Predicting lower third molar eruption on panoramic radiographs after cephalometric comparison of profile and panoramic radiographs

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SUMMARY Previous studies have suggested methods for predicting third molar tooth eruption radiographically. Still, this prediction is associated with uncertainty. The aim of the present study was to elucidate the association between cephalometric measurements on profile and panoramic radiographs and to find a simple and reliable method for predicting the eruption of the mandibular third molar by measurements on panoramic radiographs. The material consisted of profile and panoramic radiographs, taken before orthodontic treatment, of 30 males and 23 females (median age 22, range 18–48 years), with no known diseases. Cephalometric measurements on panoramic and profile radiographs were performed and compared, i.e. the size of the gonial angle and sagittal distance from the alveolar margin between the mandibular central incisors to the anterior border of the mandibular ramus. Furthermore, the mesiodistal width of the second molar was measured. Statistical methods included analysis of method error. The probability of eruption was modelled using logistic regression analysis. Correlation was observed between all measurements on profile and panoramic radiographs. The skeletal variable expressing the length from the ramus to the incisors (olr–id) showed a statistically significant correlation. By combining this length with the mesiodistal width of the lower second molar, the prediction of eruption of the lower third molar was strengthened. A new formula for calculating the probability of eruption of the mandibular third molar was made and a graph constructed for easy assessment. In conclusion, a simple method for predicting the eruption of the third molar is presented.

Introduction

The prediction of eruption of the mandibular third molar tooth is of major concern when planning orthodontic treatment. This prediction is associated with great uncertainty.

The third molars are the teeth most frequently affected by agenesis (Dermaut et al., 1986) and also by impaction (Ventä et al., 1997). According to most studies, the prevalence of impaction is 17–32 per cent, almost identical for maxillary and mandibular third molars. In most studies, the prevalence of impacted third molars is 20–30 per cent, significantly higher in women. The large discrepancies may be due to differences in diagnostics or ages.

Over time, many studies have presented different methods for predicting eruption of the third molar (Bowdler and Morant, 1936; Björk et al., 1956; Richardson, 1977; Olive and Basford, 1981; Svendsen et al., 1985; Ventä et al., 1997; Uthman, 2007). For this purpose, most studies have employed profile radiographs (Björk et al., 1956; Kaplan, 1975; Richardson, 1977), but also bite wing, periapical, panoramic, and frontal radiographs have been used (Svendsen et al., 1985; Ventä et al., 1997; Uthman, 2007). In a study early study by Bowdler and Morant (1936), skiagrams were used.

Profile radiographs

In a longitudinal study performed on profile radiographs, Richardson (1977) concluded that the radiographic prediction of eruption of the third molar cannot be made before the age of 10–11 years. The study also showed that cases with a short narrow mandible and a small mandibular angle are often associated with third molar impaction, evaluated at the age of 18 years.

Bowdler and Morant (1936) suggested that the individual growth pattern is important for eruption of the third molar. Björk et al. (1956) stated that absence of eruption is usually due to missing space in the retromolar area, which is the area between the second molar and the mandibular ramus. Björk et al. (1956) concluded that mandibular growth and delayed dental maturity are the most significant parameters for predicting third molar eruption. Different skeletal factors were suggested as important for expressing variation in the size of the retromolar space. These factors were mandibular growth length, growth direction of the condyle, and the direction of tooth eruption.

When analysing which of these factors play the most significant role for the risk of impaction, Björk et al. (1956)
found that vertically directed condylar growth was the most important factor followed by a short length of the mandible and a reduced alveolar prognathia. If these three factors are combined with delayed maturity of the third molar, four of five cases of impaction could be explained (Björk et al., 1956). In cases of impaction of the third molar, the size of the retromolar space measured on profile radiographs was significantly diminished in 90 per cent of the cases (Björk et al., 1956). Björk and co-workers went a step further in 1985 when the eruption path of the third molar was studied on frontal radiographs (Svendsen et al., 1985).

Panoramic radiographs

The advantage of panoramic radiographs when predicting eruption is that these images provide a complete overview of the dentition regarding tooth developmental stage, number of teeth, malformations of teeth, eruption, and resorption processes. The problem when evaluating third molar eruption on panoramic radiographs is that it is difficult to evaluate skeletal parameters, such as size and shape accurately.

