Relationship Between The Maxillary First Molar Roots And The Maxillary Sinus Floor: A Cone Beam Computed Tomoraphy Analysis

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ABSTRACT: Background The knowledge of the relationship between the root apices of maxillary teeth and the inferior wall of the maxillary sinus is crucial in diagnosis and treatment, not only in the field of endodontics but also other disciplines of dentistry. The close anatomical relationship between the maxillary molar roots and the maxillary sinus floor, may result in maxillary sinusitis of odontogenic origin. Previous studies have evaluated the relationship the relationship between the maxillary molar roots and the maxillary sinus floor (MSF) with inconclusive results. Previously, periapical and panoramic radiographs were used to determine the proximity of root apices and the maxillary sinus floor. However, superimposition of anatomic structures and errors caused by magnification render these methods less accurate diagnosis. With the Cone Beam Computed Tomography, the relationship between maxillary root apices and MSF can be accurately determined The study set out to determine the relationship between the roots of the maxillary first molar and the maxillary sinus floor. **Design and objective:** A descriptive cross sectional study employing consecutive sampling of 327 maxillary first molar roots was conducted. The aim of the study was to establish the relationship between the maxillary first molar roots and the maxillary sinus using Cone Beam Computed Tomography analysis. **Methods**: An analysis of Cone beam computed tomography scans of Filipino patients was done. The iRYS deconstruction software version 5.6 was used to analyze images. Descriptive statistics were used to represent the relationship between the roots of the maxillary first molar and the maxillary sinus floor. Comparison was done across age groups, gender and side (left or right). A summary of the numerical variables (vertical distances measured) was given in terms of mean, standard deviation, median, minimum and maximum whereas categorical variable (age and gender) given in terms of percentages and frequencies. **Results**: In this study, the vertical distance measured from the root tip to the MSF, was 1.39mm for the palatal root, 1.14mm for the Mesiobuccal root and 1.08mm for the Distobuccal root. Therefore, the closest root to the floor of the sinus was the Distobuccal root, followed by the Mesiobuccal and then the Palatal root. For both genders the root tips on the right side were closer to the MSF than those on the left side. For both left and right side the root tips were closer to the MSF in males and in younger patents for both genders. **Conclusion.** The closest root to the maxillary sinus floor was the distobuccal followed by mesiobuccal and then palatal. Differences in tooth position (right or left), age and gender were noted. **Recommendation:** The roots tips of the maxillary first molar are located close to the Maxillary sinus floor. For that matter, clinicians must exercise extreme caution during endodontic procedures.

Key words: Maxillary sinus floor, vertical distance

INTRODUCTION:

The maxillary sinus or the antrum of Highmore is the largest of the four human paranasal sinuses. (Abd-alla A. M et al. 2013). Each of the two left- and right-side pyramidal shaped maxillary sinuses, are located below the zygomatic region and above the teeth. The other three sinuses are frontal, ethmoidal and sphenoidal air sinuses. The alveolar process of the maxilla forms the maxillary sinus floor (MSF) (Inawaga, J. et al. 2019) and is lined with Schneiderian membrane which undergoes thickening of greater than 2mm during periodontal and periradicular diseases (Shanbhag, S. et al. 2013). The volume of the maxillary sinus undergoes change with age, initially increasing from when it begins to develop at 10months intrauterine until the age of 20 and then decreasing thereafter. (Ariji Y. et al. 1994, Ariji Y. et al. 2006). The age related change in adult maxillary sinus volume is thought to be associated with absence or presence of maxillary posterior teeth (Nuñez-Castruita A et al. 2012). As a result of the proximity of the posterior teeth to the maxillary sinus, extraction of the maxillary posterior teeth can also result in pneumatization of the maxillary sinus, which may lead to root apices of these adjacent teeth being intruded into the sinus (Hamby, R. et al. 2014). Previous studies that have evaluated the proximity of the maxillary posterior teeth, including the first molar, to the MSF among different populations have provided inconclusive results (Goller-Bulut et al. 2015, Shokri, A. et al. 2015, Kang, S. et al. 2015).

