Original Article

Prediction of Maxillary Third Molar Impaction in Adolescent Orthodontic Patients

Jon Årtun[a]; Faraj Behbehani[b]; Lukman Thalib[c]

Abstract: The purpose of this study was to identify risk factors for maxillary third molar impaction in adolescent orthodontic patients. Radiographs made before treatment (T1) and after treatment (T2) and at a minimum of 10 years postretention (T3) of 132 patients that allowed accurate diagnosis of impaction vs eruption of one or both maxillary third molars were evaluated. Although univariate logistic regression revealed that the decision to extract premolars reduced the risk of impaction by 76% ($P < .01$), this parameter was not included in the final prediction model at T1. Multiple logistic regression analyses revealed that third molar impaction could be predicted at T1 according to the size of the retromolar space and the amount of mesial molar movement that will occur during active appliance therapy, reducing the risk of impaction by 22% and 34% for every millimeter increase in distance, respectively ($P < .01$). At T2, multiple logistic regression revealed that the odds of impaction were more than 60 times higher ($P < .01$) if the third molar was angulated mesially as compared with less than 30° distally relative to the occlusal plane and almost five times ($P < .05$) higher if the third molar was angulated more than 30° distally as compared with less than 30° distally. Similar analyses at T2 showed 29% reduced risk of impaction for every millimeter increase in retromolar space and 18% reduced risk for every degree increase in angle MP/SN ($P < .01$). (*Angle Orthod* 2005;75:904–911.)

Key Words: Third molar impaction; Prediction; Orthodontic patients

INTRODUCTION

One explanation for the high impaction rate of the maxillary third molars[1,2] may be insufficient periosteal apposition at the posterior outline of the maxillary tuberosities. This remodeling may vary according to the size and number of the maxillary posterior teeth and may be enhanced in subjects with pronounced forward translation of the maxillary complex with sutural growth.[3,4] The size of the retromolar space may also be affected by the direction of eruption of the posterior teeth during the functional phase. Implant studies have documented a more anteriorly directed eruption of the maxillary molars in cases with anterior growth rotation of the maxilla,[5] thereby contributing to an increase in the retromolar space. However, few studies have analyzed whether the size and position of the adolescent maxilla are predictive of third molar impaction.

Typically, the maxillary third molars assume various degrees of distal angulation during the initial stages of development, with mesial inclination being rarely observed.[6,7] During the period of root development an uprighting is therefore necessary for eruption to occur. That about 25% of the impactions are classified as distal[8] suggests that unsatisfactory uprighting is a common cause of impaction. However, overuprighting may also occur because about 12% of the impactions are classified as mesial.[8]

Advocates of maxillary second molar extraction for correction of certain types of malocclusion suggest that third molars positioned vertically or inclined up to 30° distally relative to the second molars before treatment have an excellent prognosis for eruption.[9,10] The maxillary third molars have been found to upright in

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the average adolescent orthodontic patient during active treatment after extraction of second molars[6,7,11] and first premolars[11,12] as well as during nonextraction therapy.[12] The individual variation in uprighting appears to be large,[6,7,12] suggesting that distal tipping may not be uncommon. However, the frequency of distal tipping as well as the predictive value of any treatment change in third molar angulation and actual angulation at the time of appliance removal are unknown.

Maxillary third molar impaction was infrequent in primitive populations.[13] This has been attributed to mesial drift of the posterior teeth due to excessive interproximal attrition, thereby increasing the retromolar space.[13] Similarly, maxillary third molar impaction appears to be very rare after second molar extraction.[9,10,14] It may therefore not be unexpected that a recent, comprehensive study demonstrated a clinically significant reduction in the rate of maxillary third molar impaction in orthodontic patients treated with premolar extraction compared with in patients treated nonextraction.[15] The posttreatment distance from the maxillary first molar to the pterygoid vertical (PTV) and the amount of mesial movement of the maxillary molars during active treatment were larger in the patients with eruption than in those with impaction, as well as in the patients treated with extraction than in those treated nonextraction.[15] The predictive values of extraction therapy and molar movement for maxillary third molar impaction may therefore merit a more detailed analysis.