Behbehani et al. (2006) compared panoramic radiographs from 134 patients whose treatment included extraction of four premolars (71.2 per cent) or no extraction (28.8 per cent). Behbehani et al. found that in the cases where extraction was performed, impaction of the third molar was reduced by 63 per cent. In another study by Uthman (2007), measurements were performed on a series of variables on panoramic radiographs. These variables were partly skeletal measurements and partly measurements of the mesiodistal width of the third molar. In the study by Uthman (2007), the following was measured: the jaw angle, the mesiodistal width of the third molar, the eruption space measured from the distal surface of the second molar to the anterior border of the ramus, and the eruption space measured from the distal surface of the second molar to Rickett’s point, representing the centre of the ramus. Additionally, the angle α between the line from the gonion to the symphysis and the length axis of the third molar were measured and the angle β between the length axes of the second and third molars. This study showed that the α and β angles and the gonial angle together with a space parameter were valuable parameters in predicting mandibular third molar eruption.

From the previously mentioned studies on profile and panoramic radiographs, it can be assumed that the size and shape of the mandible and the size of the teeth play a significant role for the eruption of the third molar in the mandible. These radiographs are the clinician’s basis for evaluation of eruption. From a histological point of view, many other factors play a role, such as the ability of the tooth follicle to penetrate bone (Wise and King, 2008).

Hypotheses

The first hypothesis suggests an association between the size of the jaw angle, the length of the mandible, and the eruption of the third molar in the mandible. The second hypothesis suggests a correlation between the jaw angle and the length of the mandible measured on profile and panoramic radiographs. The third hypothesis suggests that by combining craniofacial measurements with a molar size measurement, it is possible to predict eruption of the third molar in the mandible.

Purpose

The purpose of the study is to elucidate the association between cephalometric mandibular measurements on profile and panoramic radiographs and to find a simple, reproducible, and reliable method for predicting eruption of the third molar in the mandible by measurements on panoramic radiographs.

Material and methods

The material consisted of profile and panoramic radiographs, taken before orthodontic treatment, of 30 males and 23 females (median age 22 years, range 18–48 years). The frequency of eruption of the lower third molar was 56 per cent.

The material was met by the following inclusion criteria: no previous orthodontic treatment, no missing teeth in the mandible, all teeth in the mandible should be at the occlusal level (not evaluating the third molar), and root formation of the lower third molar had to be complete or nearly complete.

The frequency of third molar eruption in left and right sides of the mandible showed that the main part of the patients had either bilateral eruption or bilateral impaction. Thus, 28 (52.8 per cent) patients had fully erupted third molars in the right and left sides. Two (3.8 per cent) had eruption in the right side and impaction in the left side. Six (11.3 per cent) had eruption in the left side and impaction in the right side.

Cephalometric method

The following fix points and lines were used.

Articulare (ar). The intersection between the contour of the external cranial base and dorsal contour of the condylar head or neck.

Infra-dentale (id). The most antero-superior point on the lower alveolar margin.

Anterior border of the mandibular ramus (olr). The point appears as an intersection between a line connecting cuspsides of the first and second molars in the mandible and the contour of the anterior mandibular ramus.

The most dorsal/lateral point on the mandibular condylar process (aop).
The posterior point on the rear border of the mandibular ramus (rli).
The tangent point to the posterior mandibular corpus (mlp).
The tangent point to the anterior mandibular corpus (mla).

Cephalometric measurements

The following skeletal angles and distances were measured on profile radiographs (illustrated in Figure 1):

The gonion angle: the angle between the mandibular line, connecting mlp and mla, and the ramus line connecting ar and rli.

The distance from articulare (ar) to infradentale (id).

The distance from the anterior border of the mandibular ramus (olr) to infradentale (id).

The following bilateral skeletal measurements were performed on panoramic radiographs (illustrated in Figure 2):

The gonion angle: the angle between the mandibular line, connecting mlp and mla, and the ramus line connecting aop and rli.

The distance from the anterior border of the mandibular ramus (olr) to infradentale (id).

Figure 1 Profile radiographs illustrating the cephalometric landmarks used; id, infradentale: the most antero-superior point on the lower alveolar margin. olr, the anterior border of the mandibular ramus: the point appears as an intersection between a line connecting cuspides of the first and second molars in the mandible and the contour of the anterior mandibular ramus. ar, articulare: the intersection between the contour of the external cranial base and dorsal contour of the condylar head or neck. rli, the posterior point on the rear border of the mandibular ramus, mlp, the tangent point to the posterior mandibular corpus. gn, gnathion: the most inferior point on the mandibular symphysis.

The distance from the posterior point at the mandibular condyle, aop, to infradentale, id.

