Comparison of TCI–Benindra formula, Al-Qahtani, and Blenkin-Taylor methods for age estimation in 16–21 year olds

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Abstract. Due to the possible risk of age manipulation in 16–21 year-old individuals, particularly in cases of human trafficking, accurate methods of exact age estimation are essential. This study aimed to test the accuracy of the tooth coronal index (TCI)–Benindra formula method, which is based on the mandibular first premolar, and to compare it with other methods, namely, the Al-Qahtani and the Blenkin-Taylor methods. This result found that there were no significant differences (p > 0.05) among the three age estimation methods and that all three methods yielded ages that were close to real age, in age range of 16–21 years. Therefore, the TCI–Benindra formula, the Al-Qahtani, and the Blenkin-Taylor methods may be used for accurate age estimation, specifically in Indonesian population.

1. Introduction
Apart from being a human rights violation, human trafficking or illegal human trade is a global public health issue and is correlated with health risks, such as psychological trauma and injury due to violence [1]. Indonesian Law on the Placement and Protection of Indonesian Migrant Workers (Law No. 39, 2004) states that the age of Indonesian migrant workers must be between 18 and 39 years and labor resources (Law No. 13, 2003) define children as individuals below 18 years of age. These regulations have led to trafficking organizations concealing the age and identity of illegal trade victims, such as children below 18 years of age. As it has become a critical issue in Indonesia, forensic science, which can be used for age estimation, is then being applied to identify such cases of identity concealment.

A method used to determine or estimate age is based on dental anatomy and is performed by dentists. Age identification from dentition can be done clinically, histologically, or biochemically; however, the teeth need to be extracted for all these methods [2]. On the other hand, identification using radiological method(s) is non-invasive as it does not require tooth extraction [2,3]. Multiple methods of age estimation using dental radiographic analysis have been published. Ikeda (1985) found a correlation between pulp chamber size and age and derived the tooth coronal index (TCI) formula. This concept was further investigated by Drusini (2005) to estimate age in individuals aged 20–80 years based on the mandibular second premolar and the second molar from panoramic radiographs [4].

A previous study by Benindra (2012) used the TCI method to derive an age estimation formula for individuals aged 16–21 years [5]. However, this formula has not been compared with other methods of age estimation. Therefore, the present study aimed to test the precision of age estimation using the TCI–Benindra formula and to compare it with other methods, such as the Al-Qahtani (2009) and the Blenkin-Taylor (2012) methods.
2. Methods

Periapical intraoral radiographs and panoramic images of 34 subjects, aged 16–21 years, who presented at the Radiology Clinic at the Teaching Dental Hospital, Faculty of Dentistry, Universitas Indonesia, were recruited for the study. The TCI–Benindra formula method was used to estimate age by measuring coronal height (CH) and coronal pulp chamber height (CPCH) of the mandibular first premolar and applying it to the TCI formula (Ikeda, 1985) (Figure 1) [6].

![Figure 1. Coronal height (CH) and coronal pulp cavity height (CPCH).](image)

TCI = CPCH × (100 / CH)

The TCI value was then substituted in the age formula of Benindra (2012):

Estimated Age = 29.16 − (0.4 × TCI)

The estimated age obtained from this formula was compared to the estimated age obtained using the Al- Qahtani method that uses the available age index on dentition growth and development atlases. Next, the applicability of the TCI–Benindra formula method on panoramic radiographs was also tested and it was found that there were no significant differences in age estimation compared to the intraoral periapical radiograph. Another set of 25 panoramic and lateral cephalometry radiographs of patients were also used. Panoramic radiographs were used to estimate age using the TCI–Benindra method by measuring CH and CPCH on the mandibular first premolar. Lateral cephalometry radiographs were used to estimate age using the Blenkin-Taylor methods, which is based on age index in the dentition growth and development atlas. The Wilcoxon signed rank test and paired t-test were used to assess significant differences among age estimates by the TCI–Benindra formula, the Al-Qahtani, and the Blenkin-Taylor methods. Statistical analyses were performed on the SPSS program (Ver. 17).

