ORIGINAL ARTICLE

Prediction of mandibular third-molar impaction in adolescent orthodontic patients

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Introduction: The purpose of this study was to identify risk factors for mandibular third-molar impaction in adolescent orthodontic patients. **Methods:** Radiographs made before (T1) and after (T2) treatment and at least 10 years postretention (T3) of 134 patients that allowed accurate diagnosis of impaction vs eruption of at least 1 mandibular third molar were evaluated. **Results:** Univariate logistic regression analyses at T1 showed that the decision to extract premolars ($P < .05$), an increase of 1 mm in mesial molar movement ($P < .05$), and an increase of 1 mm in eruption space measured from second molar to Xi point (centroid of the ramus) ($P < .01$) reduced the risk of impaction by 63%, 22%, and 30%, respectively. An increase of 1° in mandibular third-molar angulation relative to the occlusal plane increased the risk of impaction by 11% ($P < .01$). Multivariate logistic regression analyses at T1 showed that reduced eruption space ($P < .01$), signs of forward mandibular growth rotation ($P < .01$), and female sex ($P < .05$) increased the risk of impaction. However, association tests documented increased frequencies of extractions and more mesial molar movement in female patients with erupted third molars. Univariate logistic regression analyses at T2 showed that every millimeter of increase in eruption space measured from the second molar to the anterior border of the ramus and to Xi point reduced the risk of impaction by 29% and 22%, respectively ($P < .01$), whereas every degree of increase in the angle between the occlusal surface and the occlusal plane increased the risk of impaction by 11% ($P < .01$). Multivariate logistic regression analyses at T2 showed that increased eruption space reduced the risk of impaction ($P < .05$), whereas increased mesial angulation of the third-molar bud ($P < .01$) and signs of forward growth rotation ($P < .05$) increased the risk of impaction. (Am J Orthod Dentofacial Orthop 2006;130:47-55)

One explanation for the high impaction rate of mandibular third molars might be insufficient development of the retromolar space.[1-3] If the remodeling resorption at the anterior aspect of the mandibular ramus (R) is limited, the eruption of the mandibular third molars could be blocked.[4,5] The variation in R resorption is correlated with the direction of condylar growth,[4] which in turn affects morphology and position of the adult mandible.[5] Condylar growth in a predominantly vertical direction is associated with reduced resorption at the anterior aspect of the R and forward growth rotation of the mandible, whereas more backward-directed growth at the condyles is associated with increased resorption and posterior growth rotation.[5,6] The molars tend to erupt more forward during the functional phase in patients with anterior growth rotation, partly compensating for the limited amount of resorption at the anterior border of the R.[4] Because morphologic parameters at adolescence might predict the remaining type of mandibular growth rotation, they could also be useful in predicting impaction of mandibular molars.[7] Few studies have analyzed that issue in adolescent orthodontic patients, and attempts at using a multivariate approach are rare.[4]

Another explanation for mandibular third-molar impaction might be an unfavorable path of eruption. Typically, the tooth bud is mesially angulated during the initial stages of calcification and root development.[8-11] Longitudinal evaluations show that the average subject with no history of orthodontic treatment experiences uprighting of the mandibular third molars during early adolescence.[10,11] However, individual variations in change can be large, and a few third molars might experience increased mesial angulation during early[11] and late[10] adolescence. The combined rate of mesial and horizontal impactions of about 46%[12] suggests that unsatisfactory uprighting is a common cause of impaction. Because the rate of distal impaction is about 6%[12] and the tooth bud rarely is distally angulated

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during the initial developmental stages,[8,11] over-uprighting might occur in some patients. It is unclear whether the angulation of the mandibular third molar at adolescence is of predictive value for successful eruption at complete root development.[13,14] There are indications that excessive initial mesial angulation and minimal uprighting during follow-up might increase the likelihood of impaction.[8,13] One study suggested that in most cases a space of about 1 mm can be observed between the developing third molar and the second molar.[8] The space appears to close rather rapidly, and the predictive value of the size of the space for impaction is unclear.[13]