Significant research has been conducted in the past decades to establish the function of the maxillary sinus, indicating that the maxillary sinuses serve to improve the respiratory function of the nose (H.L Sieron et. al. 2020). The MS also

plays a role in the immune defense of the nasal cavity by producing nitrogen monoxide, reducing the weight of the skull and by protecting the orbit and the brain (H. L Sieron et. al. 2020). Infections involving teeth can spread into the maxillary sinus through periapical tissues and cause odontogenic maxillary sinusitis, which has been estimated to about 10% to 12% of all sinusitis (Ariji, Y. et al. 2006). Maxillary sinusitis can also occur because of inflammation of the Schneiderian membrane secondary to periapical and marginal lesions of dental roots that extend into or close to the MSF (Pokorny, A. et al. 2013). Over instrumentation, over irrigation, and over obturation during endodontic treatment can extend into the maxillary sinus causing endo-antral syndrome or odontogenic maxillary sinusitis and traumatic alterations, which are complex problems for dentists and otolaryngologists (Oberli, K. et al. 2007, Kamburoğlu, K. et al. 2017). The diagnosis of such sinus disease of odontogenic origin is not simple and can be confusing for the patient and the medical and dental care providers (Brook I. et al. 2006).

This current study employed cone-beam computed tomography (CBCT), which is a three-dimensional (3D) imaging technique that is superior in diagnosis and treatment planning process (Leonardi Durta et al. 2016), to analyze the relationship between the maxillary first molar roots and the maxillary sinus floor. Although periapical and panoramic radiographs were previously used to determine the proximity of root apices to the MSF, superimposition of anatomic structures and errors caused by magnification rendered these methods less accurate for diagnosis (Oberli, K. et al. 2007). When compared with conventional CT, CBCT uses lower radiation, higher resolution and shorter scanning time compared yet provide high-quality 3D images. With the CBCT images, the relationship between maxillary root apices and MSF can be accurately determined (Ludlow, J.B. et al. 2006).

Although periapical and panoramic radiographs have been used to determine the proximity of rot apices to the MSF, superimposition of anatomic structures and errors caused by magnification make these methods less accurate for diagnosis (Oberli, K et al 2007). Cone Beam Computed Tomography (CBCT), which is three –dimensional (3D) imaging technique is a superior tool in the diagnosis and treatment planning process, to analyze the relationship between the maxillary first molar roots and the maxillary sinus floor (Leonardi Durta et al. 2016). When compared with conventional computed tomography (CT), CBCT uses lower radiation, higher resolution, and shorter scanning time, yet provides high quality 3D images allowing a more accurate assessment of, the relationship between maxillary root apices and MSF (Ludlow. J.B et al. 2006).

To the best of the researcher's knowledge, there are no studies that have been conducted to establish the relationship between the root tips of the first maxillary molar and the maxillary sinus floor in a Filipino population. Philippines is located in south-East Asia and according to the 2020 Philippines Statistics Authority report, it has a population of about 109 million people. The aim of this study was to determine the relationship between the MS and the root apices of the maxillary first molar among adult Filipino using CBCT images. The distance from each root tip of the maxillary first molar (vertical distance) was measured and compared across age groups and gender. We hypothesized that the vertical distance from the root tips of the maxillary first molar to the MSF varies significantly across age groups.

Results from this study will inform on the relationship between the maxillary first molar roots and the MSF. The appreciation of this relationship is essential in increasing successful surgical and nonsurgical endodontic diagnosis and treatment.

MATERIALS AND METHODS

Research locale

CBCT records of 62 patients previously obtained from Insights Diagnostics Imaging Solutions (St. Patrick's Healthcare Clinic, Mandaluyong city, Metro Manila, Philippines) were used in this study. Insights diagnostics is an imaging centre specializing in ultra-high definition dental and maxillofacial scans. It serves as a referral centre for universities, public and private dental facilities within and without Metropolitan Manila.

The study was conducted in the Endo-Perio postgraduate discussion room, College of Dentistry, University of the East, Manila Philippines.

Research design

A descriptive cross sectional study was conducted. The relationship between the maxillary first molar roots and the MSF was determined. This was achieved by measuring the respective distances from each root tip to the MSF and comparing the left and right sides, across age groups and gender.

Respondents

Subjects of the study were Filipino patients aged 12 years and 66 with permanent first maxillary molars. They were assigned into three age groups namely; 10-30 years, 32-50 years and 50+ years.

Sampling design

A consecutive sampling technique was used. CBCT scans that had been taken for various dental treatments were use in this study. A former researcher had previously acquired the scans, which were saved on compact discs.

Instrumentation

iRYS Viewer software version 5.6, operated by a Lenovo intel Pentium 2.16 GHz run by Windows 8.1 pro (2013 Microsoft corporation) was used to analyze CBCT images.