3. Results

Because normality tests revealed non-normal distribution for the Al-Qahtani method (P < 0.05), the Shapiro–Wilk test was used (n = 34); therefore, the Wilcoxon test was used instead of the paired t-test.

|                      | N  | Median (Minimum–Maximum) | Average ± s.b.     | P         |
|----------------------|----|--------------------------|--------------------|-----------|
| TCI–Benindra Method  | 34 | 18.05 (15.7–21.2)        | 18.465 ± 1.5031    | 0.245     |
| Al-Qahtani Method    | 34 | 18.5 (15.5–21.5)         | 18.735 ± 1.4577    | p<0.05    |

The Wilcoxon test yielded a p value of 0.245 for a comparison between the TCI and Al-Qahtani methods (Table 1), implying no significant difference between these methods.

Similarly, due to non-normal distribution of data for the Blenkin-Taylor method (p < 0.05), the Wilcoxon test was used to compare age estimations between the TCI–Benindra formula and Blenkin-Taylor methods (Table 2).
Table 2. Comparison of estimated age between TCI–Benindra formula and Blenkin-Taylor methods

| Method                        | N  | Median (Minimum-Maximum)       | Average ± s.b.   | P     |
|-------------------------------|----|--------------------------------|-----------------|-------|
| TCI–Benindra                  | 25 | 18.7 (15.7–23.5)               | 18.952 ± 1.9789 | 0.872 |
| Formua method                 |    |                                | 18.952 ± 1.9789 |       |
| Blenkin-Taylor methods        | 25 | 21 (13.8–21)                   | 18.984 ± 3.0144 |       |

p<0.05 (significant difference)

The Wilcoxon test yielded a p value of 0.872, implying no significant differences between the TCI–Benindra Panoramic and Blenkin-Taylor methods.

4. Discussion

The results showed that there was no significant difference between age estimation using the TCI–Benindra formula method, which is based on dental periapical radiographs, and the Al-Qahtani method (p > 0.05), implying that both methods estimate age that is close to true age. However, there are several advantages and disadvantages to both methods.

The advantages of TCI-Benindra and Al-Qahtani methods are that both methods are easy and quick with low costs of estimation. Importantly, these results prove that the Al-Qahtani method can be applied on the Indonesian population. Nevertheless, the Al-Qahtani method also has its disadvantages. Age estimation using Al-Qahtani methods use panoramic or lateral oblique radiographs, in subjects older than 14 years, it requires third molars appearance [7,8]. However, not all subjects have third molars, which may be missing or non-existent. In addition, the shape of third molars is variable, which can affect age estimation, apart from the obstacles arising from determining age using the atlas, such as abnormalities or delayed eruption. On the other hand, the TCI–Benindra formula cannot be applied if the first premolars do not exist; this can be related to the Ikeda theory (1985), which states that the correlation coefficient between chronological age and age estimation was high for second premolars and first molars of the mandible; therefore, it is possible to apply the TCI–Benindra formula method to these two teeth [9].

Next, age estimation using the TCI–Benindra formula with panoramic radiography was compared to the Blenkin-Taylor methods, and initial studies were performed to ascertain if there were any significant differences between the TCI method with the periapical dental radiograph and the panoramic radiograph. Statistical analyses showed no significant difference between the TCI method with periapical dental radiograph and panoramic radiograph (p > 0.05). From these results, it can be concluded that the TCI–Benindra formula method can be applied to measurements obtained from dental periapical radiographs or panoramic radiographs. Further, age estimation using the TCI–Benindra formula method, compared to Blenkin-Taylor methods, showed no significant differences between the two methods, implying that these two methods accurately estimate age.

There are several advantages and disadvantages of these methods that should be considered before choosing an appropriate age estimation method. The advantage of TCI–Benindra formula method is that the method can be applied on both periapical dental and panoramic radiographs. Moreover, the advantages of TCI–Benindra and Blenkin-Taylor methods are that they are easy and quick with low cost of estimation. Our results also prove that the Blenkin-Taylor methods, which were tested on a modern Australian population, are applicable to the Indonesian population. The disadvantage of Blenkin-Taylor methods is that data from this method showed high levels of standard deviation compared to the TCI–Benindra method, possibly due to the fact that age is provided in ranges by Blenkin-Taylor atlas rather than as a specific number [10]. Another difficulty in determining the age index using the Blenkin–Taylor atlas occurs when there are developmental abnormalities such as delayed eruption [10].
5. Conclusion
The TCI–Benindra formula, the Al-Qahtani, and the Blenkin-Taylor methods could accurately estimate true age. Age estimation using the Al-Qahtani and Blenkin-Taylor methods can be applied on the Indonesian population. Age estimation using the TCI–Benindra method can be applied on periapical dental as well as panoramic radiographs.

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