Skull materials indicate that third-molar impaction was relatively infrequent in primitive populations.[15-17] This has been attributed to mesial drift of the posterior teeth due to excessive interproximal attrition, thereby increasing retromolar space. Similarly, third-molar impaction is rarely observed after second-molar extraction.[18,19] A recent comprehensive study demonstrated a clinically significant reduction in the rate of mandibular third-molar impaction in orthodontic patients treated with premolar extractions compared with patients treated without extractions.[20] Although the study design precluded conclusions about cause-and-effect relationships,[20] the results strongly suggest that the increased potential for mesial molar movement during extraction-site closure, with concomitant increase in retromolar space, was the major reason for the intergroup difference in third-molar impaction.

Attempts have been made to analyze the predictive value of the adolescent eruption space for mandibular third-molar impaction.[21,22] The mean eruption space in a sample of 75 orthodontic patients, measured on lateral cephalograms between the distal aspect of the mandibular second molar to Ricketts' Xi point[22] along the occlusal plane (see Fig 1 for Xi location), was found to be 30 mm for erupted mandibular third molars and 21 mm for impacted mandibular third molars.[21,22] If the distance was less than 19 mm, the chances of impaction were reported to be 95%. It has also been suggested that the probability of third-molar impaction is directly related to the proportion of the third molar in front of the anterior border of the R.[21,22] If half of the developing third molar was anterior to the R, corresponding to an eruption space of about 5.5 mm, the chance of eruption was only 50%.[21,22] These findings could not be confirmed in a recent comprehensive study,[20] in which more than 40% of the subjects with less than 19 mm from the distal aspect of the mandibular second molar to Xi point experienced eruption of the mandibular third molars, as well as 55% of those with distances of 3.5 mm or less between the distal aspect of the second molar and R.[20] In previous studies, only the predictive value of eruption space was evaluated, without using multivariate analyses to take into account the possible effect of other variables.[21,22] Multivariate analyses have been used to establish a predictive model for impaction of the mandibular third molars of young adults by using panoramic radiographs.[23,24] However, attempts at establishing a predictive model for adolescent orthodontic patients are very limited.[10,13] The samples were small, and only a few variables were tested. In addition, some subjects were less than 20 years of age when impaction was diagnosed. Several studies indicate favorable positional changes of the third molars leading to eruption up to 26 years of age.[25-28]

The purposes of this study were to try to establish a predictive model for mandibular third-molar impaction before (T1) and after (T2) orthodontic treatment in adolescent orthodontic patients, and to identify risk factors for impaction. These results might be of considerable clinical significance. In situations with several mechanical options, the alternative with the least risk of impaction might be favored. However, the nonextraction alternative might be favored in borderline extraction patients unless the chance of impaction can be predicted as minimal. Also, appropriate follow-up routines and optimal timing for surgical removal of the third molars can be established in patients judged to be at increased risk of impaction at debonding.

MATERIAL AND METHODS

Our sample included lateral cephalograms, panoramic or periapical radiographs, and study models made at T1 and T2 and at follow-up at least 10 years postretention (T3) of all patients without dentofacial deformities, severe facial asymmetries, or missing teeth other than 4 premolars, and who had been treated without extractions (n = 242) or with extraction of 4 premolars (n = 315) by faculty members and graduate students in the Department of Orthodontics at the University of Washington, Seattle. All cephalograms were made with a standard focus-to-object distance of 5 feet. The film cassette was adjustable in a lateral direction and was typically placed as close to the cephalostat as possible. A total of 389 patients had radiographic evidence of at least 1 third molar at T1 or T2. Patients who had both mandibular third molars removed before apical root closure or eruption on any follow-up radiographs or models or whose radiographs did not allow identification of the apices of any remaining mandibular third molars were eliminated The final sample comprised 134 patients (mean ages: 12.4 years at T1 [SD 1.7], 15.2 years at T2 [SD 1.9], and 30.0

years at T3 [SD 4.3]); 55.2% of the patients were female. Nonextraction treatment was performed in 28.8% of the patients, and 50.0% were treated with extraction of the mandibular first premolars and 21.2% with extraction of the mandibular second premolars. Angle Class I, Class II, and Class III malocclusions were present in 38.0%, 57.5%, and 4.5% of the subjects, respectively.

