Original Article

Association between third mandibular molar impaction and degree of root development in adolescents

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ABSTRACT

Objective: To compare the root development and the growth rate of the mandibular third molar (M3 inf) in individuals where the M3 inf erupted vs individuals exhibiting M3 inf impaction.

Materials and Methods: Serial standardized intraoral radiographs (Eggen technique) were taken annually of the mandibular third molar region from 132 subjects (71 male and 61 female) from 15 to 20 years of age. Based on the films, 264 lower third molars were classified into an eruption and an impaction group. Root development was recorded according to a quantitative method described by Haavikko (1970), and the eruption status was analyzed using logistic regression.

Results: In total, 155 (59%) of the M3 inf erupted, and 109 (41%) were impacted at age 20. In 44 (33%) patients both M3 inf were impacted, in 21 (16%) patients one tooth was erupted and the contralateral tooth impacted, and in 67 (51%) patients both M3 inf were erupted. The more mature a tooth was at age 15, the higher was the probability of eruption (odds ratio: 3.89, $P < .001$). The growth rate of the root development stage was statistically significantly associated with the probability of eruption (odds ratio: 10.50, $P = .041$).

Conclusions: Delayed mandibular third molar root development is associated with impaction. Radiographs taken at age 15 may predict the risk of impaction and thereby guide decision making for the orthodontist or the oral and maxillofacial surgeon. (*Angle Orthod.* 2013;83:3–9.)

KEY WORDS: Dental age; Radiologic development; Third molar; Impaction

INTRODUCTION

In treatment planning, the orthodontist or the oral surgeon is often challenged to predict the probability of eruption or impaction of mandibular third molars (M3 inf) in young patients. This prediction is commonly based on a radiographic assessment, and it often gives ambiguous answers. No accurate predictive method has been developed because the etiology of mandibular third molar impaction is complex. Long-term clinical studies found several conditions related to third molar impaction: lack of space in the third molar region,[1–6] third molar angulation,[7–9] ectopic position,[10] obstruction of the eruption pathway,[1] late third molar mineralization/early physical maturity,[1,10–12] and other factors (e.g., sex, racial and socioeconomic differences, and genetic and endocrinologic factors).[13]

Few studies have investigated the association between third molar impaction and the stage of root development in adolescents. Based on examination of a skull material, Hammer[10] in 1930 suggested that late development of a third molar was related to third molar impaction. In 1956, Björk et al.[1] demonstrated an association between impaction and retarded maturation of the third molars. This finding emerged from a study of the mineralization of the third molar crown in 12-year-old boys compared with the tooth development stage in adulthood of the same 243 individuals.

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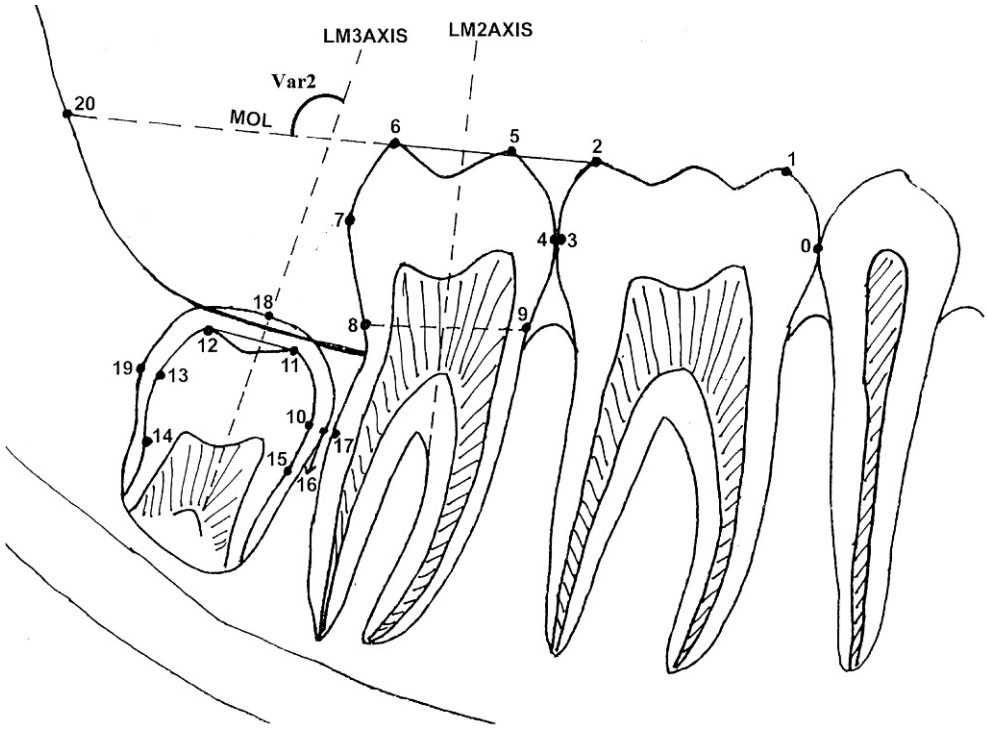