There are suggestions that the distance from the distal contact point of the maxillary third molar to PTV at the time of appliance removal is a valid predictor for whether the third molars will erupt[16–18] and that at least 18 mm is required for this.[16] However, a recent, comprehensive study found that 20% of adolescent orthodontic patients with eruption space equal to or larger than 18 mm at the time of appliance removal experienced impaction.[15] In addition, the largest space associated with impaction was 24 mm, and the smallest space associated with eruption was 13 mm. The variation in eruption space associated with impaction and eruption, therefore, may be larger than that suggested previously.

The purpose of this study was to try and establish a predictive model for maxillary third molar impaction before and after orthodontic treatment of adolescent orthodontic patients. The results of the study may be of considerable clinical significance. In situations with several mechanical options, the alternative with the least risk of impaction may be favored. However, the nonextraction alternative may be favored in borderline extraction cases unless the chance of impaction after premolar extraction can be predicted as minimal. Also, appropriate follow-up routines and optimal timing for removal may be established in patients judged to be at increased risk of impaction at the time of appliance removal.

MATERIALS AND METHODS

Orthodontic records made before (T1) and after (T2) treatment and at follow-up including at lest 10 years postretention (T3) of all adolescent patients without dentofacial deformities treated nonextraction (N = 242) or with extraction of four premolars (N = 315) by faculty members or graduate students in the Department of Orthodontics at the University of Washington were examined. A total of 389 patients had radiographic evidence of one or more third molars at T1 or T2. Patients who had removal of both maxillary third molars before evidence of apical root closure or before evidence of eruption on any follow-up models or radiographs or who did not allow radiographic identification of the apices of any remaining maxillary third molars were eliminated.

The final sample consisted of 132 patients (mean ages: T1—12.25 years [SD 1.65], T2—15.19 years [SD 1.87], and T3—30.18 years [SD 4.57]) of which 107 patients allowed bilateral and 25 allowed unilateral scoring of third molar impaction vs eruption. Nonextraction treatment was performed in 31% of the patients, whereas 64% were treated with extraction of maxillary first premolars and 5% with extraction of maxillary second premolars. Angle Class I, II, and III malocclusions were present in 42%, 53%, and 5% of the sample, respectively. Independent *t*-tests and chi-square tests revealed no significant difference in age or in distribution of Angle Class between the selected and excluded patients ($P > .05$). However, women constituted 56% and 67% of the selected and excluded patients, and extraction was performed in 66% and 56% of the selected and excluded patients, respectively ($P < .05$, chi-square test).

Impaction and eruption

Third molar impaction was defined as incomplete eruption at T3 or with radiographic evidence of apical closure. Third molar eruption was defined as presence in full occlusion at T2, at any follow-up, or at T3.

Morphologic parameters

Movement of the maxillary first molars (MM) from T1 to T2 was measured to the nearest 0.1 mm along the averaged occlusal plane on cephalometric images at T1 and T2 superimposed according to Doppel et al.[19] Eruption space was measured as the distance from PTV to the distal surface of the upper first molar crown

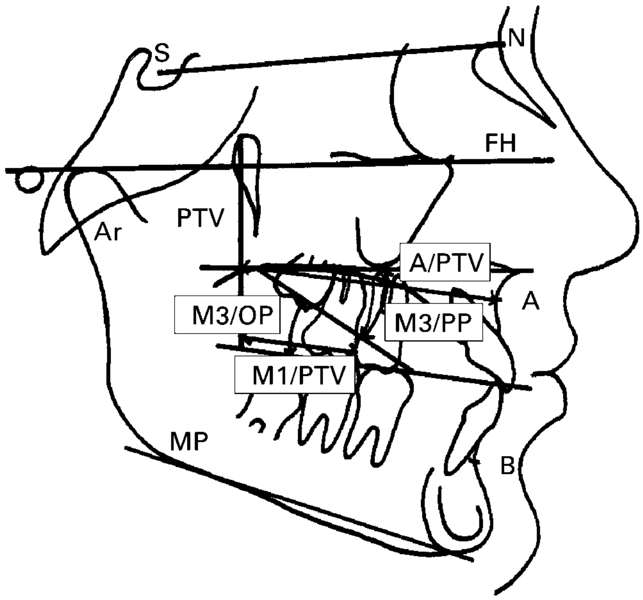

FIGURE 1. Line drawing illustrating definitions of morphologic parameters.

