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LOWER THIRD MOLAR IMPACTION FORECAST BASED ON ANGULATION OF THEIR AXIS ON PANORAMIC X-RAYS

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The aim of the study was to evaluate the diagnostic value (sensitivity and specificity) of lower third molar bud impaction in 121 patients aged 7 to 23 years who presented to an orthodontic clinic with complaints of different malocclusions. All patients underwent multiple panoramic radiographs during orthodontic treatment, specifically: before treatment initiation, after completion of phase 1 therapy, after fixed appliance therapy, and during the retention period.

A retrospective analysis was conducted on a total of 1,085 lower third molar buds across 551 panoramic radiographs obtained from patients with maloclusions before, during, and after orthodontic treatment, as well as during the retention phase.

The study revealed that starting from the age of 14, the inclination angle of lower third molar buds allow prediction of their impaction rate with a sensitivity of 64.8±6.5% and a specificity of 71.4±6.0%. As age increases, higher sensitivity and specificity enable impaction rate prediction even with smaller angles (less than 40°).

The application of these diagnostic methods can enhance the effectiveness of preventive measures for pathological conditions associated with delayed tooth eruption.

Keywords: lower third molars, impaction, eruption dynamics on panoramic radiographs

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Introduction. It is well known that the lower third molars impaction (LTM) is one of the most common pathologies in patients with maloclusions [2,4,18,27]. Studies show that as age increases, the angulation of LTM germs changes, and often, after orthodontic treatment, their pressure on the lower dental arch leads to relapses and crowding in the anterior region of the mandible [1,17,24]. At the same time, a group of authors believes that the eruption of LTM does not affect crowding and does not lead to relapses of maloclusions [13,28].

Classical diagnostics for detecting LTM germs and their angulation was based on radiographic examination—orthopantomography (Panoramic X-ray) [3,8,16]. For a more detailed study of the germ position and their relationships, computed tomography (CT) is subsequently performed [14]. However, due to the high radiation dose associated with CT, repeated dynamic examinations are not feasible. Therefore, orthopantomography remains a relevant diagnostic method, allowing for a comprehensive assessment of this anatomical region over time and tracking changes in the angulation of LTM germs, their subsequent eruption, or impacted position [5,19,21].

The aim of this study was to assess the diagnostic significance (sensitivity and specificity) of retained lower third molar germs in patients presenting to an orthodontic clinic with complaints of malocclusion.

Materials and Methods. Our study included 121 patients with various maloclusions (MO). Among them, 54 were male (44.6%) and 67 were female (55.4%). Pearson's Chi-Square test revealed no significant gender-based differences (p=0.589). In total, 550 orthopantomograms of these 121 patients were analyzed, and the dynamic changes in the angulation of 1,085 LTM were examined in relation to age.

Statistical Processing. The statistical analysis of the results was carried out using variation methods (Mann-Whitney U-test), dispersion analysis (F-Fisher and FS-Fisher-Snedecor), and ROC analysis (calculation of cut off points, sensitivity, and specificity of the test) in the IBM SPSS Statistics 26 software package. The null hypothesis was rejected at $p < 0.050$ [20].

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Results. For the analysis, two data groups were organized. The first group included the results of orthopantomograms of teeth 38 or 48 that had fully erupted over time (n = 626), while the second group included orthopantomograms of retained (unerupted) or extracted teeth during observation (n = 459).

In the analysis of orthopantomograms of 7-year-old patients, the average angulation of erupted teeth in 10 cases was 59.2±3.6°, while in 3 cases where the teeth were later retained, the average angulation was 49.2±0.9° (p = 0.318).

At the ages of 8 and 9, the angulation of third molars that later failed to erupt was higher (61.4±7.4° and 61.4±8.9°) compared to those that were retained (63.7±8.4° and 55.3±3.6°), respectively. However, at this stage, it is still premature to decide on the extraction of third molars (p = 0.631 and 0.136).

