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Assessment of the Relation between Maxillary PosteriorTeeth and the Sinus Floor in Different Facial types: Cone Beam Computed Tomography.

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Abstract— The maxillary posterior teeth-sinus link is neglected. Whenplanning the orthodontic intrusion of the posterior teeth, it is vitalto understand the anatomical connection between the maxillarysinus floor (MSF) and the maxillary posterior teeth (MPT), sincea close distance may induce root resorption or impede tooth movement. Treatment planning and MSF-root apices relationship evaluation employ periapical and panoramic radiographs. **Materials and methods** (1) sample size collection,(2) Linear and angular measurement, (3) statistical analysis. Theaim of the present study is to assess the relation betweenmaxillary posterior root apices and the sinus floor in differentfacial types by using 3 dimensional CBCT imaging. **Results**: Hyperdivergent roots were closer to the sinus floor than hypodivergentor norm divergent roots. If hyperdivergent face biotype patient's needsecond molar intrusion to address anterior open bite, this may notwork. **Conclusion**: 36 scans were categorized by Tweed triangle intonorm divergent (12), hypodivergent (12), and hyperdivergent (12).To corroborate the group and FMA angle, reconstructed lateralcephalometry evaluated total anterior face height and FH-SN angle. Root apices scored: score (0): the root of the tooth is away from thecortical border of the sinus, with a zone of cancellous bone in between; score (1): the root is laterally projected, away from the sinus; score (2):the tip of the root is in contact with the sinus; score (3): the root tip isprojecting into the maxillary sinus in each facial type (46).

Keywords: Maxillary sinus, Anteriorextension, Canine apex,Incisor, Cone beam computedtomography

Introduction

The maxillary sinuses are the most extensive paranasal sinuses, which are very small at birth but expand by physiologic pneumatization until completion of skeletal development or around 20 years. The maxillary sinus often extends from the distal aspect of the canine tooth to the posterior wall of the maxilla above the tuberosity. Evaluation of the relationship between the maxillary sinus and the dentition is essential for dental procedures, such as implant or apical surgeries and orthodontic treatments.

The inferior sinus wall is a curved structure formed by the lower third of the medial wall and the Bucco alveolar wall, and the floor is formed by the alveolar process of the maxilla. The adult sinus is variable in its extension. In about half of the population, the sinus floor extends between adjacent teeth or individual roots, creating elevations in the antral surface, commonly referred to as 'hillocks.

Orthodontists consider facial growth pattern and oral function when developing a treatment plan. Less attention is given to the relationship between the maxillary posterior teeth and the maxillary sinus.

When planning the orthodontic intrusion of the posterior teeth, it is important to understand the anatomical relationship between the maxillary sinus floor (MSF) and the maxillary posterior teeth (MPT), because a close distance between the two may cause root resorption or slow tooth movement in the orthodontic intrusion. Periapical and panoramic radiographies are conventional imaging techniques used for treatment planning and evaluating the close relationship of the root apices and the MSF. However, they can only provide two-dimensional (2D) images, causing superposition and magnification of anatomic structures impending proper diagnosis. As a three-dimensional (3D) imaging technique, CBCT has important significances in clinical diagnosis and planning process, contributing to the establishment of effective therapeutic protocols.

The present study aimed to assess the relationship between the maxillary sinus floor and maxillary posterior teeth roots using cone beam computed tomography in different facial biotypes.

Aim of study:

The aim of the present study is to assess the relation between maxillary posterior root apices and the sinus floor in different facial types by using 3 dimensional CBCT imaging.

Material and methods

1. Sample size calculation

The sample size for this study was calculated according to Arkin (1984), using the following equation:

n = $(\mathbf{Z\alpha})* (\mathbf{S})\mathbf{2}\ (\mathbf{d})\mathbf{2}$ n = sample size

S = Standard diversion $\mathbf{Z\alpha}$= 1.96 at significant level 95% d = different between factors

Z	*S*	*D*
1.96	**6.12**	**2**

Total sample size n (2)= 35.971 ≈ 36
Experimental layout

Z	*S*	*D*
1.96	**6.12**	**2**

Total sample size n (2)= 35.971 ≈ 36
Experimental layout

Groups	**Treatments (names)**	**No. of samples**
Group I		12
Group II		12
Group III		12
Total		**36**

The study included 36 CBCT scans (12 scans of each group, neurodivergent, hypodivergent, and hyperdivergent) collected from the database of patients affiliated to (Oral radiology department). The study was approved by the research ethical committee of (Faculty of Dentistry, Suez Canal University).

The scans of the patients were selected visually by a dent maxillofacial radiologists calibrated prior conducting the study. The scans were obtained from I-Cat scanner (Imaging Sciences, Hatfield, PA, USA) under fixed parameters (120 KVP, 37 mA, and 0.25 µm in 26.9 seconds) with amorphous silicon flat panel detector. Field of View (FOV) was adjusted separately for each human skull according to its size and dimension.