Independent *t* tests showed no significant difference in age ($P > .05$), and chi-square tests showed no significant difference in distribution of Angle class ($P > .05$) between the selected and rejected patients. However, 56% and 67% of the selected and excluded patients were female, and extractions were performed in 66% and 56% of the selected and excluded patients, respectively ($P < .05$, chi square test).

Third-molar impaction was defined as incomplete eruption at T3 with radiographic evidence of apical closure. Third-molar eruption was defined as the presence of buccal or ligual cusps at the level of occlusal plane at T2, at any follow-up, or at T3. Variations in buccolingual inclination were not considered.

Movement of the mandibular first molar (MM) from T1 to T2 (MM T1/T2) was measured along the averaged occlusal plane on the superimposed images of the cephalograms with a digital caliper (Fred V. Fowler, Newton, Mass). Mandibular superimposition was carried out according to the method of Björk.[6] Eruption space was defined as the distance from Ricketts' Xi point[21,22] or from the anterior border of the R[4,22] to the distal surface of the mandibular second-molar crown along the occlusal plane (M2/Xi and M2/R, respectively) (Fig 1). M2/Xi and M2/R were not measured in 56 subjects at T1 and 11 subjects at T2 because of incomplete eruption of the second molars. Third-molar angulation was measured as the angle between the occlusal surface and the occlusal plane (M3/OP) as well as the mandibular plane (M3/MP) (Fig 1); changes in third-molar angulation were determined by subtracting M3/MP at T2 from M3/MP at T1.

The width of the mandibular third molar (WM3) was measured as the distance from the mesial to the distal anatomic contact points. The space between the third and second molars (M2/M3) was measured as the shortest distance between the mesial aspect of the third-molar bud and the distal outline of the crown or the root of the second molar. Mandibular prognathism was measured as SNB angle, and sagittal and vertical skeletal relationships were evaluated as ANB and MP/SN angles, respectively. Mandibular corpus length was measured from Point B to the anterior outline of the mandibular R (B/R) or to Ricketts' Xi point (B/Xi) along the occlusal plane, and total mandibular length as the distance from articulare (Ar) to pogonion (Pg). Mandibular morphology was evaluated by measuring the gonial angle and the angle between MP and the line from Ar to Pg (beta angle). Small gonial and MP/SN angles and a large beta angle indicate a tendency for anterior growth rotation, whereas the opposite suggests a tendency for posterior rotation.

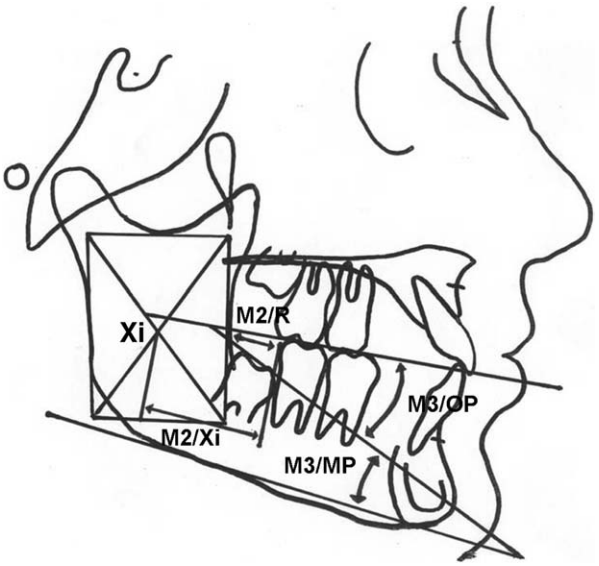

Fig 1. Line drawing illustrating definitions of parameters used for evaluation of eruption space and third-molar angulation.

The reproducibility of the measurements was assessed by statistically analyzing the difference between double measurements taken at least 1 week apart on 10 subjects randomly selected. The error of the method was calculated from the equation

$$S_x = \frac{\sqrt{\sum D^2}}{2N}$$

where *D* is the difference between duplicated measurements, and *N* is the number of double measurements.[29] The errors ranged from 0.11 mm for WM3 to 1.12 mm for M2/R.