(M1/PTV) along the occlusal plane,[16] third molar angulation as the angle between the occlusal surface, and the occlusal (M3/OP) and palatal (M3/PP) planes (positive reading denoting distal angulation), the size of the maxillary third molar crown (WM3) as the mesiodistal width, and maxillary length from point A to PTV along OP as well as to articulare (A/Ar), all to the nearest 0.5 mm or degree (Figure 1).

Error of the method

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

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

where D is the difference between duplicated measurements and N is the number of double measurements.[20] The errors ranged from 0.12 mm (WM3) to 0.76 mm (M1/PTV).

Statistical analyses

Impaction was scored as present if one or both maxillary third molars were diagnosed as impacted. Change in third molar angulation from T1 to T2 was calculated by subtracting angle M3/PP at T2 from angle M3/PP at T1. Logistic regression analyses were used to identify predictors for impaction. Initially, univariate logistic regression was used to test for any associations between individual variables estimated at T1 and T2 and impaction (Table 1). Following that routine, 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, the variable with the lowest P value was included. Previously entered variables were excluded if their effects were no longer significant ($P > .05$) on inclusion of a new variable. The final model was determined when no remaining variables had a significant effect ($P > .05$).

RESULTS

Variables at T1

The univariate logistic regression showed that the decision to extract premolars reduced the risk of im-

TABLE 1. Variables Used in the Logistic Regression Analyses Before (T1) and After (T2) Treatment of 132 Adolescent Orthodontic Patients Treated With and Without Extraction of Maxillary Premolars to Test for Any Associations With Maxillary Third Molar Impaction

Independent Variables	Time	Unit
Age	T1, T2	Years
Angle Class	T1, T2	I, II, III
Sex	T1, T2	Male/female
Premolar extraction (ex)	T1	Yes/no
Distance max 6 to PTV (M1/PTV)	T1, T2	Millimeters
Movement max 6 (MM) T1/T2	T1	Millimeters
Angulation max 8 to OP (M3/OP)	T1, T2	Degrees
Angulation max 8 to OP (M3/OP)	T2	<0 degree/0–30 degrees/>30 degrees
Change in angulation max 8 (M3/PP T1/T2)	T2	Degrees
Change in angulation max 8 (M3/PP T1/T2)	T2	<0 degree/>0 degree
Distance point A to PTV (A/PTV)	T1, T2	Millimeters
Distance Point A to Articulare (A/Ar)	T1, T2	Millimeters
Width max 8 (WM3)	T1, T2	Millimeters
Angle SNA	T1, T2	Degrees
Angle ANB	T1, T2	Degrees
Angle MP/SN	T1, T2	Degrees

TABLE 2. Pretreatment Variables With Significant ($P < 0.05$) and Marginally Significant ($P < 0.10$) Effect on Maxillary Third Molar Impaction According to Univariate Logistic Regression Analyses in 132 Adolescent Orthodontic Patients

Variable	Effect (SE)	Sign	Odds Ratio (Confidence Interval)
Extraction	−1.42 (0.41)	$P < .01$	0.24 (0.11–0.54)
M1/PTV	−0.14 (0.06)	$P < .05$	0.87 (0.77–0.98)
MM T1/T2	−0.32 (0.10)	$P < .01$	0.73 (0.60–0.88)
WM3	0.36 (0.21)	$P < .10$	1.44 (0.95–2.17)