At the age of 10, the angulations of both erupted and unerupted third molars were nearly identical. As seen in the table, in this age subgroup, teeth erupted in 17 cases, while in 23 cases they remained retained, despite the fact that the germ positions were nearly the same - 59.4±2.2° for erupted teeth and 60.6±1.6° for retained teeth (p = 0.827).

This trend was observed up to the age of 13, after which the average angulation values in the eruption group and the retention group began to statistically differ.

An important statistical indicator representing the probability of a correct prediction is the ROC analysis (Receiver Operating Characteristic), which can assess prediction accuracy by constructing a graph and calculating the area under the ROC curve. Cutoff points were determined based on the coordinates of the ROC table, and sensitivity and specificity for predicting retention in the subsequent periods of the study were calculated based on these points.

According to the ROC analysis, at 10

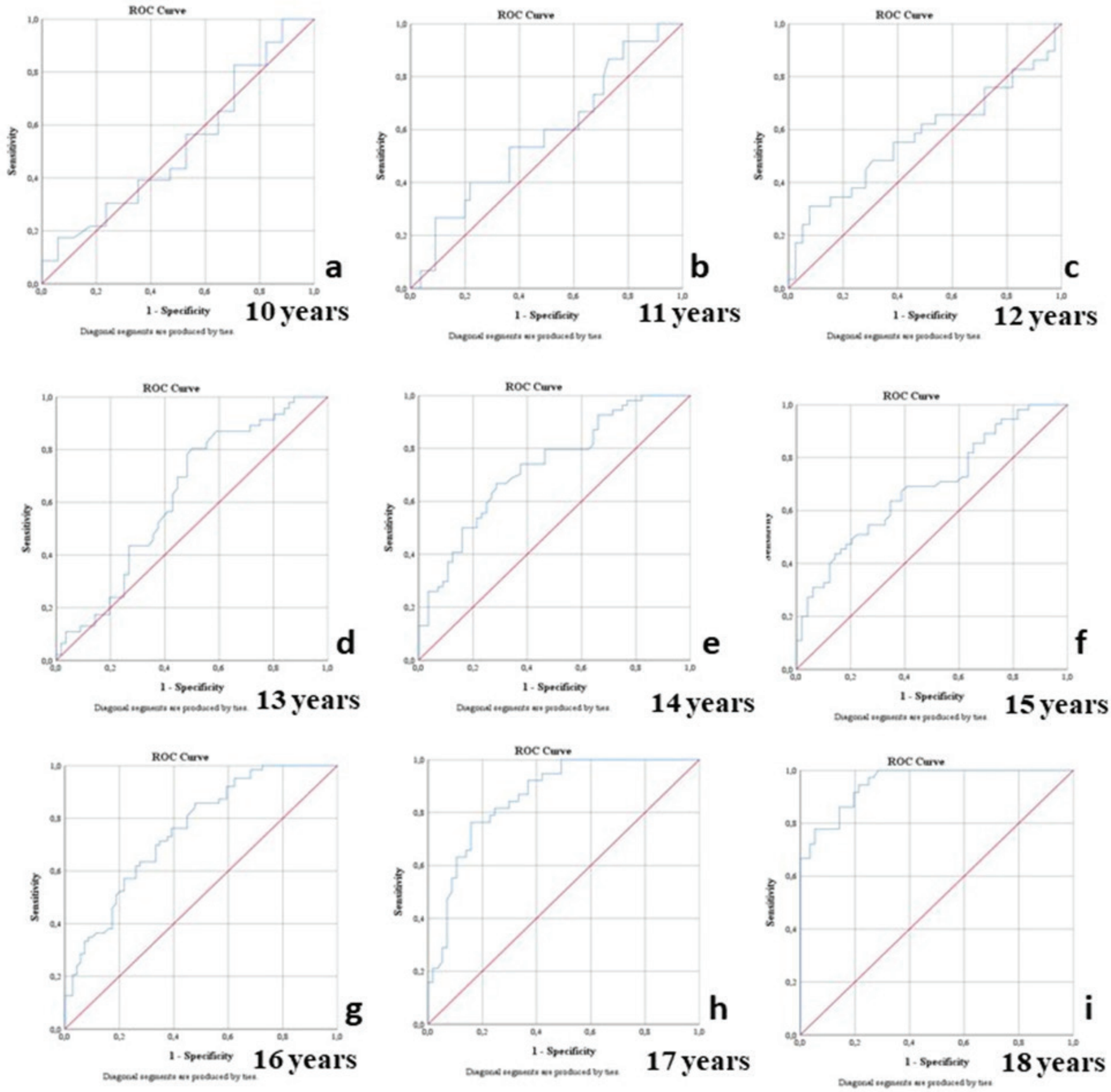

Fig. 1. Results of ROC analysis in different age periods

years old, the informativeness of the angulation values was unreliable (p=0.827), at 11 years old (p=0.376), and at 12 years old (p=0.313) - i.e., it was impossible to predict retention in these age groups (Fig. 1a, b, c). Starting from 11 years old, signs of impaction appeared, but no statistically significant results were found. For instance, at 11 years old, 15 third molar germs were impacted, with an angulation of 57.3±2.8°, while 55 erupted teeth had an angulation of 54.0±1.6°.

At the age of 12, the cutoff angle was 62.75°, meaning that as this angle increases, the probability of tooth retention also increases. At this age, there are good specificity indicators, but they are not sensitive in relation to retention (Table 1).

Table 1

Indicators of the Angulation of L3M Germs in Different Age Periods