Figure 1. Inclination of lower M3 (LM3AXIS) in relation to molar occlusal-line (MOL) in degrees (Var2).

Björk et al.[1] considered late maturation of the M3 a factor of significance in prognostication of third molar impaction. Thirty years later, Svendsen and Björk[12] investigated the association between impaction and the combination of a late M3 mineralization and early physical maturity. They showed that in horizontally impacted third molars, the stage where bifurcation appears radiographically (mineralization stage E, Demirjian et al.[14]) occurred significantly later than in normally erupting lower M3s in both sexes (29 months later in girls and 9 months later in boys). Late mineralization was concurrent with the union of the distal epiphysis of the radius as an indicator of physical maturity. It was shown that late mineralization of third molars has a greater effect on impaction than early physical maturity, but a combination of both strengthened the influence on abnormal eruption. Svendsen and Björk[12] concluded that late M3 mineralization is a consistent factor for impaction of third molars, and a quite reliable assessment of the risk for third molar impaction seems possible from the tooth-development stage in relation to chronologic age.

A more recent cross-sectional study from 1994 by Köhler et al.[11] described that the impaction of mandibular wisdom teeth can cause a delay in root development from 2 and up to 3½ years. Friedrich et al.[15] repeated this cross-sectional study and found that impaction of mandibular third molars had no significant relation to the velocity of root formation.

Apart from the study from Svendsen and Björk,[12] none of the previous studies have investigated the annual mineralization progression and root development of the mandibular third molar in a prospective longitudinal study.

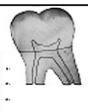
Ordinal Root development stage	5	6	7	8	9	10	11	12
Radiographic interpretation								
Definition of root development stages from Haavikko[13]	Crown ¾ completed ($Cr_{¾}$)	Crown completed (Cr_{c})	Initial root formation (R_{i})	Root length ¼ ($R_{¼}$)	Root length ½ ($R_{½}$)	Root length ¾ ($R_{¾}$)	Root length complete ($A_{½}/R_{c}$)	Apex closed (A_{c})

Figure 2. Connection of the ordinal scale and the tooth development stages according to Haavikko.[13]

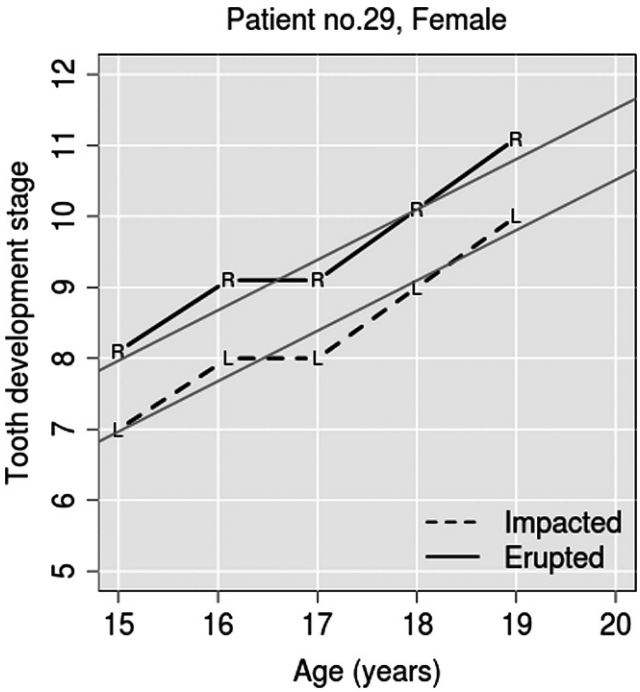


Figure 3. Data of a female patient with impaction of the left M3 inf and eruption of the right M3 inf. Regression lines are shown.