• Inclusion criteria of the scans were:

1. Clear CBCT scans with no motion artifacts
2. Aged 15-30 Years Old
3. Craniofacial structure with no anomalies
4. Fully permanent dentation and occlusion

• Exclusion criteria were

1. Previous traumatic injuries
2. Craniofacial abnormalities and tumors
3. History of orthodontic treatment

Each scan was assessed by inserting their DICOM files (Digital imaging and communication in Medicine) into Invivo dental software version 5.2 (Anatomage Inc., San Jose, CA) to assess the relationship between root apices of upper posterior teeth to floor of maxillary sinus according to roots score by Jung and Cho figure.5 (46)

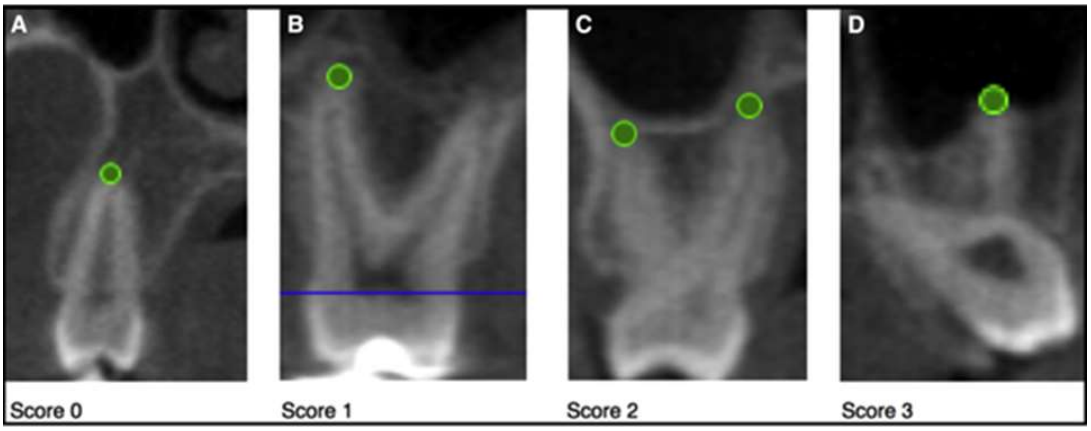

Figure 1: Modified scores from the study of Jung and Cho. for root tip-maxillary sinus relationship (46) .

(A), score 0: the root of the tooth is away from the cortical border of the sinus, with a zone of cancellous bone in between; (B), score 1: the root is laterally projected, away from the corticalborder of the sinus; (C), score 2: the tip of the root is in contact with the cortical border of the sinus; (D), score 3: the tip of the root is projecting into the maxillary sinus (46).

Lateral Cephalometric view was made from 3D volume of each scan using Super ceph module after superimposing right and left sides of the scanned human skull Figure.6 and Figure.7.

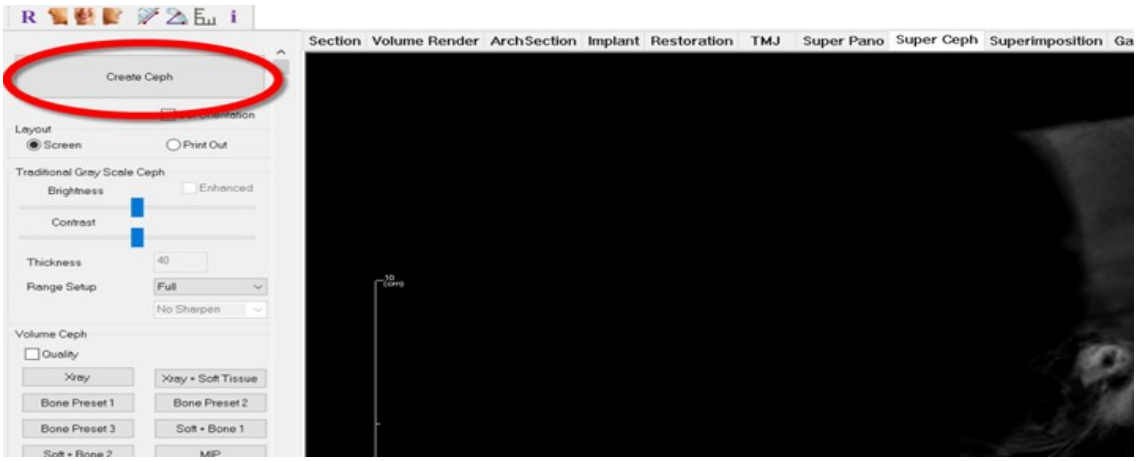

Figure 2: Superceph module of Invivo dental software to Create lateral Cephalometric view.