Impaction was scored as present if at least 1 mandibular third molar was diagnosed as impacted. Logistic regression analyses were used to identify predictors for impaction. Initially, univariate logistic regression was used to test for associations between variables estimated at T1 and T2 and impaction (Table I). After that, forward stepwise multiple logistic regression was used to develop a prediction model at T1 and at T2. Variables were successively entered into the model if their effects were significant at $P < .05$. At each step,

Table I. Variables in logistic regression analyses before (T1) and after (T2) treatment of 134 adolescent orthodontic patients treated with and without extraction of mandibular premolars to test for associations with mandibular third-molar impaction (scores for categorical parameters in parenthesis)

Independent variables	*Time*	*Unit*
Age	T1, T2	
Angle class	T1, T2	I(1), II(2), III(3)
Sex	T1, T2	Male(1)/female(2)
Premolar extraction	T1	Yes(1)/no(0)
M2/R	T1, T2	mm
M2/Xi	T1, T2	mm
MM T1/T2	T1	mm
M3/OP	T1, T2	°
M3/MP/T1–M3/MP/T2	T2	°
Ar to Pg	T1, T2	mm
B/R	T1, T2	mm
B/Xi	T1, T2	mm
WM3	T1, T2	mm
M2/M3	T1, T2	mm
Beta angle	T1, T2	°
Gonial angle	T1, T2	°
SNB angle	T1, T2	°
ANB angle	T1, T2	°
MP/SN angle	T1, T2	°

Table II. Pretreatment variables in final prediction model for mandibular third-molar impaction according to forward stepwise logistic regression in 134 adolescent orthodontic patients

Variable	*Effect (SE)*	*Significance*	*Odds ratio (CI)*
Sex	1.83 (0.87)	$P < .05$	6.24 (1.14-34.25)
M2/Xi	–0.69 (0.21)	$P < .01$	0.50 (0.33-0.76)
Gonial angle	–0.19 (0.07)	$P < .01$	0.83 (0.72-0.95)

the variable with the lowest P value was included. Previously entered variables were excluded if their effects were no longer significant ($P > .05$) upon inclusion of a new variable. The final model was determined when no remaining variable had a significant effect ($P > .05$) (Tables II and III). Association tests were performed if necessary to explain unusual findings.

RESULTS

Univariate logistic regression at T1 showed that the decision to extract premolars reduced the risk of impaction by 63% (Table IV). In addition, an increase of 1 mm in MM T1/T2 and M2/Xi reduced the risk of impaction by 22% and 30%, respectively, whereas an increase of 1° in M3/OP increased the risk of impaction

Table III. Posttreatment variables in final prediction model for mandibular third-molar impaction according to forward stepwise logistic regression in 134 adolescent orthodontic patients

Variable	*Effect (SE)*	*Significance*	*Odds ratio (CI)*
M2/Xi	–0.27 (0.11)	$P < .05$	0.77 (0.62-0.96)
M3/OP	0.13 (0.05)	$P < .01$	1.13 (1.03-1.25)
Beta angle	0.30 (0.14)	$P < .05$	1.36 (1.03-1.78)

Table IV. Pretreatment variables with significant ($P < .05$) and marginally significant ($P < .10$) effect on mandibular third-molar impaction according to univariate logistic regression analyses in 134 adolescent orthodontic patients

Variable	*Effect (SE)*	*Significance*	*Odds ratio (CI)*
Extraction	–0.99 (0.40)	$P < .05$	0.37 (0.17-0.81)
MM	–0.25 (0.11)	$P < .05$	0.78 (0.63-0.97)
M2/Xi	–0.36 (0.13)	$P < .01$	0.70 (0.55-0.89)
M3/OP	0.10 (0.04)	$P < .01$	1.11 (1.03-1.19)
MP/SN	–0.07 (0.04)	$P < .10$	0.93 (0.87-1.00)
Gonial angle	–0.06 (0.03)	$P < .10$	0.94 (0.88-1.00)

Table V. Variables associated with sex in subjects with erupted mandibular third molars

Variable	*Males*	*Females*	*Significance*
MM T1/T2	2.75 mm	3.80 mm	$P < .05$
Extraction	64.4%	91.5%	$P < .01$

by 11% (Table IV). Increases of 1° in MP/SN and gonial angles reduced the risk of impaction only marginally ($P < .10$)—by 7% and 6%, respectively (Table IV).