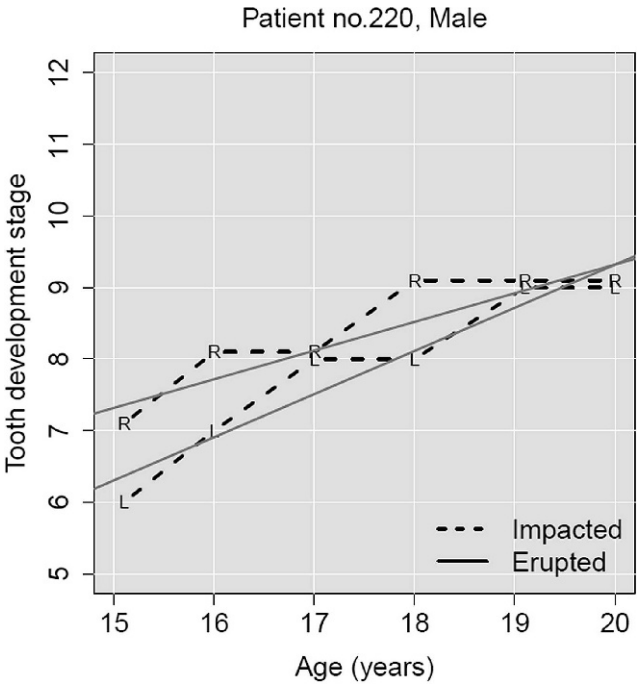


Figure 5. Data of a male patient with impaction of both M3 inf. Regression lines are shown.

Study Aims

The goals of this study were to:

- compare the root development of M3 inf of an impaction vs an eruption group and demonstrate a possible difference,
- investigate whether there is an association between delayed root development and impaction of M3 inf,
- examine whether there is a gender-related difference in root development, and
- investigate the relative influence of growth rate and root development at age 15 on impaction.

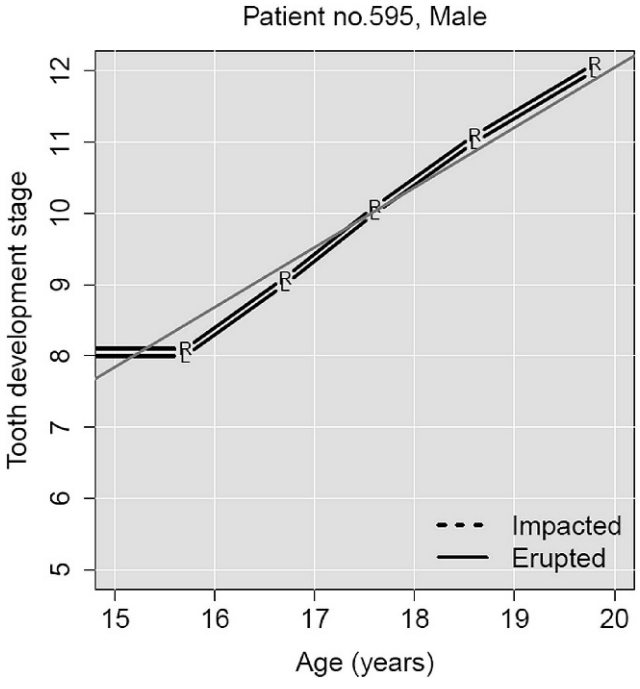


Figure 4. Data of a male patient with eruption of both M3 inf. Regression lines are shown.

MATERIALS AND METHODS

Inclusion and Exclusion Criteria

This longitudinal prospective study, approved by the Danish National Committee on Health Research Ethics in 1988 included 607 Danish schoolchildren at the age of 15 years (±3 months). The inclusion criteria included the following: both mandibular M3-tooth germs present and thereby no agenesis, no agenesis of other permanent teeth, no extractions of permanent teeth before or during the investigation period, and no orthodontic treatment of permanent teeth before or during the investigation period.

Inclusion was based on radiographs of the third molars meeting the criteria mentioned. The included cases were then further divided into an impaction and eruption group. All lower third molars were viewed as separate cases, and a patient was allowed to contribute with more than one tooth. Therefore, unilateral and bilateral impactions were possible outcomes.

