Original Article

Three-dimensional evaluation of maxillary sinus volume, skeletal and dentoalveolar maxillary anterior region, in unilateral palatally impacted maxillary canine (Cross-sectional study)

Sahar Y. Faiq and Zaid Dewachi[1]

Abstract

OBJECTIVES: Three-dimensional evaluation of maxillary sinus volume using VR mesh and correlate it with the volume of maxillary canine, lateral incisor, and dentoalveolar and skeletal dimensions in both impacted and non-impacted sites.

MATERIALS AND METHODS: In a retrospective cross-sectional study, cone beam computed tomography scans of 100 patients with unilateral palatally impacted maxillary canine were analyzed. Canine, lateral incisor, and maxillary sinus volumes on the impaction and non-impaction sides were measured using DICOM files, with three-dimensional softwares (MIMICS) and VR mesh to accomplish this assessment.

RESULTS: There were no significant differences in canine and lateral incisors volumes between male and female patients in the impacted side at ($p > 0.05$) while the maxillary sinuses volume revealed a statistical difference ($P = 0.022$) between male (12642 ± 810) and female (12481 ± 650) patients in the impacted side. A strong positive correlation was found between canine and lateral incisor volume for male patients in the non-impacted ($r = 0.420**$, $P = 0.008$) and impacted sides ($r = 0.334*$, $P = 0.038$).

CONCLUSIONS: There were no significant differences in the canine volume, the height of the anterior alveolar ridge (AARHMLI), and anterior dentoalveolar (ADAHMLI) of maxillary lateral incisors in the impacted/non-impacted side, but it showed a statistically significant difference for the lateral incisors volume in the impacted and non-impacted sides for male and female patients. The maxillary sinus volumes revealed a statistical difference between males and females in impacted and non-impacted sides.

Keywords:

Canine impaction, cone beam computed tomography, MIMICS, palatal canine displacement, VR mesh

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Introduction

Maxillary canine impaction was somewhat relatively common. So when not taking into consideration of the third molar, the maxillary canine is the tooth that becomes impacted the most frequently.[1] The prevalence of the impacted maxillary canines is described to be in the range between 0.9% and 3.3%.[1] Reports stated that the majority of maxillary canine impaction occurs unilaterally at which most of the cases (50%–85%) are palatally displaced.[1] The etiology of these sorts of impactions

has been correlated to one of two theories; the genetic theory and the guidance theory. According to the genetic viewpoint, palatally displaced maxillary canines are mostly the result of genetic causes.[2] Additionally, Becker[3] demonstrated a 2.4 × increase in impacted canines next to missing laterals. Both genetic and local environmental factors may be to blame for this, which is consistent with both views.[3] However, the precise cause of an impacted canine condition is still unknown.

Among the four paranasal sinuses, the maxillary sinus is considered to be the largest, and it is a bilateral air-filled chamber that existed in the maxilla.[4] Oishi *et al*.[5] used the conventional coronal and sagittal planes to measure the distance between the canine and posterior teeth and the maxillary sinus floor, and the results revealed considerable discrepancies between the measurements in these two planes. The canine teeth showed a significant disparity. This can be due to the maxilla's curved anatomy and the canine tooth's unique position in the jaw. The maxillary sinus volume is statistically remarkably smaller in the side of impaction (11377.17 ± 1386.87 mm^3) compared to the contralateral side (12770.71 ± 1621.24 mm^3).[6] A decrease in the maxillary sinus volume can be predicted when the maxillary canines are impacted.[6]

Modern two-dimensional (2D) radiographs, such as periapical, occlusal, and panoramic radiographs, continue to be the most popular utilized method for the initial diagnosis, treatment planning, and localization of un-erupted teeth despite the recent introduction of novel diagnostic imaging techniques.[7] However, 2D radiography pictures are severely limited in their ability to show the precise location of these teeth, the effect they will have on adjacent teeth, the anatomy of roots, and other nearby structures which is absolutely relevant for treatment planning.[8]

By eliminating image superimposition, computed tomography (CT) enables the rebuilding of scanned-in structures in several planes in addition to three-dimensional (3D) reconstructions.[8] Cone-beam computed tomography (CBCT), a more contemporary and widely accessible modality in dentistry, generates diagnostic 3D in high-quality pictures with the lowest distortion at a reasonably low cost and with a much lower radiation dose than other CT modalities.[9] A recent CBCT study shows that the maxillary sinus extends to the canine area in 68.9% of the cases and the incisor region in 15.5%.[10] The high frequency of the sinus extension to the canine tooth area necessitates a thorough evaluation of the region regarding the relationship between the maxillary sinus and the dentition.