Age (y.o.)	Area Under the Curve				
	Area	Standart error deviation	Asymptotic significance (p)	95% Confidence Interval	
				Lower bound	Upper bound
10	0.520	0.094	0.827	0.336	0.705
11	0.576	0.084	0.367	0.412	0.740
12	0.572	0.074	0.315	0.427	0.717
13	0.626	0.055	0.029*	0.517	0.734
14	0.730	0.047	<0.001*	0.637	0.823
15	0.689	0.051	0.001*	0.588	0.789
16	0.753	0.041	<0.001*	0.672	0.834
17	0.861	0.037	<0.001*	0.789	0.934
18	0.952	0.019	<0.001*	0.914	0.989
19	0.973	0.017	<0.001*	0.940	1.000
20	0.971	0.022	<0.001*	0.928	1.000
21	1.000	0.000	<0.001*	1.000	1.000
22	1.000	0.000	<0.001*	1.000	1.000
23	1.000	0.000	<0.001*	1.000	1.000

We studied the angulation results of 28 impacted and 38 unerupted teeth and found that in 28 patients with impacted third molars, the angulation was >62.8°, meaning the sensitivity of this indicator was 31.0±8.6%. Of the 38 unerupted teeth, 36 had an angulation less than 62.8°, meaning the specificity of this indicator in predicting impaction was quite high (92.3±4.3%).

Significant correlations between erupted and impacted third molars in terms of angulation were found starting from the age of 13 (Table 2).

The angulation was found to be a relatively specific and sensitive indicator for further prediction of impaction (p = 0.029) at the age of 13 (Fig. 1d). In this age group, the angulation of 46 impacted and 56 unerupted teeth was studied, revealing that for further impaction of third molars, the angulation was >47.1°, meaning the sensitivity of this indicator was 78.3±6.1%. Of the 56 unerupted teeth, 29 had an angulation less than 47.1°, meaning the specificity of this indicator in predicting impaction was 51.8±6.7%. The area under the ROC curve, which is an integrated parameter of sensitivity and specificity, was 0.626±0.055 (95% CI: 0.517-0.734), p = 0.029, and can be considered statistically significant. Therefore, starting from 13 years old, the impaction of third molars can be predicted.