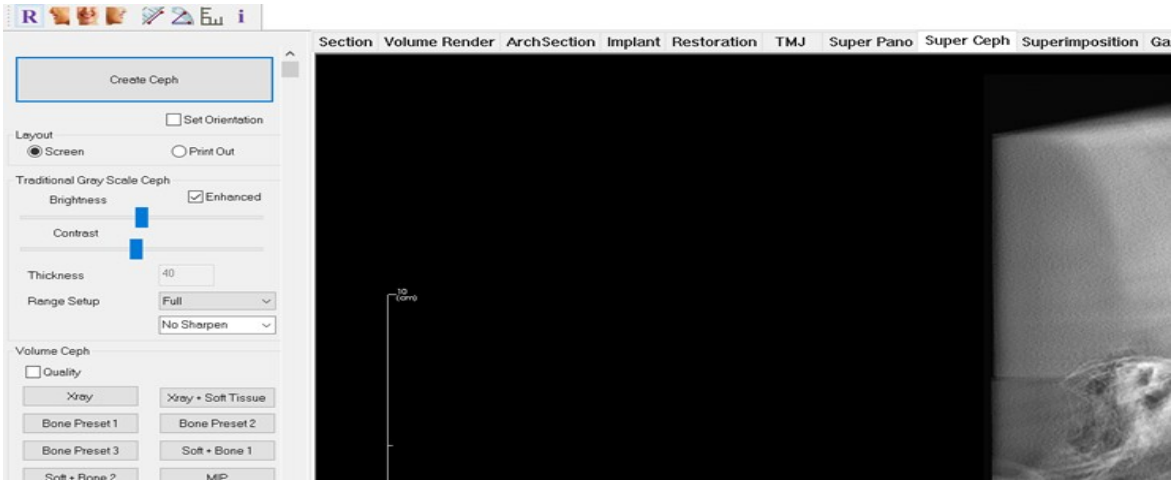

Figure 3: Reconstructed lateral cephalometric view.

Each scan was classified to normodivrgent, hypodivrgent and hyperdivrgent according to different facial biotypes based on the Tweed triangle and the FMA angle, the patients were divided into 3 facial biotype groups (64).

• **Group A:** Norm divergent (FMA, 22º- 28º)

• **Group B:** Hypodivergent (FMA, < 22º)

• **Group C:** Hyperdivergant (FMA > 28º)

The Frankfort mandibular plane angle (FMA) was calculated as the angle formed by the intersection of the Frankfort horizontal plane and the mandibular plane. Normal value was considered to be 25º ± 3º (64).

2. Linear and Angular measurements:

• FMA (Frankfort horizontal mandibular plane angle)

• FH-SN (Frankfort horizontal plane ,Sella - Nasion plane angle)

• Total Anterior facial height (TAFH): (from Nasion (N) to Menton (ME) were made onreconstructed Lateral Ceph.) figure.8 and figure.9

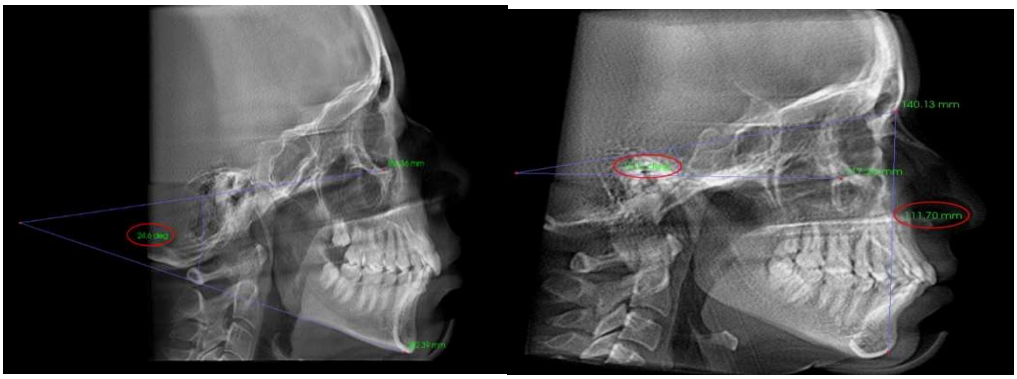

Figure 4: FMA Figure 5: FH-SN and TAFH

From MPR (Multi planar reformatted) screen, the scan was reoriented so that upper posterior teeth would be perpendicular on maxillary sinus floor to standardize the view of measurement on all root apices Figure.10.