Eruption was defined when the M3 inf was fully erupted to its functional position in occlusal level with

Table 1. Mean and Standard Deviation of Patient Age at the Different Examinations

Examination	N	Mean Age (SD), y	Female Patients, N (%)	Male Patients, N (%)
1	132	15.0 (0.24)	61 (46.2)	71 (53.8)
2	128	15.9 (0.24)	60 (46.9)	68 (53.1)
3	129	17.0 (0.25)	60 (46.5)	69 (53.5)
4	131	18.0 (0.25)	61 (46.6)	70 (53.4)
5	128	19.0 (0.26)	59 (46.0)	69 (53.9)
6	94	20.0 (0.24)	46 (48.9)	48 (51.0)

the lower second molar on one or more of the intraoral radiographs. Completion of all six annual visits was not required. Impaction was defined as an anteriorly angulated arrested eruption in a position colliding with the M2 inf on the terminal intraoral radiograph. The anterior angulation was defined as an inclination of lower M3 in relation to molar occlusal-line between 90° and 180° (Figure 1). Completion of all six annual visits was required.

The exclusion criteria included: impaction cases below 90° (vertically and distally impacted M3 inf) and radiographs of insufficient quality and/or films not displaying the entire root.

Data Collection

At 15 years of age, a clinical examination of the lower third molar region was performed. A panoramic radiography (OPG) and standardized intraoral radiographs (using a right angle Eggen technique[16]) of the lower third molar region were taken. Reexaminations were scheduled annually (±3 months) in a follow-up period of 5 years with one intraoral radiograph of each M3 inf taken every year, and at a terminal visit (20 years of age) another OPG was taken.

Data Processing and Digitalization

All intraoral films were digitized and the development stages of the third molars were determined according to Haavikko.[13]

The digitized pictures were adjusted with auto levels and contrast with Adobe Photoshop CS3 to ensure optimal image quality for interpretation. In the first evaluation, the stages from initial root formation to ¾ root length were compared to the last picture with complete root length for optimal measurements. In the second evaluation by the same observer, pictures were analyzed blinded and in a random order. For the statistical analyses, the development stages according to Haavikko were transformed into an ordinal scale (Figure 2).

Statistical Analysis of Data

The data were summarized using frequencies, means, and standard deviations. For each tooth, the root development was approximated by a linear function of age using ordinary least square regression. Individual plots with root development stage associated to age were made of all patients and for each tooth. The resulting regression slope represented the growth rate, and the intercept at age 15 represented a common baseline stage for all further analyses (Figures 3 through 5). Logistic regression was then used to analyze the association of the eruption status at age 20 with the root development process, which was summarized by the growth rate and the stage at age 15 as described above, and with patient gender. In order to assure that all patients contributed with data from two wisdom teeth, the standard error was estimated with the generalized estimating equations approach.[17] The level of statistical significance was set at 5%.

RESULTS

All six annual visits were completed for a total of 249 patients. One hundred thirty-two patients with known chronologic age and gender met the inclusion criteria. Seventy-one patients were male and 61 were female, and their mean ages ranged from 15 to 20 years (Table 1). Seventy-five patients were in the eruption group, and 57 patients were in the impaction group (Table 2).

Table 2. Patient Data on Eruption and Impaction Status

Factor	Patients, N (%)
Eruption group	75 (56.8)
Impaction group	57 (43.2)
Unilateral and bilateral division	
Bilateral impaction	44 (33.3)
Unilateral impaction	21 (15.9)
Bilateral eruption	67 (50.8)

Table 3. Data on Eruption and Impaction Status[a]

Eruption State	M3 inf, N (%)
Eruption	155 (58.7)
Impaction	109 (41.3)
Total M3 inf	264 (100)

[a] M3 inf indicates mandibular third molar.

Table 4. Mean and Standard Deviation of Root Development Stages for Left and Right M3 inf at the Different Examinations[a]

Examination	Root Development Stage Right M3 inf Female	Root Development Stage Left M3 inf Female	Root Development Stage Right M3 inf Male	Root Development Stage Left M3 inf Male
1	7.4 (0.96)	7.4 (0.89)	7.6 (0.87)	7.5 (0.97)
2	8.1 (0.97)	8.1 (1.00)	8.4 (0.97)	8.5 (1.05)
3	8.9 (1.18)	8.9 (1.08)	9.2 (1.02)	9.3 (1.11)
4	9.6 (1.25)	9.7 (1.15)	10.0 (0.98)	10.0 (0.94)
5	10.3 (1.21)	10.3 (1.19)	10.8 (0.95)	10.7 (0.89)
6	10.8 (1.02)	10.7 (0.98)	11.4 (0.74)	11.3 (0.83)

[a] M3 inf indicates mandibular third molar.