The stepwise forward multiple logistic regression analyses documented that female sex increased the odds of impaction more than sixfold; increases of 1 mm in M2/Xi and 1° in gonial angle reduced the risks of impaction by 50% and 17%, respectively (Table II). The odds of mandibular third-molar impaction could be predicted according to the following equation: exponent (30.45 + 1.83 [sex] – 0.69 [M2/Xi] – 0.19 [gonial angle]). However, the independent t test showed more mesial molar movement ($P < .05$), and the chi-square test showed higher frequencies of premolar extractions ($P < .01$) in female than in male patients with erupted third molars (Table V).

Univariate logistic regression at T2 showed that every millimeter of increase in M2/R and M2/Xi reduced the risk of impaction by 29% and 22%, respectively, whereas every degree of increase in M3/OP increased the risk of impaction by 11% (Table

Table VI. Posttreatment variables with significant ($P < .05$) and marginally significant ($P < .10$) effect on mandibular third-molar impaction according to univariate logistic regression analyses in 134 adolescent orthodontic patients

Variable	*Effect (SE)*	*Significance*	*Odds ratio (CI)*
M2/R	–0.35 (0.09)	$P < .01$	0.71 (0.59-0.84)
M2/Xi	–0.25 (0.07)	$P < .01$	0.78 (0.68-0.89)
M3/OP	0.11 (0.03)	$P < .01$	1.11 (1.05-1.18)
Ar to Pg	–0.06 (0.03)	$P < .10$	0.94 (0.88-1.00)
MP/SN	–0.06 (0.03)	$P < .10$	0.94 (0.88-1.00)
Beta angle	0.10 (0.06)	$P < .10$	1.11 (0.98-1.25)
Gonial angle	–0.05 (0.03)	$P < .10$	0.95 (0.99-1.00)

VI). The parameters Ar to Pg, MP/SN angle, beta angle, and gonial angle were only marginally ($P < .10$) associated with impaction (Table VI).

The stepwise forward multiple logistic regression analyses documented that every millimeter of increase in M2/Xi reduced the risk of impaction by 23%, and every degree of increase in M3/OP and beta angle increased the risk of impaction by 13% and 36%, respectively (Table III, Fig 2). The odds of mandibular third-molar impaction could be predicted by the following equation: exponent (−6.05 – 0.27 [M2/Xi] + 0.13 [M3/OP] + 0.30 [beta angle]).

DISCUSSION

Our results might support previous findings that a large third-molar eruption space[21,22] and increased eruption space due to mesial molar movement after premolar extraction[20] can reduce the risk of third-molar impactions. However, individual variation in molar movement is large,[20] probably because of differences in amount of canine retraction concomitant with incisor alignment and differences in biomechanics used for Class II correction. As essential components of the chosen treatment plan, any effects of differential space closure after premolar extraction in amount of molar movement can be determined before treatment. We therefore included molar movement among the pretreatment variables when searching for predictors for third-molar impaction. Similarly, because any effects that closure of premolar extraction sites and amount of molar movement have on retromolar space are expressed at appliance removal, we did not include those parameters when testing for predictors at the end of treatment.