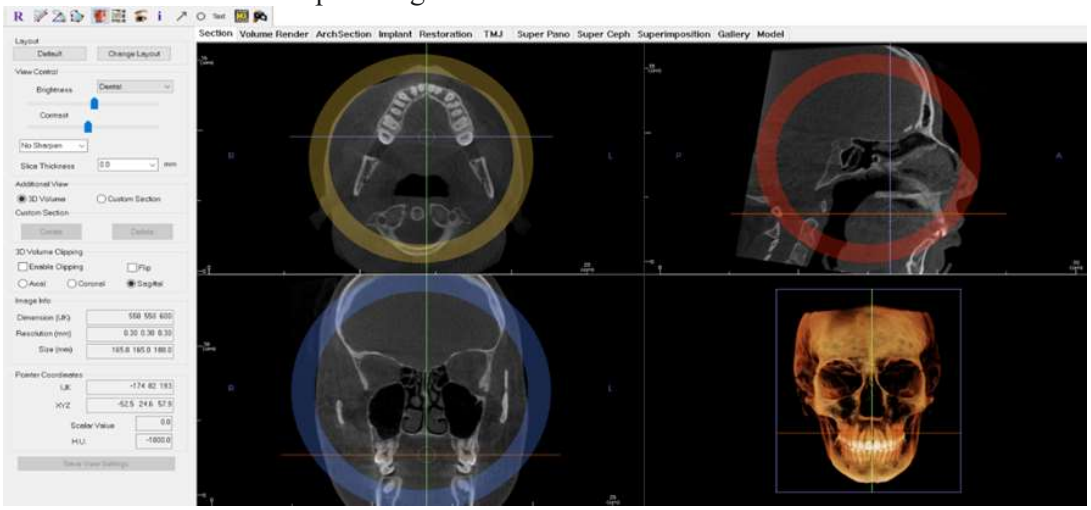

Figure 6: MPR screen to standardize the view of measurement

From Coronal view, roots scores were assessed bilaterally for all root apices starting from upper first premolars anteriorly and proceeding backward till upper second molars posteriorly figure.11, figure.12, and figure.13 (46).

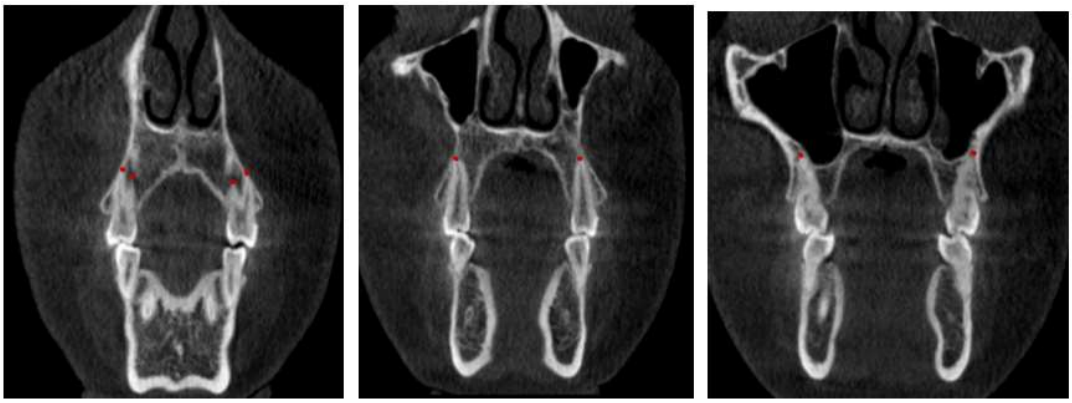

Figure 7: upper 1st premolars (Score: 0) **Figure** 8: Upper 2nd premolars (Score: 0) **Figure** 9:

MB roots of Upper 1st molar (Score: 1) The roots scores obtained from all scans included in the study were tabulated for statistical analysis.

3. Statistical analysis

Data distribution and normalcy tests were used to examine numerical data (Kolmogorov-Smirnov and Shapiro-Wilk tests). Root scores were non-parametric, while age data was parametric. Mean, SD, median, and range data were reported. The three groups were compared using one-way ANOVA for parametric data.

When ANOVA was significant, pair-wise comparisons employed Tukey's post-hoc test. KruskalWalli's test compared three groups with non-parametric data. When Kruskal-Wallis was significant, Dunn was employed for pair-wise comparisons. Facial biotypes were the independent variable and root scores were the dependent variable in a linear regression model that adjusted for age. Frequencies and percentages represented qualitative data. Fisher's exact test compared the three groups. The significance threshold was 0.05. IBM SPSS Statistics for Windows, Version 23.0, analyzed data. IBM, Armonk, NY.

Results

i. Demographic data

From table (1), there was a statistically significant difference between mean age values in the three groups. Pair-wise comparisons between the groups revealed that hyperdivergent group showed the highest mean age with non-statistically significant difference from hypodivergent group but a statistically significantly higher value than normodivergent group which showed the lowest mean age.