A total of 1230 intraoral radiographs of the 264 lower third molars were available for the 132 patients with 155 lower third molars in the eruption group and 109 in the impaction group (Table 3).

The root development stage for right and left M3 inf were viewed separately in male and female patients at each annual examination and showed no right or left differences in development stage (Table 4).

The root development for M3 inf at age 15 was between initial root formation and ¼ root length (median stage = 8). The impaction group had a mean root development in the initial root formation area (median stage = 7), whereas the eruption group was more in the ¼ root length area (median stage = 8). Male patients had a higher growth rate and mean root development stage in both the impaction and eruption group at age 15 years compared to female patients as shown in Table 5. In both genders, the impaction group had a lower growth rate and root development stage at age 15 in comparison with the eruption group. In a plot of root development stages associated to age at the six annual examinations, the impaction group also scored a lower growth rate and root development stage for both genders (Figure 6).

The logistic regression model showed a significant association between the root development stage at age 15 and the probability of eruption (odds ratio: 3.89; $P < .0001$) (Table 6). A tooth in development stage 8 at age 15 years has about four times higher chance for eruption than a tooth in stage 7 at age 15 years. The association of the development rate and the eruption probability was statistically significant showing a higher probability for eruption with increasing slope (odds ratio: 10.50; $P = .041$). M3 inf in male patients showed a slightly but not significantly lower probability of eruption (odds ratio: 0.66; $P = .29$).

Only one observer was used and the correlation between the first evaluation and the reevaluation was 76.45%. The kappa value was 0.68. In the first evaluation the stages from initial root formation to ¾ root length were compared to the last picture with complete root length for optimal measurements, and therefore a full-blinded evaluation could not be obtained. In the second evaluation, the pictures were scored 3 years after the first occasion without knowledge of previous scores and pictures were selected randomly and blinded.

DISCUSSION

A significant difference in third mandibular molar root development between the impaction and eruption group was demonstrated. This shows an association between impaction and a delayed M3 inf tooth development in comparison with an erupting M3 inf.

Our analysis showed that a tooth with ¼ root length at age 15 years has about four times higher probability of eruption than a tooth with only initial root formation at age 15 years. The root development growth rate between age 15 and 20 was less important than the development stage at age 15. This indicates that the root development stage at age 15 years has a prognostic value in prediction of tooth impaction at age 20. If a mandibular third molar has not started its initial root formation and therefore only the crown is detected on an intraoral radiograph in a 15-year-old

Table 5. Summary of the Regression Lines Mean Root Development and Slope of Root Development

Slope of Regression Lines at Age 15 y	N	Mean Root Development Stage at Age 15 y	Mean Growth Rate	SD	Mean Explained Variation
Eruption female	72	7.8	0.80	0.18	0.96
Impaction female	50	6.8	0.73	0.20	0.96
Eruption male	83	7.9	0.88	0.15	0.96
Impaction male	59	7.1	0.86	0.17	0.95
All	264	7.5	0.83	0.18	0.96

