1), implying a significant difference between the two methods. Before testing the age estimation using TCI panoramic and Schour and Massler methods, TCI-Benindra method was tested on panoramic radiographs and intraoral periapical radiographs and the results were compared; Table 2 presents a comparison of the results.

Table 2. Comparison of age estimation between TCI-Benindra method on panoramic and intraoral periapical radiographs.

| Paired t-Test                  | N   | Mean ± SD   | Mean Difference ± SD | IK 95%       | P     |
|-------------------------------|-----|-------------|----------------------|--------------|-------|
| Age estimation with Panoramic TCI | 25  | 19.05 ± 1.96| 0.75 ± 3.17          | 0.56–2.06    | >0.05 |
| Age estimation with Dental TCI | 25  | 19.80 ± 2.45| 0.75 ± 3.17          | 0.56–2.06    | >0.05 |
No significant differences were observed in the age estimation results using TCI-Benindra method on panoramic and intraoral periapical radiographs \((P > 0.05)\), implying no significant difference between the age estimation formula of TCI-Benindra method on the panoramic and intraoral periapical radiographs. Based on these results, a paired \(t\)-Test was conducted to assess whether there was a significant difference between the estimation formula of TCI-Benindra method on a panoramic radiograph and Schour and Massler method on a lateral cephalometric radiograph.

**Table 3.** Comparison of age estimation between TCI-Benindra and Schour and Massler methods.

| Paired \(t\)-Test                      | \(N\) | Mean ± SD | Mean Difference ± SD | IK 95%       | \(P\)  |
|--------------------------------------|-------|-----------|----------------------|-------------|-------|
| Age estimation using panoramic TCI   | 25    | 19.05 ± 1.96 | 0.75 ± 3.17         | 0.56–2.06   | >0.05 |
| Age estimation using Schour and Massler | 25    | 19.80 ± 2.45 | 0.75 ± 3.17         | 0.56–2.06   | >0.05 |

Table 3 reveals that age estimation using TCI-Benindra and Schour and Massler methods did not differ significantly \((P > 0.05)\), implying no significant difference between the two methods.

4. Discussion

This study demonstrated a significant difference between the estimated age using TCI-Benindra method and Kvaal method, which is in accordance with Landa et al. who applied Kvaal method to digital orthopantomograms by measuring the values for three mandibular teeth; they reported the estimation results to be significantly different from the actual age [5]. The results of the present study may have been affected by several factors. Kvaal method is used to measure a significant number of teeth including six teeth comprising central incisors, lateral incisors and second premolars on the maxillary arch as well as lateral incisors, canine and first premolars on the mandibular arch, which considerably affects the assessment. In addition, the measurement error may have occurred because of difficulty in determining the reference point on the radiograph; determining the reference point was solely based on the ability of the observer [6]. Thus, as more teeth were measured, the reference points to be determined were also more, signifying a substantial likelihood of bias. In contrast, as TCI-Benindra method uses only one tooth (the mandibular first premolar), less number of reference points had to be determined, and the possibility of a bias was less. Moreover, Kvaal method cannot be used for double-rooted teeth as it will affect the measurement of the root width and pulp width at point A, B and C. However, TCI-Benindra method can be performed on double-rooted teeth because the measurement is only located on the crown and crown pulp.

Another factor that could have affected TCI-Benindra and Kvaal methods was the radiograph used. Panoramic radiographs are used for the latter, whereas intraoral periapical radiographs are used for the former. Apparently, panoramic radiographs have a higher probability of distortion because films and tubes rotate around patients during the process of obtaining the radiograph. In addition, the quality of the radiograph used could also have affected the results of this study. Walker et al. (2009) reported that one of the areas where panoramic radiographs are susceptible to artefacts and misinterpretations is the region anterior to the mandible. Thus, possible causes of radiolucency were the mental region and superimposition of intervertebral space, thereby reducing the details of the image. Using two mandibular anterior teeth in this coveted study could have affected the age estimation results.

Although TCI-Benindra method offers some significance over Kvaal method, there are some disadvantages as well. In case of absence of a mandibular first premolar due to the absence of a tooth
bud or tooth extraction due to caries or for orthodontic purposes, a substitute for the tooth is required to perform the measurement. However, in such cases, the second premolar may be used for anatomical reasons as the mandibular second premolar resembles the first premolar [7]. In addition to this, another limitation of TCI-Benindra method has been found in newly researched samples in the age group of 9–21 years, wherein it cannot accurately determine the age below 9 years and above 21 years.

In this study, TCI-Benindra method was tested using panoramic and intraoral periapical radiographs; insignificant differences were observed in the results for the two radiographs, suggesting that the method could be used on both radiographs. In addition, we determined whether TCI-Benindra method could be compared with Schour and Massler method using lateral cephalometric radiographs. We found that panoramic radiographs had the disadvantage of a higher possibility of distortion and radiation exposure than the intraoral periapical radiographs. In addition, based on the statistical results of the study through the comparison of mean values, the age estimated using TCI on an intraoral periapical radiograph has a smaller mean difference from the actual age than that estimated using a panoramic radiograph; the smaller the difference in the mean value, the better the accuracy.

In this study, a comparison between TCI-Benindra and Schour and Massler methods revealed no significant differences. Although both methods gave results that were equally close to the actual age, a comparison of mean values revealed that Schour and Massler method had larger mean values than TCI-Benindra method. Thus, age estimation using TCI-Benindra method was slightly different from that using Schour and Massler method. This could be attributed to the fact that Schour and Massler age indices use a range or interval; this possibility might affect the value of the standard deviation, raising the possibility of deviation of large data. Notably, disadvantages of Schour and Massler method are evident in the abnormalities of the dental development. In case of presence of supernumerary teeth, it would be difficult to compare the development of a person’s teeth using the age index. In addition, delayed eruption and absence of tooth buds (anodontia) would pose challenges for age estimation based on the age index on the atlas.

5. Conclusion
Age estimation for the age group of 16–21 years using TCI-Benindra and Schour and Massler methods exhibited results that were closest to the actual age, and significant differences were observed in age estimation results between TCI-Benindra and Kvaal methods.

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