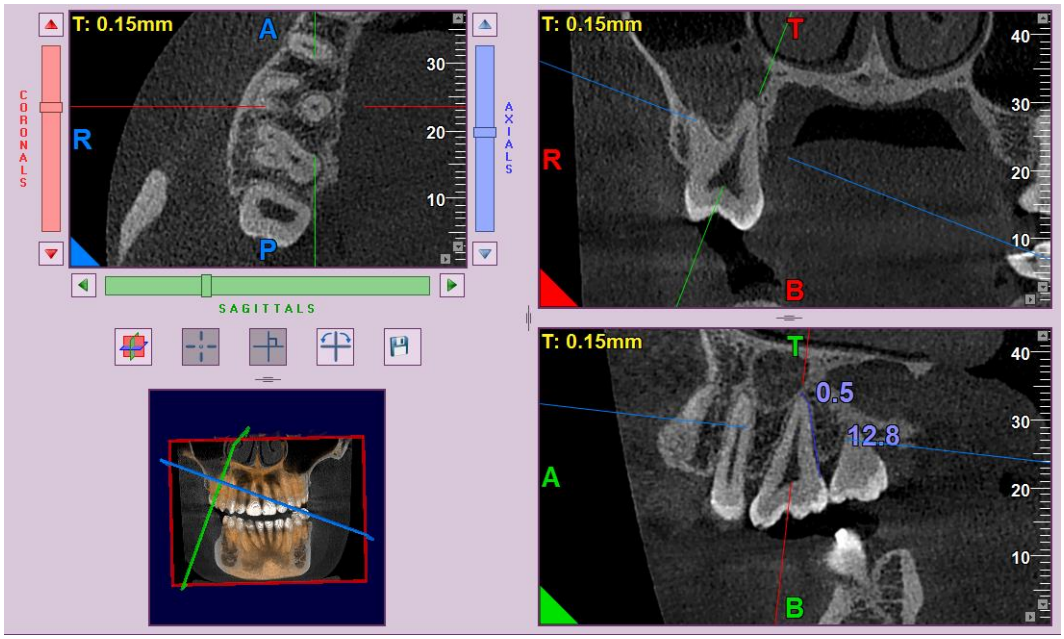
Measurements of each tooth were recorded on data entry sheets.

Data collection

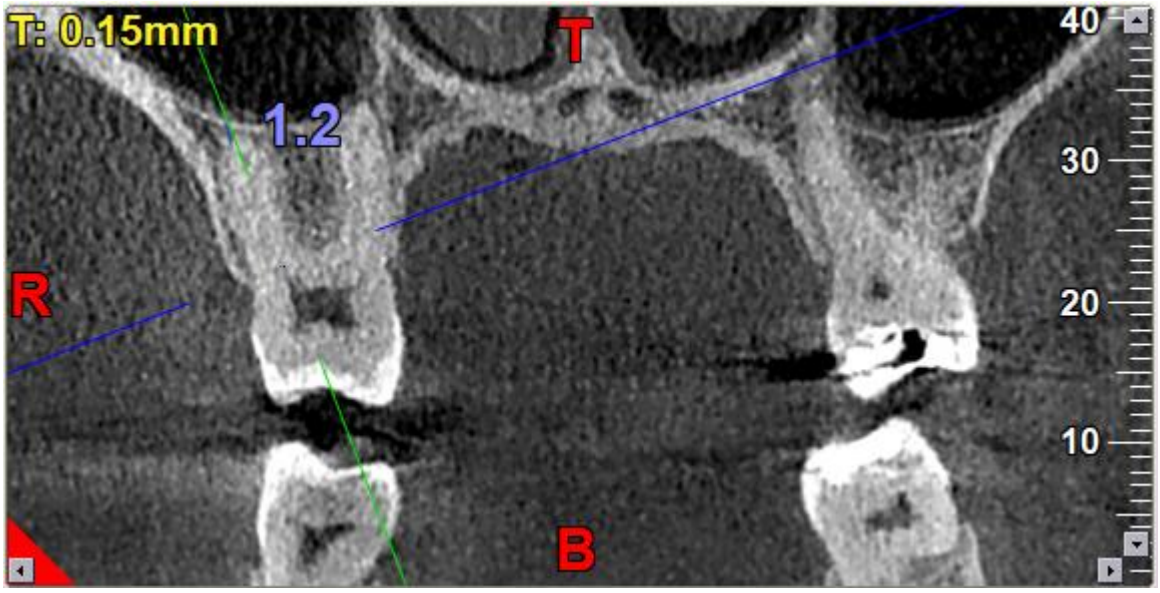
CBCT records of patients, saved on compact discs had been obtained from Insights Diagnostics Imaging Solutions by a previous researcher. The CBCT machine model used to take the scans was a Myray Hyperion X9 (Cefla dental group, Imola, Bologna, Italy) that was operated at 90kV and 10mA with an exposure time of 9 seconds. The voxel size was 75 µm, field of view 11x 8 cm and thickness slice was 0.15mm.