All patients in the three groups were males.

Table 1: Descriptive statistics and results of one-way ANOVA test for comparison between mean age values in the three groups

Age (Years)	Normodiverget (n = 12 patients)	Hypodivergent (n = 12 patients)	Hyperdivergent (n = 12 patients)	*P*-value
Mean (SD)	20.5 (3.6) ^{B}	23.3 (3.3) ^{AB}	24.5 (3.6) ^{A}	0.026 *

**: Significant at P ≤ 0.05, Different superscripts indicate statistically significant difference*

ii. Prevalence of different scores

1. First premolars

The study included 138 first premolar roots distributed as follows: 46 roots in Norm divergent group, 44 roots in Hypodivergent group and 48 roots in Hyperdivergent group. All first premolar roots had score (0) so no statistical comparison between the three groups could be done.

2. Second premolar

The study included 90 second premolar roots distributed as follows: 26 roots in Norm divergent group, 32 roots in Hypodivergent group and 32 roots in Hyperdivergent group. As regards buccal roots; there was a statistically significant difference between root scores in the three groups (P-value = 0.003, Effect size = 0.363).The Hypodivergent group showed the highest prevalence of Score (0) followed by Hyperdivergent then Norm divergent groups. Norm divergent group was the only group that had Score (1). Norm divergent group showed the highest prevalence of Score (2) followed by Hyperdivergent then Hypodivergent groups. Hyperdivergent group was the only group that had Score (3). As regards palatal roots; there was a statistically significant difference between root scores in the three groups (P-value = 0.018, Effect size = 0.603). Hypodivergent group showed the highest prevalence of Score (0) followed by Hyperdivergent while Norm divergent group didn't have Score (0). None of the groups had Score (1). Norm divergent group showed the highest prevalence of Score (2) followed by Hyperdivergent while Hypodivergent group didn't have Score (2). Norm divergent group was the only group that had Score (3).

Table 2: Relation of second premolars in all groups to the maxillary sinus

Root	Root score	Norm divergent		Hypodivergent		Hyperdivergent		P-value	Effect size (d)
		N	%	N	%	N	%		
Buccal	Score (0)	9	37.5	20	83.3	14	58.3	0.003*	0.363
	Score (1)	5	20.8	0	0	0	0		
	Score (2)	10	41.7	4	16.7	9	37.5		
	Score (3)	0	0	0	0	1	4.2		
Palatal	Score (0)	0	0	8	100	6	75	0.018	0.603
	Score (2)	1	50	0	0	2	25		
	Score (3)	1	50	0	0	0	0		

*: *Significant at $P \leq 0.05$*

* score 0: the root of the tooth is away from the cortical border of the sinus, with a zone of cancellous bone in between, score 1: the root is laterally projected, away from the cortical borderof the sinus, score 2: the tip of the root is in contact with the cortical border of the sinus, score 3:the tip of the root is projecting into the maxillary sinus (46).

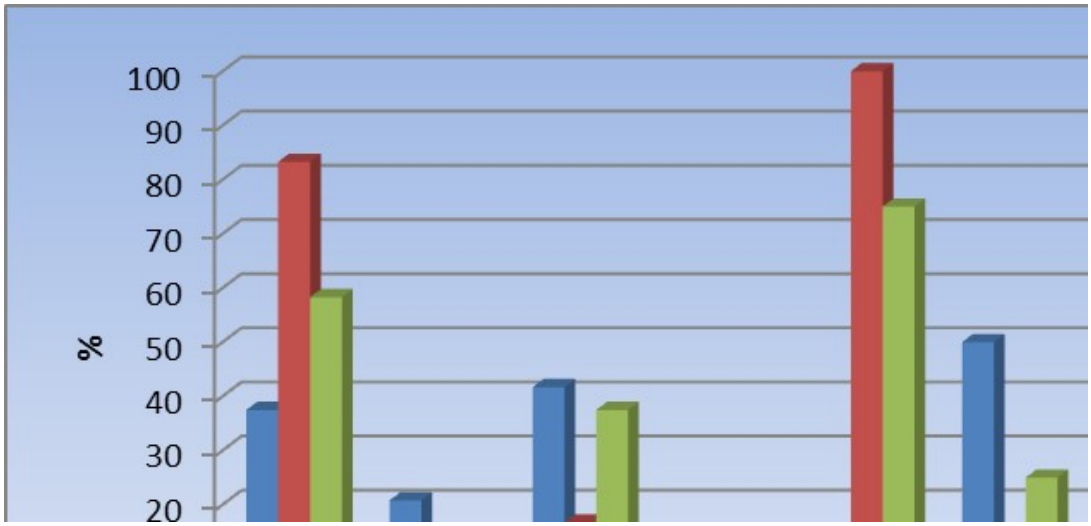

Figure 10: Bar chart representing relation of root scores of uppr second premolars in the three groups

* score 0: the root of the tooth is away from the cortical border of the sinus, with a zone of cancellous bone in between, score 1: the root is laterally projected, away from the cortical border
of the sinus, score 2: the tip of the root is in contact with the cortical border of the sinus, score 3:
the tip of the root is projecting into the maxillary sinus (46).