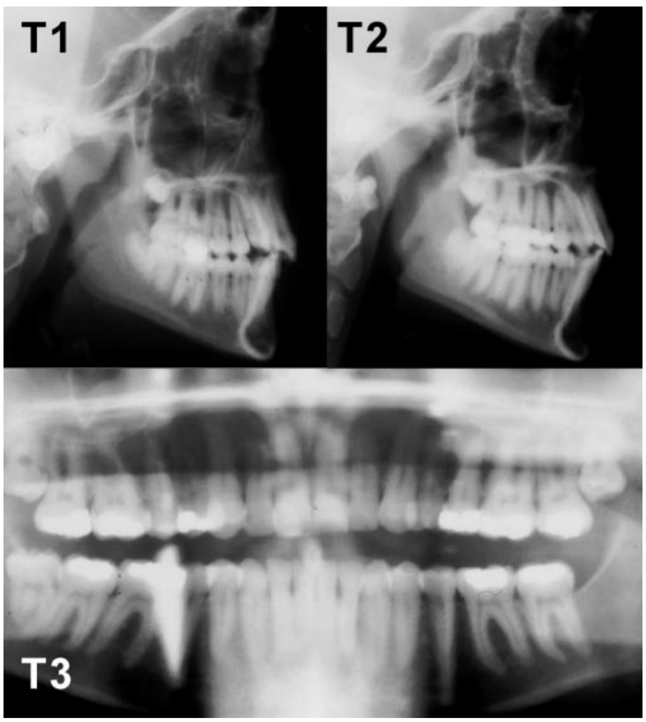

FIGURE 2. Nonextraction patient with impaction of both maxillary third molars. T1: Age = 12.7 years, M1/PTV = 15.0 mm, M3/OP = 36.0°, MM T1/T2 = −0.6 mm; T2: Age = 16.2 years, M1/PTV = 15.0 mm, M3/OP = 39.0°, M3/PP/T1-M3/PP/T2 = 4.0°, SN/MP = 35.0°; T3: Age = 27.2 years. No remaining variables had a significant effect ($P > .05$).

paction by 76% (Table 2). Similarly, every millimeter increase in distance M1/PTV as well as mesial molar movement from T1 to T2 reduced the risk by 13% and 27%, respectively. An increase in WM3 was only marginally associated with an increased risk of impaction (Figures 2 through 4; Table 2). The stepwise forward multiple logistic regression analyses documented that only M1/PTV and MM T1/T2 were included in the final prediction model, reducing the risk of impaction by 22% and 34%, respectively, with every millimeter of increase in distance (Figures 2 through 4; Table 3). The odds of maxillary third molar impaction could be predicted according to the following formula:

$$\exp\,[3.91 - 0.26(\text{M1/PTV}) - 0.42(\text{MM T1/T2})].$$

Variables at T2

The univariate logistic regression showed that every millimeter increase in M1/PTV reduced the risk of impaction by 19% and that an increase in angle M3/OP of 1° increased the risk by 3%.

The odds of impaction were more than 30 times higher if angle M3/OP was negative as compared with within the range from 0° and 30° and more than five times higher if angle M3/OP was larger than 30°. Similarly, the odds of impaction were almost four times higher if the angle M3/PP increased from T1 to T2 as opposed to if it reduced (Table 4).

An increase in WM3 and a reduction in angle MP/SN were only marginally associated with impaction (Figures 2 through 4; Table 4). A negative as well as a larger than 30° angle M3/OP were included in the final prediction model as risk factors, whereas an increase in distance M1/PTV and in angle MP/SNL were included as preventive factors (Figures 2 through 4; Table 5). The odds of maxillary third molar impaction could be predicted according to the following formula:

$$\exp\,[10.48 + 4.21(\text{M3/OP} < 0) + 1.59(\text{M3/OP} > 30) - 0.34(\text{M1/PTV}) - 0.20(\text{MP/SN})].$$