The iRYS viewer software version 5.6 was used to manipulate the CBCT images, and do the required measurements.

The MPR mode was selected. Images were adjusted to a magnification of 212 % and the gray scale contrast selected to allow for detailed analysis of the images. The midpoint was centered on the first maxillary molar in the coronal and the image adjusted until all the three roots were distinctly visible in the coronal view. The mid-point was then placed at the center of the palatal canal. The vertical line in the axial was adjusted accordingly, parallel to the long axis of the root palatal root. The vertical line was adjusted in the sagittal axis, in the most parallel position to the long axis of the tooth while observing the clearest point of visualization of the inferior border of the maxillary sinus. In the sagittal plane, using the distance icon on the tool bar, the measurement of the vertical distance from the root tip to the inferior border of the maxillary sinus was done. The image with the measurements were then saved by clicking on the save image icon. Screenshots of the images were also taken by clicking on the screenshot icon. The same procedure was repeated for the mesiobuccal and distobuccal roots. The measurements were then transferred to data entry sheets prior to statistical analysis.



Screenshot showing coronal, axial, sagittal and 3D sections of a palatal root



Screenshot of a sagittal l section showing measurement of vertical distance (VD) of a Distobuccal root. The VD measured is 1.2mm

Statistical analysis
SSPS 22.0 (IBM Corp., Armonk, NY, USA) for windows software was used to conduct statistical tests.

Reliability of data gathered was tested using intra class correlation coefficient.

Descriptive statistics were done for the age, gender, and vertical distance from the tip of each root to the MSF. A summary of the numerical variables (vertical distances measured) was given in terms of mean, standard deviation, median, minimum and maximum whereas categorical variable (age and gender) given in terms of percentages and frequencies.

Assumptions
The measurements of the individual root lengths and the respective vertical distances being relied on in the study were made in the sagittal plane of the CBCT scans. The assumption is that these measurements represent the actual dimensions of the teeth in the patients' mouths.

RESULTS AND ANALYSIS

The study set out to determine the relationship between the maxillary first molar roots and the maxillary sinus floor. In this study, 109 palatal roots, 109 mesiobuccal roots and 109 distobuccal roots of first maxillary molars, making a total of 327 roots were included. The distance from each root tip to the MSF was measured and compared in terms of gender across age groups.

Intraclass Correlation Coefficient: Reliability testing between independent calibrated examiners
Two sets of measurements taken by two independent calibrated examiners were compared using the Intraclass correlation coefficient. The coefficient for both single measures and average values is 0.999, which is very close to the value of 1, with significance values of 0.000. This indicates that there is a significant high similarity between the two measurements.

Table 1: Demographics and laterality

		Frequency	*Percentage*
Sex (n=62)	Male	30	48.4
	Female	32	51.6
Age group (n=62)	10-30	36	58.1
	31-50	22	35.5
	51+	4	6.4
Values (n=327)	Negative	44	13.5
	Positive	283	86.5

There were 62 patients.
Slightly more than half of the patients were female.
Majority of the patients were from the age group 10-30yrs. Only 6.4% of the patients were aged 51yrs and more.

Table 2: Positive VD for right maxillary first molar by root and gender

	Sex	*N*	*Mean*	*SD*	*Min*	*Max*
P	M	22	1.37	0.98	0	3.5
	F	21	1.37	1.06	0	3.5
MB	M	25	1.04	0.73	0	2.6
	F	26	1.14	0.84	0	3.4
DB	M	25	0.98	0.74	0	2.5
	F	24	1.09	0.76	0	2.7

For the maxillary right side, the MB and DB root tips were closer to the MSF in males than females. The palatal root tip was placed at the same distance from the MSF for both genders. The closest root tip to the MSF for both genders was the DB followed by the MB then the palatal.