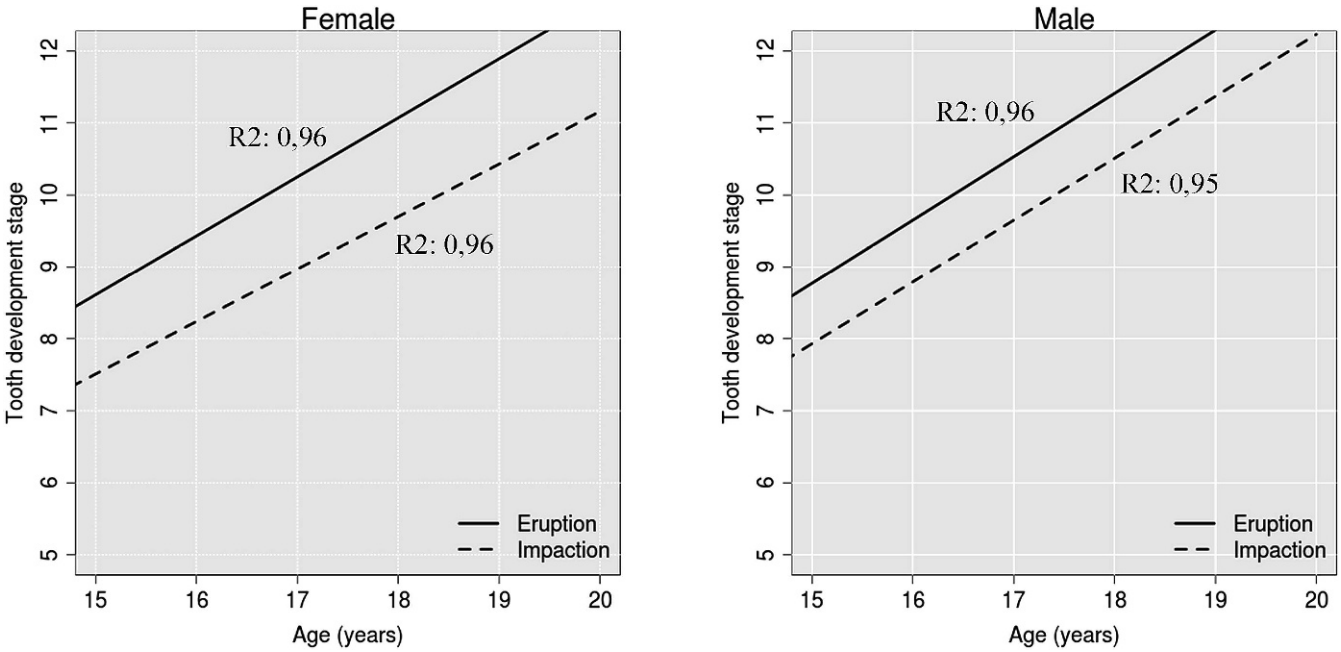


Figure 6. Plot of all root development stage vs age for the impaction group (dotted line) and eruption group (full line) for female and male patients.

patient, there is a higher risk for impaction. These findings are in agreement with previous investigations like the study of Svendsen and Björk.[12]

Comparison of Result to the Etiology of Impaction

The etiology of mandibular third molar impaction is complex, and late tooth development at age 15 cannot be used as a single factor in prediction, but the influence of delayed root development should be compared with the other causes mentioned in the introduction: lack of retromolar space and third molar angulation. A full understanding of the interactions between the etiological factors of the mandibular third molar impaction needs further investigation.

Source of Error

In this study, all intraoral radiographs of the lower third molar region were taken with a standardized Eggen technique.[16] This limits the variation of cone angulations and thus makes it possible to compare radiographic images over time. A small difference in cone angulations must be accepted with this method, which might affect the interpretation of the images.

Table 6. Results From the Logistic Regression

Factor	Odds-Ratio	*P*
At age 15 y	3.89	<.0001
Slope	10.50	.0409
Sex: males	0.66	.2869

The method used to graduate the development stages was according to Havvikko.[13] This method has been questioned by Kullman et al.[18] because it relies on the subjective assessment of the development of the root and is based on the experience of the observer. This consideration has been taken into account, and therefore all possible stages from initial root formation to ¾ root length were compared to the last picture with complete root length for optimal measurements. In this study, the kappa value was 0.68, showing a moderate subjectivity inherent in the Havvikko method.

Applicability in Biological Age Determination

In forensic medicine, the accuracy of biological age determination is important in crime cases or in the assessment of the age of immigrants. Often a skeletal and dental age determination is used because it is a simple, noninvasive, reproducible examination at a low cost.[19] The development of the third molar is especially used to determine the age of adolescent immigrants.[20] An accurate and valid method for producing reliable and dependable age determination outcomes is highly desirable. In light of the present study, the association between impaction of third molars and velocity of root development in its early stages could improve the accuracy of the means and deviations of the current development stages by various authors used in determination of biological age. Until now, no studies have been found to distinguish between impaction and eruption in determination of the mean ages of development stages of third molars.

CONCLUSIONS

- There is a significant association between the root development stage of M3 inf at age 15 years and the probability of eruption at 20 years (odds ratio: 3.89; $P < .0001$).
- Delayed M3 inf root development is associated with the risk of impaction, and radiographs taken at age 15 may predict the risk of impaction and thereby serve as a decision-making guide for the dentist, orthodontist, or the oral and maxillofacial surgeon.
- The association between delayed root development and impaction needs further investigation to determine its relative importance in the multifactorial etiology of third mandibular molar impaction.

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