DISCUSSION

Our findings support inferences from a recent comprehensive study[15] that orthodontic treatment with extraction of maxillary premolars significantly reduces the probability of third molar impaction. Our results also suggest that mesial movement of the maxillary molars during active treatment prevents third molar impaction. That extraction was not included as a variable in the pretreatment prediction model (Table 3) suggests a colinearity between extraction and molar movement, with the amount of molar movement being the most important. This supports our previous suggestion that the mechanism for the reduced frequency of impaction after premolar extraction therapy is the potential for increased eruption space due to mesial movement of the molars during extraction site closure.[15]

The large individual variation in molar movement[15] may be due to differences in the amount of canine retraction concomitant with incisor alignment as well as differences in headgear use for Class II correction. As essential components of the chosen treatment plan, we elected to include molar movement among

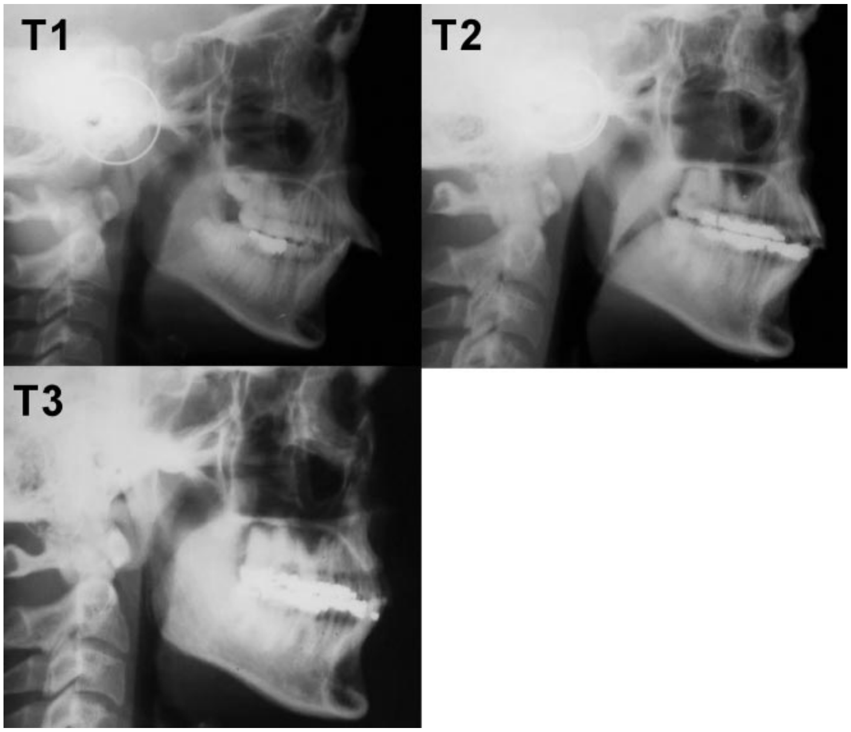

FIGURE 3. Nonextraction patient with eruption of both maxillary third molars. T1: Age = 14.2 years, M1/PTV = 19.0 mm, M3/OP = 26.5°, MM T1/T2 = 1.0 mm; T2: Age = 17.5 years, M1/PTV = 23.0 mm, M3/OP = 5.0°, M3/PP/T1-M3/PP/T2 = 13.0°, SN/MP = 29.0°; T3: Age = 31.0 years.