3. First molar

The study included 216 first molar roots distributed as follows: 72 roots in Norm divergent group, 72 roots in Hypodivergent group and 72 roots in Hyperdivergent group.

As regards Mesio-buccal roots; there was a statistically significant difference between root scores in the three groups (P-value = 0.009, Effect size = 0.322). Hyperdivergent group showed the highest prevalence of Score (0) followed by Hypodivergent then Norm divergent groups. Norm divergent group showed the highest prevalence of Score (1) followed by Hypo- and Hyperdivergent groups which showed the same prevalence of Score (1). Norm divergent group showed the highest prevalence of Score (2) followed by Hypodivergent then Hyperdivergent groups. Normodivergent group was the only group that had Score (3).

As regards Disto-buccal roots; there was no statistically significant difference between root scores in the three groups (P-value = 0.123, Effect size = 0.241).

As regards Palatal roots; there was a statistically significant difference between root scores in the three groups (P-value <0.001, Effect size = 0.396). Hypodivergent group showed the highest prevalence of Score (0) followed by Hyperdivergent then Norm divergent groups. Norm divergentgroup showed the highest prevalence of Score (1) followed by Hyperdivergent group while Hypodivergent group didn't have Score (1). Hypodivergent group showed the highest prevalence of Score (2) followed by Norm divergent then Hyperdivergent groups. Norm and Hyper-divergent groups showed the same prevalence of Score (3) while Hypodivergent group didn't have Score (3).

Table 3: Relation of first molar in all groups to the maxillary sinus

Root	Root score	Norm divergent		Hypodivergent		Hyperdivergent		P-value	Effect size (d)
		N	%	N	%	N	%		
Mesio-Buccal	Score (0)	1	4.2	10	41.7	11	45.8	0.009*	0.322
	Score (1)	8	33.3	6	25	6	25		
	Score (2)	13	54.2	8	33.3	7	29.2		
	Score (3)	2	8.3	0	0	0	0		
Disto-Buccal	Score (0)	1	4.2	6	25	7	29.2	0.123	0.241
	Score (1)	4	16.7	6	25	6	25		
	Score (2)	18	75	11	45.8	11	45.8		
	Score (3)	1	4.2	1	4.2	0	0		
Palatal	Score (0)	1	4.2	10	41.7	7	29.2	<0.001*	0.396
	Score (1)	6	25	0	0	1	4.2		
	Score (2)	11	45.8	14	58.3	10	41.7		
	Score (3)	6	25	0	0	6	25		

**: Significant at $P \leq 0.05$*

* score 0: the root of the tooth is away from the cortical border of the sinus, with a zone of cancellous bone in between, score 1: the root is laterally projected, away from the cortical borderof the sinus, score 2: the tip of the root is in contact with the cortical border of the sinus, score 3:the tip of the root is projecting into the maxillary sinus (46)

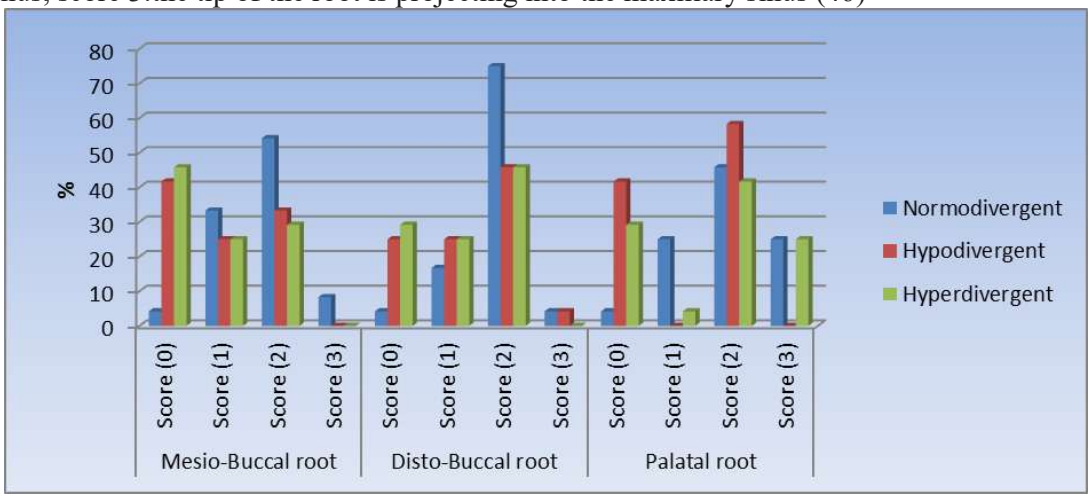

Figure 11: Bar chart representing relation of root scores of uppr first molars in the three groups * score 0: the root of the tooth is away from the cortical border of the sinus, with a

zone of cancellous bone in between, score 1: the root is laterally projected, away from the cortical border of the sinus, score 2: the tip of the root is in contact with the cortical border of the sinus, score 3: the tip of the root is projecting into the maxillary sinus (46).