Dentition analysis

Third molar. The third molar was defined as erupted when the tooth was aligned with the molar occlusal plane seen on a panoramic radiograph. This was confirmed by drawing a line from the mesial cusp of the first molar posterior to the cuspides of the second molar and then further on to the third molar. Panoramic radiographs allowed for evaluation of the left and right side molars individually.

Second molar. The largest mesiodistal width of the second molar was measured using a digital calliper on the panoramic radiograph. The width was expressed as the longest mesiodistal distance measured on the second molar in the right and left sides of the mandible. The calliper had a precision of 0.03 mm. During the measurements, the results were rounded off to the nearest 0.5 mm.

Statistical methods

Spearman’s rank correlations were calculated for evaluation of the associations between the measured variables. In order to analyse the association of each variable with eruption of the third molar, a multivariate logistic regression model was employed in which eruption is the dependent variable and the explanatory variables are age, gender, and jaw angles as well as the distances aop/ar to id and olr to id (the linear distances as described previously). Results are presented by the odds ratio (OR) with 95% confidence interval (CI), the probability of eruption, and the area under the receiver operating characteristic curve (AUC) as a measure of discrimination. The significance level was set to 1 per cent. Calculations were done using SAS (v9.2; SAS Institute, Cary, North Carolina, USA).

Method error

All measurements were performed by authors A.B. and H.G. When results differed, the mean was used. In general, there was a difference lower than 1.0 degrees between the two authors’ angle measurements and less than 1 mm difference between distance measurements.

Results

Agreement between measurements on profile and panoramic radiographs

Significant correlation was observed between the length of the mandible and eruption of the lower third molar. The correlation between the gonion angle and eruption was not significant. The correlations are demonstrated in Table 1.

The study showed a significant correlation between the jaw angle on profile and panoramic radiographs (<0.0001)
and between the right and left sided measurements of the jaw angle on panoramic radiographs (<0.0001). On panoramic radiographs, significant correlations were observed between the jaw angle in the left and in the right side. Substantial correlations were found between the distances olr–id and aop–id on panoramic radiographs, both in the same side and when comparing the left and right sides (Table 1).

Bilateral correlation on panoramic radiographs

The measurements for the right and left sides on panoramic radiographs are highly significantly correlated. Additionally, highly significant correlations were observed in the same side, for both the right and the left side, between the distance aop–id and the distance olr–id ($P < 0.0001$; Table 1).

Inclusion of the second molar width

The study also showed that by combining olr–id with the mesiodistal width of the lower second molar, the prediction of eruption of the lower third molar was strengthened.

The mean mesiodistal width of the lower second molar was 14.5 mm. This width is used as a calibrating factor in the following new formula that calculates the calibrated distance olr–id:

![Figure 2 Panoramic radiographs illustrating the cephalometric landmarks used. 1, right side and 2, left side aop: the most dorsal/lateral point on the mandibular condylar process. olr: the anterior border of the mandibular ramus, the point appears as an intersection between a line connecting cusplides of the first and second molars in the mandible and the contour of the anterior mandibular ramus. Id, infradentale: the most antero-superior point on the lower alveolar margin. rli: the posterior point on the rear border of the mandibular ramus. mlp: the tangent point to the posterior mandibular corpus. mla: the tangent point to the anterior mandibular corpus.](image)

Table 1 Spearman rank correlation coefficients of the variables measured on profile (shown in bold) and panoramic radiographs.