Our univariate analyses confirm previous findings that premolar extraction reduces the risk of third-molar impaction[20] (Table IV). The mechanism might be the potential for increase in eruption space through mesial molar movement during extraction-site closure. However, neither extraction nor mesial molar movement was included in the final pretreatment prediction model. The unusual finding that sex was the most predictive parameter in the model (Table II), with a sixfold increased risk of impaction in female patients, suggests colinearity between sex and premolar extraction as well as mesial molar movement in our sample. This was confirmed in our post-hoc analyses, showing more mesial molar movement and higher frequencies of extractions in the female subjects with subsequent eruption of the third molars (Table V). This might suggest that male extraction patients in general have greater arch length deficiencies and greater needs for canine retraction during treatment, thereby minimizing the effect on increasing the eruption space during extraction-site closure. However, we cannot rule out that this finding was specific to our sample because female patients were overrepresented among the excluded patients, implying the possibility of a similar effect of extraction on mesial molar movement and on eruption space in both sexes in the general orthodontic population.

Our findings suggest that eruption space is a better predictor for third-molar eruption when measured to Ricketts' Xi point rather than to the anterior border of R at T1 and T2 (Tables II and III). One reason for the low predictive value of M2/R could be the relatively large method error for this dimension (1.12 mm), probably due to difficulties in locating the anterior border of the R on the lateral cephalograms, especially with double contours due to right/left differences in projection (Fig 3).

We believe that vertical condylar growth associated with forward mandibular growth rotation, expressed by a large beta angle[4] (Tables III and VI), a small gonial angle[4,13] (Tables II, IV, and VI), and a small MP/SN angle (Tables IV and VI), is associated with increased risk of mandibular third-molar impaction. Among these 3 variables, only gonial angle was included in the final pretreatment prediction model, affecting the odds of impaction by 17% (Table II), whereas beta angle was included in the final postreatment prediction model, affecting the odds of impaction by 36% (Table III). These findings confirm an association between forward mandibular growth rotation and limited resorption at the anterior aspect of the R, eventually leading to reduced third-molar eruption space and subsequent impaction.[4]

Variables that were used to assess dental-base relationship (Angle class), skeletal-base relationship (ANB angle), mandibular prognathism (SNB angle), and mandibular corpus length (B/R and B/Xi) did not show predictive value for mandibular third-molar im-

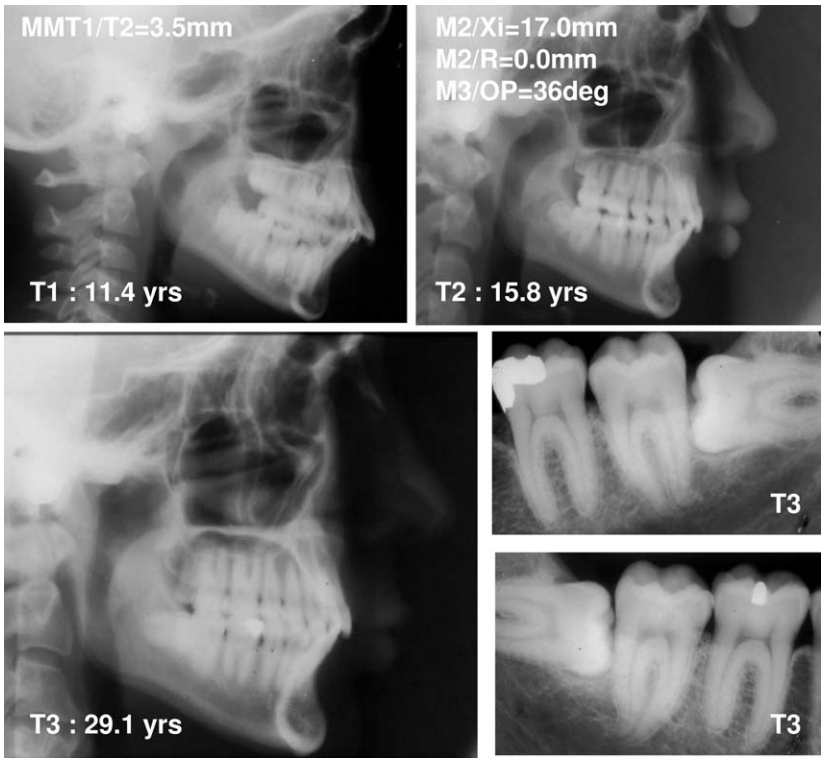

Fig 2. Nonextraction patient with horizontal impaction of both mandibular third molars. Eruption space could not be measured at T1 because of incomplete eruption of M2. Note small eruption space and unfavorable mesial angulation of mandibular third molar relative to occlusal plane at T2.