At the age of 14, according to the ROC analysis, the area under the ROC curve was 0.730 ± 0.047 (95% CI: 0.637-0.823), p < 0.001. These data were obtained from the study of angulations of 54 retained and 56 unerupted teeth, and it was found that when a tooth was subsequently retained, its angulation was greater than 51.8°, meaning the sensitivity of this indicator was 64.8±6.5%. When studying the angulations of the 56 erupted teeth, 40 of them had an angulation less than 51.8°, meaning the specificity of this indicator in prediction was 71.4±6.0% (Fig. 1e).

A similar trend is observed with increasing age. At the age of 15, when studying 55 retained and 49 erupted teeth, it was found that the cutoff point was 54.7°, meaning that if the angle was greater than this value, the tooth was retained, and if it was smaller, the tooth erupted. This is confirmed by the area

Table 2

Informative Value of Indicators by Age Group at Cut off Points

Statistical parameters	12 years	13 years	14 years	15 years	16 years	17 years	18 years	19 years	20 years
Cut off Point	≥ 62.8	≥ 47.1	≥ 51.8	≥ 54.7	≥ 42.3	≥ 46.3	≥ 36.9	≥ 37.6	≥ 39.7
Sensitivity Sn%	31.0±8.6	78.3±6.1	64.8±6.5	43.6±6.7	85.7±4.4	76.3±6.9	94.4±3.8	100.0±0	100.0±0
Specificity Sp%	92.3±4.3	51.8±6.7	71.4±6.0	85.7±5.0	52.2±6.0	84.2±4.8	78.6±5.5	92.0±3.8	88.5±6.3
GDV %	66.2±5.7	63.7±4.8	68.2±4.4	63.5±4.7	68.2±4.1	81.1±4.0	84.8±3.7	95.1±2.4	93.0±3.9
pPV%	75.0±12.5	57.1±6.2	68.6±6.5	77.4±7.5	62.1±5.2	76.3±6.9	73.9±6.5	88.6±5.4	85.0±8.0
nPV%	64.3±6.4	74.4±7.0	68.7±6.1	57.5±5.8	80.0±6.0	84.2±4.8	95.7±3.0	100.0±0	100.0±0
LR+	moderate	not suitable	moderate	moderate	not suitable	moderate	moderate	excellent	good
LR-	not suitable	moderate	moderate	not suitable	moderate	moderate	excellent	excellent	excellent

Note: Cut off point; Sn (Sensitivity); Sp (Specificity); ODV (Total Diagnostic Value); pPV (Positive Predictive Value); nPVт- (Negative Predictive Value); LR+ (Positive Likelihood Ratio); LR- (Negative Likelihood Ratio) under the ROC curve, which was 0.689 ± 0.051 (95% CI: 0.588-0.789), p < 0.001. In the case of retention of 24 teeth out of 55, the sensitivity of this indicator was 43.6±6.7%. When erupting 42 teeth out of 49, the specificity was 85.7±5.0% (Fig. 1f).

With increasing age, the area under the ROC curve continuously increases: at 16 years old, it was 0.753±0.041 (p <0.001); at 17 years old, it was 0.861±0.037 (p <0.001); at 18 years old, it was 0.952±0.019 (p <0.001); at 19 years old, it was 0.973±0.017 (p <0.001); at 20 years old, it was 0.971±0.022 (p <0.001); from 21 to 23 years old, it was 1.000±0.000, respectively (p <0.001) (Figs. 1g, h, i).

According to Table 2, starting at 17 years old, cut of point reliably decreased: 46.3° at 17, 36.9° at 18, 37.6° at 19, and 39.7° at 20 (Fig. 2).

At 16 years old, the results of 63 retained and 69 erupted teeth were studied, with the cutoff point being 42.3°. Of the 63 retained teeth, 54 had a sensitivity of 85.7±4.4%. When 36 teeth out of 69 erupted, the sensitivity was 52.2±6.0%.

When studying 38 retained and 57 erupted teeth in patients aged 17, the cutoff point was 46.3°. In these patients, the sensitivity for retention was 76.3±6.9%, and for eruption, it was 84.4±4.8%.