<table>
<thead>
<tr>
<th></th>
<th>ar–id profile</th>
<th>olr–id profile</th>
<th>Gonial angle panoramic 1</th>
<th>aop–id 1</th>
<th>olr–id 1</th>
<th>Gonial angle panoramic 2</th>
<th>aop–id 2</th>
<th>olr–id 2</th>
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<td>Gonial angle</td>
<td>0.20</td>
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<td>0.85</td>
<td>0.31</td>
<td>0.12</td>
<td>0.88</td>
<td>0.15</td>
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<td>0.41</td>
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<td>0.41</td>
<td>&lt;0.0001</td>
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<td>0.50</td>
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<td>olr–id profile</td>
<td>0.46</td>
<td>0.0005</td>
<td>0.12</td>
<td>0.77</td>
<td>0.46</td>
<td>0.29</td>
<td>0.79</td>
<td>0.43</td>
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<td>0.0005</td>
<td>0.04</td>
<td>&lt;0.0001</td>
<td>0.0013</td>
<td></td>
<td></td>
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<tr>
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<td>0.01</td>
<td>0.88</td>
<td>0.92</td>
<td>0.92</td>
<td>&lt;0.0001</td>
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<td>olr–id 1</td>
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<tr>
<td>aop–id 2</td>
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<td>0.74</td>
<td>0.74</td>
<td>0.74</td>
<td>0.74</td>
<td>&lt;0.0001</td>
<td>0.74</td>
<td>&lt;0.0001</td>
</tr>
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The corresponding P-values are shown below the correlation coefficients. The P-value testing the hypothesis that the correlation coefficient is 0 is shown below.
Multivariate logistic regression analysis showed that olr–id was the only significant explanatory variable for the right and left sides. For the left side, the OR for olr–id was 1.34 (95 per cent CI: 1.13–1.60, \( P = 0.001 \)). The \( P \)-values to include gender, age, aop–id, and gonial angle in the final model were 0.94, 0.69, 0.70, and 0.42, respectively. The AUC was 0.86. Similarly, for the right side, the OR for olr–id was 1.16 (95 per cent CI: 1.05–1.28, \( P = 0.005 \)). The \( P \)-values to include gender, age, aop–id, and gonial angle in the final model were 0.18, 0.11, 0.04, and 0.66, respectively. The AUC was 0.75.

A graph illustrating the values of olr–id, with the corresponding probability of eruption of the lower third molar was done for easy assessment (Figure 3).

**Discussion**

The present study is a radiographic study evaluating the space in the mandible available for the third molar. The size of the second molar is measured as a substitute for the size of the third molar, which is difficult to determine on panoramic radiographs. The rationale behind performing these measurements is that less space and a large molar makes eruption impossible, while the opposite, adequate space, and a normal sized or smaller molar, allows for eruption. These two parameters, space and tooth size, were the focus of the present study.

The first hypothesis of the present study was that there is an association between the size of the jaw angle, the length of the mandible, and the eruption of the third molar in the mandible. This hypothesis could be confirmed in part since an association between the length of the mandible and eruption was seen. The longer the mandible, the more probable is eruption of the third molar. Meanwhile, an association could not be confirmed between the jaw angle and eruption of the third molar in the mandible.

The second hypothesis was that there is a correlation between the size of the jaw angle and the length of the mandible evaluated on profile and panoramic radiographs. This hypothesis could be confirmed. Calculations of Spearman correlation coefficients showed significant associations between these variables measured on panoramic and on profile radiographs.

The third hypothesis was that by combining craniofacial measurements with a molar size measurement, it is possible to predict eruption of the third molar in the mandible. The hypothesis could be confirmed as the study showed that by combining a measurement for the length of the mandible, olr–id, with the mesiodistal width of the second molar in the mandible, the discrimination for predicting eruption of the third molar increases.

This study has developed an easy clinically applicable method for evaluating the probability of eruption of the third molar in the mandible based on calculations of measurements on panoramic radiographs. Even so, there are critical remarks to the material. The examined material is small but apparently normally distributed. It is expected that a larger material would present these results more clearly. The study has focused on panoramic and profile radiographs. The disadvantage of using panoramic radiographs is primarily inaccuracies during exposure caused by the unfixed location of the patient in the radiographic apparatus. If the patient is not completely centred, one side on the radiograph will clearly appear larger than the other as a result of distortion. Other errors

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\text{olr–id} = \frac{\text{olr–id} \times 14.5 \text{ mm}}{\text{Lower second molar width}}
\]

**Figure 3** The figure shows the estimated probability of eruption for the left (dotted line) and the right (full line) sides as a function of olr–id.
may occur due to displacement of the bite block according to the patient’s head. This will allow the patient to tilt his/her head up or down and results in distortion in the radiograph making the jaw appear too low or too high. It would be possible to reveal the precise influence of tilting by evaluating radiographs of skulls tilted at different angles. In practice, the patient is always unfixed and head tilting cannot be measured exactly. Therefore, this inaccuracy must be taken into consideration.

Hattab and Alhaija (1999) demonstrated that the size of the jaw angle measured on panoramic varied from 116 to 122 degrees for females and males. This corresponds well to the findings in the present study. Hattab and Alhaija (1999) used the same measurement parameters as the ones used in the present study. Kay et al. (2010) found an average jaw angle for females and males for erupted and non-erupted third molars of approximately 120 degrees.