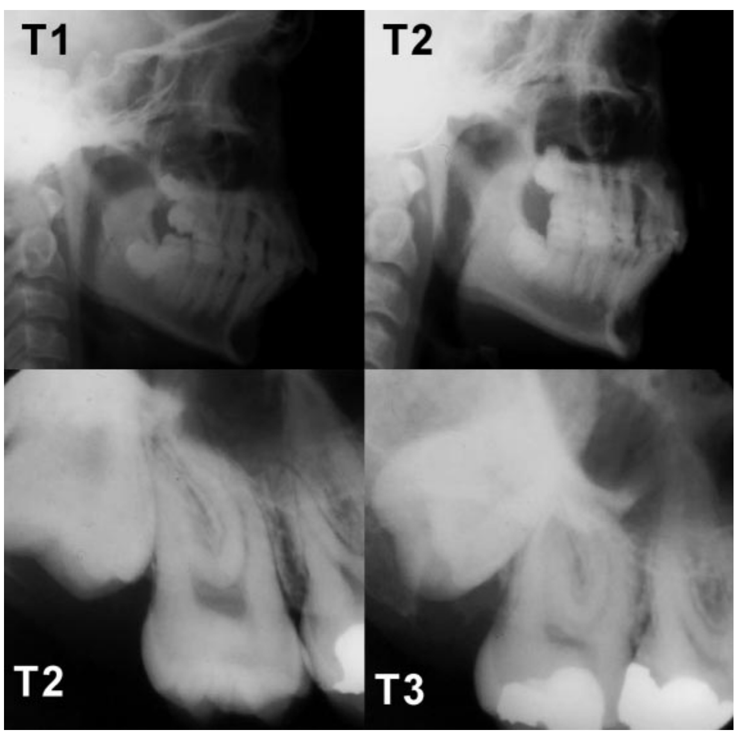

FIGURE 4. Extraction patient with impaction of both maxillary third molars. T1: Age = 13.2 years, M1/PTV = 15.5 mm, M3/OP = 16.0°, MM T1/T2 = 4.5 mm; T2: Age = 15.6 years, M1/PTV = 24.0 mm, M3/OP = 15.0°, M3/PP/T1-M3/PP/T2 = 12.0°, SN/MP = 26.0°; T3: Age = 30.1 years.

TABLE 3. Pretreatment Variables Included in the Final Prediction Model for Maxillary Third Molar Impaction According to Forward Stepwise Multiple Logistic Regression in 132 Adolescent Orthodontic Patients

Variable	Effect (SE)	Sign	Odds Ratio (Confidence Interval)
M1/PTV	−0.26 (0.10)	$P < .01$	0.78 (0.64–0.94)
MM T1/T2	−0.42 (0.14)	$P < .01$	0.66 (0.50–0.87)

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 may have on the retromolar space are expressed at the time of appliance removal, we did not include those parameters when testing for predictors at completion of treatment.

We could support the notion[16–18] that an increase in retromolar space reduces the risk of maxillary third molar impaction. Our multivariate analyses suggest that the odds of impaction can be predicted before treatment according to the size of this space and the amount of mesial molar movement during active treatment (Table 3). To avoid loss of four maxillary teeth, the clinical implication of this finding may be to choose nonextraction treatment in borderline extraction patients presenting with insufficient retromolar space unless any predictable mesial movement of the molars after extraction will imply only a minimal risk of impaction. Our multivariate analyses suggest that the size of the retromolar space is a significant impaction predictor also at the end of treatment. Accordingly, patients judged to have a severely reduced retromolar space at the time of appliance removal may be referred for maxillary third molar enucleation.

Although our findings do not allow conclusions regarding the minimum retromolar space needed for predictable eruption, our previous communication suggests that the chance is minimal if the eruption space is less than 13 mm at the time of appliance removal.[15]

Our univariate analyses suggest a marginal association between the width of the maxillary third molars and subsequent impaction ($P < .10$), with a 44% increase in risk of impaction for every millimeter increase in the width of the third molar crown (Tables 2 and 4), indirectly supporting our establishment of eruption space as a significant risk factor. However, third molar width was not included in the final prediction model at either time period (Tables 3 and 5), suggesting a minimal predictive value of this parameter. Although hardly any previous attempts have been made at testing for direct association between maxillary third molar width and impaction, there are indications that the width of the maxillary second molars are larger in subjects with third molar impaction.[21]

Our findings suggest limited predictive value of pretreatment third molar angulation for subsequent impaction in adolescent patients, questioning the validity of previous clinical recommendations.[9,10] Posttreatment angulation, on the other hand, may be a clinically useful predictor (Tables 4 and 5). Our finding of 3% increase in risk of impaction for every degree increase in distal angulation in the univariate analyses (Table 4) may be an underestimation due to the very high odds of impaction in patients with mesial angulation