4. Second molar

The study included 214 second molar roots distributed as follows: 72 roots in Norm divergent group, 702 roots in Hypodivergent group and 70 roots in Hyperdivergent group. As regards Mesio-buccal as well as Disto-buccal roots; there was no statistically significant difference between root scores in the three groups (P-value = 0.125, Effect size = 0.245), and (Pvalue = 0.143, Effect size = 0.269), respectively. As regards Palatal roots; there was a statistically significant difference between root scores in the three groups (P-value = 0.024, Effect size = 0.283). Hypodivergent group showed the highest prevalence of Score (0) followed by Hyperdivergent group while Norm divergent group didn't have Score (0). None of the groups had Score (1). Norm divergent group showed the highest prevalence of Score (2) followed by Hyperdivergent then Hypodivergent group. Hyperdivergent group showed the highest prevalence of Score (3) followed by Normodivergent then Hypodivergent groups**.**

Table 4: Relation the second molar of all groups to the maxillary sinus

Root	Root score	Norm divergent		Hypodivergent		Hyperdivergent		p-value	Effect size (d)
		N	%	N	%	N	%		
Mesio-Buccal	Score (0)	0	0	1	4.2	0	0	0.125	0.245
	Score (1)	4	16.7	4	16.7	2	8.3		
	Score (2)	11	45.8	17	70.8	14	58.3		
	Score (3)	9	37.5	2	8.3	8	33.3		
Disto-Buccal	Score (0)	4	16.7	7	29.2	4	18.2	0.143	0.269
	Score (1)	8	33.3	6	25	8	36.4		
	Score (2)	9	37.5	3	12.5	2	9.1		
	Score (3)	3	12.5	8	33.3	8	36.4		
Palatal	Score (0)	0	0	7	29.2	2	8.3	0.024*	0.283
	Score (2)	19	79.2	13	54.2	14	58.3		
	Score (3)	5	20.8	4	16.7	8	33.3		

**: Significant at $P \leq 0.05$*

* score 0: the root of the tooth is away from the cortical border of the sinus, with a zone of cancellous bone in between, score 1: the root is laterally projected, away from the cortical border of the sinus, score 2: the tip of the root is in contact with the cortical border of the sinus, score 3: the tip of the root is projecting into the maxillary sinus [46].

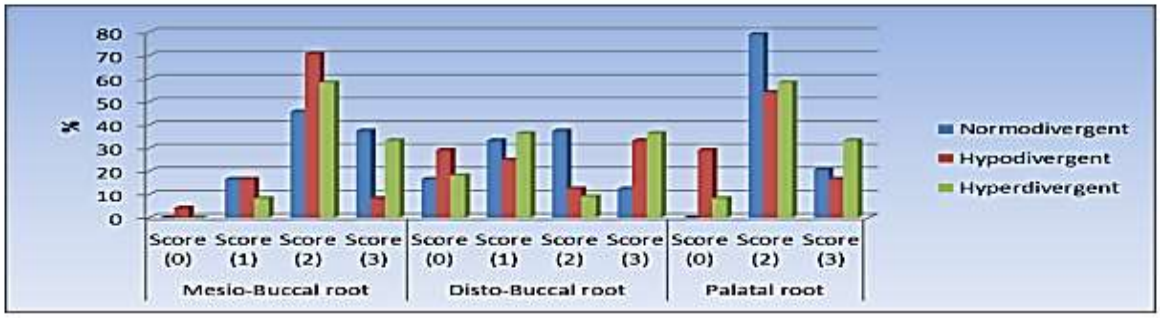

Figure 12: Bar chart representing distribution of root scores of upper second molars in the three groups

* score 0: the root of the tooth is away from the cortical border of the sinus, with a zone of cancellous bone in between, score 1: the root is laterally projected, away from the cortical border of the sinus, score 2: the tip of the root is in contact with the cortical border of the sinus, score 3: the tip of the root is projecting into the maxillary sinus (46).

iii. Regression analysis

Linear regression model was constructed using patients' and teeth scores as the dependent variables. Facial biotype was the independent variable. The model was adjusted for age. Results of the regression model showed that facial biotype was found to be a statistically significant predictor of first molars' root scores (b = -0.316, P-value = 0.024). Norm divergent group showed statistically significantly higher root score than hypo- and Hyperdivergent groups. So the norm divergent biotype is the most nearest group to the maxillary sinus floor.