The sensitivity indicator in patients with retained third molars (L3M) increases starting from the age of 18: at 18 years old, it is 94.4±3.8%; at 19 years old and 20 years old, it is 100.0±0.000%. For erupted teeth, this indicator changes as follows: at 18 years old – 78.6±5.5%; at 19 years old – 92.0±3.8%; at 20 years old – 88.5±6.3%.

This demonstrates the high prognostic significance of the angulation of third molars with the patient's age. That is, the older the patient, the easier it is to predict retention and create an accurate orthodontic treatment plan, whether involving the removal of wisdom teeth or not (Table 3).

Discussion. Problems related to the eruption of third molars (ETM) remain a central concern for patients, orthodontists, and maxillofacial surgeons [5,27]. Since the angulation of TM changes during eruption and root formation occurs near the alveolar nerve, this later poses challenges for maxillofacial surgeons during their extraction. The impact of TM on various anomalies, such as anterior crowding, lingual inclination of premolars, caries development on second molars, and potential damage to the inferior alveolar nerve, remains a subject of debate [1,14,17].

Many authors have attempted to predict TM retention based on different

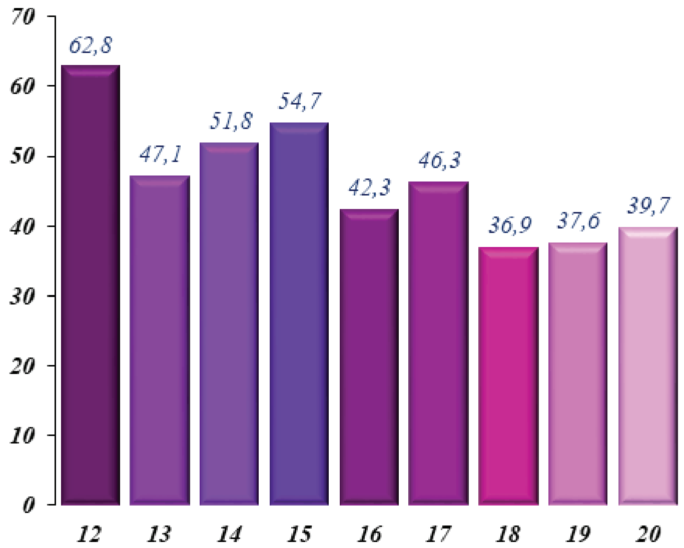

Fig. 2. Cut off Angles for Predicting Retention of Third Molars in Different Age Groups

Table 3

Factor Effectiveness Influence (EIF) of Angulation of Third Molar Germs on the Prediction of Further Eruption by Age Group

Age (y.o.)	Cut off point	Factor EIF (95% ДИ)	P_{FS}
12	>62.8	10.1 (4.7-15.5)	0.008*
13	≥ 47.1	10.5 (6.9-14.0)	0.001*
14	≥ 51.8	15.2 (12.1-18.3)	<0.001*
15	≥ 54.7	11.4 (8.0-14.8)	<0.001*
16	≥ *42.3*	19.0 (16.5-21.4)	<0.001*
17	≥ *46.3*	57.8 (56.0-59.6)	<0.001*
18	≥ *36.9*	103.2 (103.1-103.4)	<0.001*
19	≥ *37.6*	343.6 (331.7-355.5)	<0.001*
20	≥ *39.7*	217.1 (206.0-228.1)	<0.001*

statistical significance by Fisher Snedecor

parameters using orthopantomograms [9,12,19,21,25,26]. For instance, in a study conducted in 1993 involving 56 unerupted molars in 20-year-old patients, angular inclinations, root development, depth within the bone, and the relationship with the mandibular angle and second molar were measured over six years. Using logistic regression, univariate and bivariate analysis, and clustering methods, the authors developed a predictive model based on the type of impaction and designed a device to forecast TM impaction in 20-year-old patients [25,26].