TABLE 4. Posttreatment Variables With Significant ($P < 0.05$) and Marginally Significant ($P < 0.10$) Effect on Maxillary Third Molar Impaction According to Univariate Logistic Regression Analyses in 132 Adolescent Orthodontic Patients

Variable	Effect (SE)	Sign	Odds Ratio (Confidence Interval)
M1/PTV	−0.21 (0.07)	$P < .01$	0.81 (0.70–0.93)
M3/OP	0.03 (0.02)	$P < .05$	1.03 (1.00–1.06)
M3/OP negative	3.43 (1.12)	$P < .01$	30.86 (3.44–276.56)
M3/OP > 30 degrees	1.71 (0.48)	$P < .01$	5.54 (2.15–14.28)
M3/PP T1/T2 negative	1.36 (0.51)	$P < .01$	3.91 (1.44–10.64)
WM3	0.36 (0.21)	$P < .10$	1.44 (0.95–2.17)
MP/SN	−0.08 (0.04)	$P < .10$	0.92 (0.85–1.00)

TABLE 5. Posttreatment Variables Included in the Final Prediction Model for Maxillary Third Molar Impaction According to Forward Stepwise Multiple Logistic Regression in 132 Adolescent Orthodontic Patients

Variable	Effect (SE)	Sign	Odds Ratio (Confidence Interval)
M3/OP negative	4.21 (1.42)	$P < .01$	67.61 (4.21–1086.44)
M3/OP > 30 degrees	1.59 (0.69)	$P < .05$	4.92 (1.29–18.86)
M1/PTV	−0.34 (0.13)	$P < .01$	0.71 (0.55–0.92)
MP/SN	−0.20 (0.07)	$P < .01$	0.82 (0.72–0.95)

(Table 4). This may in part explain our finding of high odds of impaction also in patients with more than 30° distal angulation after categorization of the patients in three groups according to direction and severity of the angulation (Table 4). Our univariate analyses also suggest that the odds of impaction are almost four times higher in patients demonstrating distal tipping of the third molars during active appliance therapy (Table 4). However, this parameter was not included in the final prediction model, probably due to colinearity between distal tipping during treatment and more than 30° of distal angulation at the time of appliance removal.

Contrary to what may be expected,[3–5] our results do not suggest any predictive value of parameters related to maxillary size and position. The suggested preventive effect of an increase in the angle MP/SN may be due to vertical maxillary excess as a possible etiologic factor for posterior growth rotation of the mandible and that such excess is associated with an increase in the retromolar space.

The 132 patients in our sample represented every case from a large patient pool that allowed accurate diagnosis of impaction vs eruption of the maxillary 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 selected cases were similar to those that were excluded because of insufficient records. Finally, the patients in the large background pool were originally selected at random. Our sample may therefore be representative of the general population of adolescent extraction and nonextraction patients.

Only 3 of the 107 patients who allowed bilateral evaluation were diagnosed with impaction on one side and eruption on the other. Because of the small size of this subgroup and also because unilateral impaction may be considered of clinical consequence, these patients were categorized as having impaction in our statistical analyses. Because 25 patients could be diagnosed only on one side, our sample does not allow inferences regarding the frequency of unilateral impaction.

CONCLUSIONS

Maxillary third molar impaction in adolescent orthodontic patients can be predicted before treatment according to the size of the retromolar space measured as the distance from the first molar to PTV along the occlusal plane and the amount of mesial molar movement that is planned during active appliance therapy, with increasing dimensions reducing the risk of impaction. Third molar angulation, age, sex, or parameters related to maxillary size and position could not be identified as risk factors. At the end of active treatment, the parameters most predictive of impaction are mesial angulation and more than 30° of distal angulation of the third molars relative to the occlusal plane, a reduced retromolar space, and a small angle MP/SN.

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