Table 3: Positive VD for left maxillary first molar by root and gender

	Sex	*N*	*Mean*	*SD*	*Min*	*Max*
P	M	23	1.39	1.20	0	4.2
	F	21	1.44	1.22	0	4
MB	M	25	1.13	0.81	0	2.8
	F	26	1.23	1.05	0	5.2
DB	M	24	1.13	0.82	0	2.3
	F	21	1.1	1.08	0	4

For both genders, the figures for the positive VD, for all the roots were higher on the left side than the right side. This indicated that the root tips on the right side were closer to the MSF. Vertical distances for the females for both left and right side were generally higher than those of their male counterparts. Thus the root tips were closest to the MSF in males. the closest root to tem MSF for both genders and side was the DB followed by MB then Palatal.

Table 4: Negative VD for right maxillary first molar by root and gender

	Sex	*N*	*Mean*	*SD*	*Min*	*Max*
P	M	4	-4	1.19	-5.5	-2.7
	F	8	-2.13	0.38	-2.7	-1.5
MB	M	1	-1.5	-	-1.5	-1.5
	F	3	-1.63	0.72	-2.1	-0.8
DB	M	1	-0.9	-	-0.9	-0.9
	F	5	-1.52	00.95	-2.9	-0.3

Table 5: Negative VD for left maxillary first molar by root and gender

	Sex	*N*	*Mean*	*SD*	*Min*	*Max*
P	M	4	-2.65	0.98	-3.6	-1.5
	F	6	-2.98	1.70	-5.2	-1
MB	M	2	-1.75	0.64	-2.2	-1.3
	F	1	-3.2	-	-3.2	-3.2
DB	M	3	-1.1	0.36	-1.5	-0.8
	F	6	-1.73	-.51	-2.5	-1

Negative figures indicate that the root tips were placed in the maxillary antrum. For both left and right side and both genders, the palatal root tip was placed the furthest into the sinus, followed by the MB then DB. Very few root tips were placed in the maxillary sinus.

Table 6: Positive VD for right maxillary first molar by root and age

	Age	*N*	*Mean*	*SD*	*Min*	*Max*
P	10-30	24	1.13	1.04	0	3.1
	31-50	17	1.71	0.94	0	3.5
	51+	2	1.4	0.57	0	1.8
MB	10-30	28	0.95	0.69	0	2.6
	31-50	20	1.25	0.89	0	3.4
	51+	3	1.43	0.75	0.7	2.2
DB	10-30	26	0.96	0.79	0	2.7
	31-50	20	1.12	0.74	0	2.5
	51+	3	1.17	0.35	0.8	1.5

Table 7: Positive VD for left maxillary first molar by root and age

	Age	*N*	*Mean*	*SD*	*Min*	*Max*
P	10-30	24	1.28	1.17	0	4.2
	31-50	18	1.61	1.28	0	4
	51+	2	1.35	1.06	0.6	2.1
MB	10-30	31	1.09	0.75	0	2.6
	31-50	18	1.3	1.22	0	5.2
	51+	2	1.6	0.14	1.5	1.7
DB	10-30	27	0.95	0.86	0	2.7
	31-50	17	1.37	1.06	0	4
	51+	1	1.3	-	1.3	1.3

The VD for all roots and both right and left sides, generally increased with age. This indicates that the root tips were placed further from the MSF in older patients

DISCUSSION

This study set out to determine the relationship between the root of the maxillary first molar and the maxillary sinus floor. To begin with the individual roots of the maxillary first molar were identified on the CBCT scans. Thereafter, the respective vertical distances from the root tips of the maxillary first molar to the MSF were measured, for both left and right sides. The vertical distances were compared across age groups and gender. A total of 327 roots of permanent maxillary first molars were analyzed. Each root type, that is, palatal, mesiobuccal and distobuccal comprised of 109 samples. The measurements were subjected to descriptive statistical analysis. A summary of the numerical variables

(vertical distances measured) was given in terms of mean, standard deviation, median, minimum and maximum whereas categorical variable (age and gender) given in terms of percentages and frequencies.