The study showed no correlation between jaw angles and eruption of the third molar. The jaw angle was therefore not a relevant measurement when trying to find a parameter for predicting the eruption of the third molar. This finding does not correspond with the theories of Björk et al. (1956) who believed that individuals with a large jaw angle could be expected to have more space posterior in the dental arch as the condylar growth would primarily be sagittal and thus increase the length from the interdentale to the front of the mandibular ramus.

Björk found that in the anterior rotated growth types with minor resorption of the anterior border of the ramus, the retromolar space will not be adequate for eruption of the third molar. In a similar study, Richardson (1977) found that a small jaw angle measured at the age of 18 years was more often associated with impaction that eruption of the third molar. Kaplan (1975) examined a material comprising orthodontically treated patients and found that the mandibular jaw morphology associated with a large beta jaw angle was significantly connected with a higher risk of impaction.

The present study showed that a larger distance from the articulare point to the interdentale point is correlated with eruption of the third molar. It was not the intention in the present study to measure the size of the third molar as the measurement is influenced by the sagittal and transversal location of the molar. Instead, the mesiodistal width of the second molar was used. The question in this connection is how the mesiodistal width of the second molar is related to the mesiodistal width of the third molar.

A recent study by Lee et al. (2011) showed an association between tooth size within the developmental fields (tooth groups), decreasing in size in the posterior direction. With regards to the molar area, Lee et al. (2011) found that the first molar was larger than the second molar and thus a smaller third molar could be expected. Lee et al. (2011) measured all teeth except the third molars. Brooke et al. (2009) revealed the same tendency: a good correspondence between molar sizes and showed that the second molar is smaller than the first molar. Accordingly, it is expected that the third molar is smaller than the second molar. Kaya et al. (2010) showed in an analogue study that the mesiodistal width of the third molar is dependent of the width/diameter of the first and second molars.

Ganss et al. (1993) demonstrated that 70 per cent of third molars in the mandible erupt if the ratio between size of the retromolar space (length from the distal surface of the second molar to the front of the ramus) and the third molar is more than or equal to 1 on panoramic radiographs, in contrast to 17 per cent if the ratio is less than 1.

Ganss et al. (1993) also examined space in the retromolar area in individuals from childhood until adulthood. This retromolar space was different in different individuals. The conclusion of this study was that less space at an early age is connected with less space at a later age and excess of space in childhood is connected with excess of space later in life.

In almost all radiographic studies, it was concluded that the factors that influence eruption of the third molar are skeletal growth, direction of eruption, extractions in the dental arch, the shape of the root complex, the maturity of the third molar, and the retromolar space. The retromolar space is considered most important.

In the present study, the probability of eruption was modelled using a logistic regression analysis. All craniofacial measurements were included and the model was gradually reduced to include only the most important variables.

In the present study, we constructed a formula from which we can calculate the probability of eruption of the third molar for the right and left sides independently. It can be argued that a panoramic radiograph is not a very accurate image, unless routine measures are made to standardize the exposure technique. In the present study, we have been aware of this source of error and we have omitted panoramic radiographs with obvious differences between the left and right sides. The advantage of our method is that the length olr-id is compared with the mesiodistal width of the second molar in the same side.

Ventä et al. (1997) developed a transparent template to place on top of a panoramic radiograph to see whether the third molar had enough space. The advantage is of course that this template is very easy to use. It must be mentioned that this template has been patented but has seemingly not been produced. The disadvantage is that this template method requires a highly standardized radiographic exposure.

One of the strengths of the present study is that when predicting eruption of the third molar in the right side, we use skeletal measurements from the right side and when predicting eruption of the third molar in the left side, we use skeletal measurements from the left side. Another strength is that we included the second molar instead of the third...
molar. The location of the third molar in the sagittal and/or transversal planes often makes it difficult to perform a satisfactory evaluation of size. In conclusion, we have developed a simple method for predicting the eruption of the third molar.

**Funding**

The IMK Foundation is acknowledged for funding.

**Acknowledgements**

Maria Kvetny, MA, is acknowledged for linguistic support and manuscript preparation.

**References**


Bowdler H, Morant G M 1936 A preliminary study of the eruption of the mandibular third molar tooth in man based on measurements obtained from radiographs, with special reference to the problem of predicting cases of ultimate impaction of the tooth. Biometrika 28: 378–427


Richardson M E 1977 The etiology and prediction of mandibular third molar impaction. Angle Orthodontist 47: 165–172


Ventä I, Murtomaa H, Ylipaavalniemi P 1997 A device to predict lower third molar eruption. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics 84: 598–603