A graphic-metric method (panorametry) has also been proposed, allowing linear and angular measurements of the mandible. This method enables bilateral comparisons and assesses the contribution of skeletal and dental structures. It includes Dental Panorametry (measurement of posterior mandibular teeth), Mandibular Panorametry (mandible evaluation), and Total Panorametry (combined analysis of the maxilla and mandible) [19].

Retromolar space measurement was conducted to determine linear and angular differences between erupted and retained TMs on panoramic radiographs of 140 patients aged 18–30 years. The authors analyzed retromolar space from the center of the ramus (Xi-7) and the anterior edge of the ramus (AER-7), mesiodistal tooth bud width, and inclination angles of TMs. They concluded that TM eruption likelihood increases when retromolar space measured from AER-7 and Xi-7 is 13 mm and 25 mm, respectively, while mesiodistal tooth width plays a minor role [21].

A study of 264 TMs in 132 patients (71 males and 61 females) aged 15–20 years found that more mature teeth at age 15 had a higher eruption probability (odds ratio: 3.89, P < 0.001). The rate of root formation was statistically linked to eruption likelihood (odds ratio: 10.50, P = 0.041) [12].

Early prediction of TM eruption or impaction using nine linear and angular measurements on digital panoramic radiographs revealed significant differences in mean values for retromolar space, α-angle (angle between the long axis of the third molar and the gonial-symphysis plane), and β-angle (angle between the long axis of the mandibular second and third molars) (P < 0.05) [11].

A four-year study measuring TM angulation and impaction degree relative to the adjacent second molar and the occlusal plane in 43 students concluded that post-19-year changes in TM position and inclination remain unpredictable [22].

A study of 240 individuals aged 18 determined that specific Hans relationships and changes in TM bud inclination relative to the mandibular base and the second molar could predict impaction or eruption, impacting anterior mandibular crowding [24].

For improved predictive parameters, some authors recommend using computed tomography and lateral cephalograms to analyze retromolar space, angles, and proportions [6,10,14,23].

A study of 53 orthodontic patients measured and compared the mandibular angle with sagittal distance from the anterior mandibular ramus to the alveolar edge between incisors and mesiodistal second molar width. Correlations between profile and panoramic radiograph measurements led to a formula for TM eruption probability calculation [6].

Significant statistical effects of β-angle and gonion-gnathion (Go-Gn) distance on TM eruption level (P < .001 and P < .015, respectively) were found using lateral cephalograms [10]. TM impaction was significantly higher in Class II patients (62.3%) compared to Class III (31.7%; P < .013).

A clinical, biometric, and radiographic study over two years involving 78 patients concluded that retromolar space increased by 1.2–2.2 mm without extractions, 2–2.7 mm with premolar extractions, and 4.5–6.8 mm with first molar extractions. Thus, premolar extractions had minimal impact on retromolar space, whereas first molar extractions significantly increased space, which is crucial for treatment planning [23].

A survey among oral surgeons and orthodontists concluded that TM impaction cannot be reliably predicted using orthopantomograms alone [5,8,29].

A retrospective longitudinal study of TM eruption using artificial intelligence analyzed 771 patients with two panoramic radiographs: the first at 8–15 years (T1) and the second at 16–23 years. Results showed that eruption occurred if adequate retromolar space was present and the initial angle was <32° [7].

Various AI models, including EfficientNet, EfficientNetV2, MobileNet Large, MobileNet Small, ResNet18, and ShuffleNet, analyzed 6,624 TMs on 3,422 orthopantomograms. EfficientNet achieved the highest classification accuracy of 83.7% [15].

Despite extensive literature, there is still no consensus on whether to preserve or extract TM buds before or after orthodontic treatment to prevent relapse and lower incisor crowding.

Conclusion. Since TM eruption remains unpredictable, the best approach is dynamic monitoring of TM angulation over regular intervals. Our statistical data on cut-off points for TM bud inclination at different ages allow orthodontists to predict further tooth impaction. Future studies comparing cephalometric data with orthopantomograms are recommended to identify more precise early-age predictive criteria.

The authors declare no conflict of interest in the submitted article.

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