Fig 3. Patient with erupted mandibular right third molar despite nonextraction treatment, slight distal molar movement from T1 to T2, and small eruption space at T1 and T2.

Fig 4. Patient with distal impaction of both mandibular third molars despite extraction treatment, large eruption space at T2, favorable third-molar angulation at T2, and 3.2 mm mesial molar movement from T1 to T2.

paction. Although in keeping with a previous study,[13] we found that a deficiency in total mandibular length (Ar to Pg) was marginally associated with an increased risk of impaction at T2 (Table VI); this parameter was not included in the final prediction models. One explanation could be an association between mandibular size and third-molar eruption space, with the latter being the most important predictor.

Although M3/OP was not included in the final pretreatment prediction model (Table II), our findings support previous studies, suggesting that mesial angulation of the third-molar bud is a risk factor for subsequent impaction (Tables III, IV, and V).[8,13] However, our results contrast with previous findings that WM3 and a large M2/M3 space are associated with increased risk of impaction.[8,13]

A potential weakness of our study might be that we could not adjust for magnification errors of the linear measurements because the object-to-film distances, mainly due to differences in width between the ear canals, were unknown. However, given the standardized focus-to-object distance of 5 feet, mathematical calculations suggest that a difference in width of 10 cm between the ear rods will increase the magnification by only about 3%. The error is likely to be randomly distributed, and the resulting increase in variation of the

linear measurements will contribute to an increase in the confidence of our positive findings.

The 134 patients in our sample represented every case from a large patient pool that allowed accurate diagnosis of impaction vs eruption of the mandibular third molars, and they were all of sufficient age at follow-up to rule out the likelihood of subsequent eruption of the teeth diagnosed as impacted. In addition, statistical tests ensured that the subjects were similar to those who were excluded because of insufficient records with the exception of a slight underrepresentation of female patients The patients in the large background pool were originally selected at random. Our sample might therefore to a large extent represent the general population of adolescent extraction and nonextraction patients.

Only 6 of the 134 patients whose records allowed bilateral evaluation were diagnosed with impaction on 1 side and eruption on the other Because of the small size of this subgroup, and also because unilateral impaction can be considered of clinical consequence, these patients were categorized as having impactions in our statistical analyses. Because 27 patients could be diagnosed on only 1 side, our sample did not allow inferences about the frequency of unilateral impaction.

The clinical implications of our findings might favor premolar extraction treatment in borderline extraction patients only if the chances for third-molar eruption can be predicted as high. Extraction of premolars in borderline patients with insufficient retromolar space, forward mandibular growth rotation, and mesially angulated mandibular third molars should be avoided because it can eventually result in the loss of 4 mandibular teeth. Also, extraction only in the mandibular arch to camouflage a Class III malocclusion might not be recommended for patients with high chances of third-molar impaction, because failure of the mandibular third molars to erupt could result in the loss of 4 mandibular teeth, leaving the maxillary second and third molars without antagonists. If feasible, a nonextraction alternative with referral for third-molar enucleation might be a better option. Although our findings do not allow conclusions about the minimum and sufficient retromolar space needed for predictable third-molar eruption (Figs 3 and 4), our previous study suggested that the chance of eruption is minimal if the eruption space is less than 19 mm (measured from M2/Xi) and less than 3.5 mm (measured from M2/R) at appliance removal.[20]

CONCLUSIONS

Our findings suggest that increased retromolar space and mesial molar movement during active treatment reduce the risk of mandibular third-molar impaction in adolescent orthodontic patients, whereas increased mesial angulation of the third-molar buds and signs of pronounced forward mandibular growth rotation increase the risk of impaction. Eruption space and mandibular growth rotation were the most predictive parameters both before and after treatment. In addition, mesial angulation of the third molar relative to the occlusal plane was among the most predictive parameters after treatment. Our results might be of clinical significance in borderline extraction patients; the extraction alternative might be preferable only with a high chance of third-molar eruption.

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