Table 5: Results of linear regression model showing significant predictors of root scores

Dependent variable	Independent variables	Regression coefficient (b)	Standard Error (SE)	Pvalue	95% CI
Patients' score	Facial biotype	-0.146	0.086	0.098	- –0.321 0.028
Age	0.01	0.019	0.609	-0.028 – 0.048	
Second premolars' score	Facial biotype	-0.16	0.179	0.380	- –0.525 0.206
Age	0.022	0.039	0.570	-0.057 – 0.102	
First molars' score	Facial biotype	-0.316	0.134	0.024*	-0.589 – -0.044
Age	0.012	0.029	0.676	-0.047 – 0.072	
Second molars' score	Facial biotype	-0.01	0.133	0.938	- –0.281 0.260
Age	0.018	0.029	0.529	-0.041 – 0.077	

Discussion

Orthodontists focus on facial growth pattern when determining a treatment plan, but the proximity of the maxillary posterior teeth and sinus floor may change the treatment plan, especially in hyperdivergent facial types with anterior open bite that require intrusion of the posterior teeth, especially the first and second molars. The present study assesses the closeness of maxillary posterior tooth roots to the maxillary sinus floor in different facial growth patterns using CBCT, which is more accurate than PA and has a lower dosage than twodimensional x-rays (14). Based on Tweed triangle and FMA angle face biotypes, each scan was categorized as norm divergent, hypo divergent, or hyper divergent. Patients were grouped into three facial biotype groups (64).

Norm divergent (FMA, 22º- 28º) Hypodivergent (FMA, < 22º) Hyperdivergent (FMA > 28º)

This study measured face biotype using total anterior facial height and SN to FH angle. For maxillary sinus growth stability, the patient was 15–30. To eliminate gender bias, only men were sampled.

Regarding the first premolar: The present study found that all first premolar roots had score (0), meaning that all face biotypes had a zone of cancellous bone between the sinus cortical border and the root. GU et al (2018) (36) and Costea et al (2018) agreed that it may be invaded (50). This study examined 90 second premolar roots in all face biotypes. The hypodivergent group had the furthest roots apex (83%) from the maxillary sinus floor. Hyperdivergent face type was 58.3%, followed by norm divergent (37.5%). Babu et al. (2012) (40) and Costea et al. (2018) agreed (50). First molar roots: 72 per face biotype, 216 total. The normodivergent group had (4.2%) mesiobuccally roots whereas the hypodivergent group had (41.7%).

Hyperdivergent group scored (0) (45.8%). The hyperdivergent group had the furthest roots apex from the maxillary sinus floor.

The disto-buccal roots were at the same distance from the floor of MS in all three face biotype groups. Palatal roots in the hypodivergent group were furthest from the maxillary sinus floor (41.7%). This was in accord with Costea et al (50) and in contradiction with J. Duncavage et al (2011) (39), Babu et al (2012) (40), and Jun et al (2005) (43), perhaps related to sample age and sex. Regarding the second molar: The present study contained 214 second molar roots, 72% normdivergent, 72% hypodivergent, and 70% hyperdivergent due to buccal roots fused in certain teeth.

According to Sun, et al. (2020), buccal roots, both distal and mesial, were the same in all face biotypes (36).

The longest root in the second molar, the palatal root, was furthest from the maxillary sinus cortical boundary in the hypodivergent group (29.2%), followed by hyperdivergent (8.3%) and norm divergent (0%). In hyperdivergent group, palatal roots were closest to maxillary sinus floor with 33% score (3), followed by norm divergent (20.8%) and hypodivergent (16.7). Costea et al (50). Hyperdivergent roots were closer to the sinus floor than hypodivergent or norm divergent roots. If hyperdivergent face biotype patients need second molar intrusion to address anterior open bite, this may not work.

Conclusion

This study measured the closeness of maxillary posterior roots apices to the maxillary sinus floor in different face types (CBCT).
36 scans were categorized by Tweed triangle into norm divergent (12), hypodivergent (12), and hyperdivergent (12). (63).
To corroborate the group and FMA angle, reconstructed lateral cephalometry evaluated total anterior face height and FH-SN angle.

Root apices scored: score (0): the root of the tooth is away from the cortical border of the sinus, with a zone of cancellous bone in between; score (1): the root is laterally projected, away from the sinus; score (2): the tip of the root is in contact with the sinus; score (3): the root tip is projecting into the maxillary sinus in each facial type (46). Each scan scored all root apices on both sides: first premolar, second premolar, first molar, and second molar.

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