In this study, the vertical distance measured from the root tip to the MSF, was 1.39mm for the palatal root, 1.14mm for the Mesiobuccal root and 1.08mm for the Distobuccal root. Therefore, the closest root to the floor of the sinus was the DB root, followed by the MB and then the P root. In a similar study conducted by Sung H. Kang and colleagues (2015), CBCT scans of a Korean population were analysed. The vertical distance reported from the study was 1.04 mm (mesiobuccal and palatal) and 1.05 mm (distobuccal). The figures from this research are lower for the palatal and mesiobuccal root but nearly comparable for the mesiobuccal root when compared with those of the present study. This could be attributed to racial variations, differences in the operating system and parameters for the CBCT scans, the type of reconstruction software used to analyse the CBCT scans, level of expertise of the investigators in analysing the CBCT scans and sample sizes. For instance, the CBCT images used by Sung H. Kang and colleagues (2015) were obtained using a Dinnova system (Willmed, Gwangmyeong, Korea). The operating parameters were 9.0 mA, 80 kVp, 10-cm scan field of view, and 0.167-mm voxel size. Images were reconstructed using OnDemand3D software (Cybermed, Seoul, Korea). However, in the current study, the CBCT images were obtained using a Myray Hyperion X9 (Cefla dental group, Imola, Bologna, Italy) that was operated at 90kV and 10mA with an exposure time of 9 seconds. The voxel size was 75 µm, field of view 11x 8 cm and thickness slice was 0.15mm. The iRYS viewer software version 5.6 was used to reconstruct the CBCT images.

In an earlier study H.H. Kwak and colleagues (2004) investigated hemisectioned Korean heads using an image analysing system and reported even much higher figures for the vertical distances from root tips of the maxillary first molar; 3.87mm, 3.53mm and 3.01mm for the palatal, distobuccal and mesiobuccal roots respectively. This could be attributed to the dissimilarities in the accuracy of the tools used to measure the vertical distances; the Image analyzing system measuring the hemisectioned heads versus the iRYS viewer software version 5.6 used to reconstruct the CBCT scans.

Earlier, James A. Eberhardt and colleagues (1992) measured CT scans of autopsy American specimens and reported a vertical distance of 1.56 mm, 2.79mm and 2.82mm for the palatal, distobuccal and mesiobuccal roots respectively. The vertical distances reported by the study are higher than those of the current study and likewise could be attributed to the differences in measuring tools and race.

The vertical distances measured generally increased with age, and were higher in females. Thus the root tips of maxillary first molars were placed closer to the MSF in younger patients and in males. This can be attributed to difference in sizes of the maxillary sinuses between ender and ae groups. Ariji and colleagues, in adults over 20 years old, reported a mean volume of, 15.40±7.04cm3 and 13.98± 5.43cm3 for males and females respectively. the relatively smaller maxillary sinuses in females could explain the larger vertical distances. Furthermore, studies have shown differences in volume sizes on the left and right sides. [Ariji Y. et. al. 1994, Ariji Y. et. al. 2006]. This could explain the differences between the right and left vertical distances noted in the current study.

The root tips were placed closer to the maxillary sinus in younger patients. This can be attributed to the fact that the maxillary sinus volume increases up to the age of 20 years, after which it decreases. [Ariji Y. et. al. 1994, Ariji Y. et. al. 2006]. Thus with a relatively smaller maxillary sinus in older patients, the root tips of the maxillary first molar are placed further from the MSF.

In adult males, the volume correlated with body height and weight. It appears that volume changes with age might be related to skeletal size and physique.

To the best of the researcher's knowledge, this is the first research to evaluate the relationship between maxillary first molar roots and the MSF in this population. As seen in the current study, this relationship varies across age, gender and side. However, since individual differences in skeletal size, physique and racial variations cannot be overlooked, the findings of this study may advice clinicians in the management of patients, particularly those with anatomic variation in maxillary first molars

Conclusion

The following conclusions were drawn, based on the findings of this study.

The vertical distance from the root tips of the maxillary first molar to the MSF was greatest in the palatal roots, followed by the mesiobuccal root and then distobuccal root. Therefore, the root tip closest to the MSF was the distobuccal, followed by the mesiobuccal and then the mesiobuccal.

Differences in tooth position (right or left), age and gender were noted. For both genders the root tips on the right side were closer to the MSF than those on the left side. For both left and right side the root tips were closer to the MSF in males and in younger patents for both genders.

Recommendation

The roots tips of the maxillary first molar are located close to the Maxillary sinus floor. For that matter, clinicians must exercise extreme caution during endodontic procedures.

Conflict of interest

The authors deny any conflict of interest in this study.

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