Materials and Methods

This study depends on retrospective cross-sectional samples of a total of 100 patients with unilateral palatally maxillary impacted canines and non-orthodontically treated patients (out of 1000 cases). The samples were collected from (x). Ethical approval was gotten from the Research Ethics Committee, reference no. UoM.Dent/H.48/22. The patient's ages ranged from 14 to 20 years old (M: 16.30 2.27), (F: 15.23 1.33). The inclusion criteria were: excluding the third molar, full permanent dentition in both jaws with unilaterally palatally impacted canines on the maxilla, no history of orthodontic treatment or orthognathic surgery, or severe distorting of the dental arches brought on by a cleft lip or palate, absence of agenesis, absence of any buccally or bilateral impacted canines, normal breathing pattern, absence of maxillary hypoplasia, and absence of any upper respiratory tract infection or pathology. Scanning parameters with a cone-beam computed tomography (CBCT) machine (Carestream 8100) were 90 kVp, 15 s, and 2.5 mA, with a field of view 16 × 12 cm^2 and voxel size (150 × 150 × 150 μm^3).

The measurements were made using CBCT-derived anteroposterior radiographs. These measurements were anterior alveolar ridge maxillary lateral incisor (AARHMLI) through drawing a straight line extended from the floor of the nostrils till the upper lateral incisors bony ridge on the side of impacted and non-impacted canine, which is parallel to the mid-sagittal plane as shown in Figure 1a and anterior dentoalveolar maxillary lateral incisor (ADAHMLI) through drawing a straight line from the floor of the nostrils till the incisal edge of maxillary lateral incisors on the side of impacted and non-impacted canine, which is parallel to the mid-sagittal plane) as shown in Figure 1b. These two parameters were measured in millimeters.

Software 3D modeling and design, the Materialise interactive medical image control system (MIMICS) program 20.0, was used to import the digital imaging and communication in medicine (DICOM) files. MIMICS program 20.0 is typically used to generate a 3D surface model from stacks of 2D image data. The segmentation of the images was a delicate operation that required the
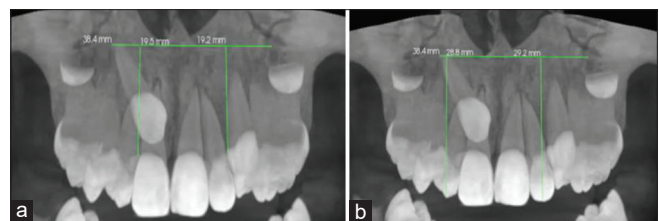

Figure 1: (a) The anterior alveolar ridge height. (b) The anterior dentoalveolar height

collaboration of two observers. Thereafter, to remove any chance of reading bias, inter-examiner calibration was carried out. Additionally, the researcher performed the procedure of segmentation blindly one week later.

The segmentation process of the maxillary canines and lateral incisors was done; semi-automatically we cropped the area of interest and then we used the Mimics Research software's "automatic threshold" feature to create the segmentation mask. To automatically recognize all of the teeth's Hounsfield values and limits, scan after scan the threshold was adjusted, and to decrease the mistakes in distinguishing pulpal tissue from dentin, we included the volumes of the pulpal tissue for each tooth. Single tooth mask was then improved in terms of quality and accuracy by first manually removing, slice by slice in the axial and sagittal views using Edit Mask, additional

portions of the segmentation mask that occur outside the tooth contour, such as some of the surrounding bone that shares the same H.U. with the tooth to be segmented and portions of the adjacent teeth that are involved in the mask during the action of cropping. When the 3D tooth model was accomplished, the volume of the tooth models was determined by the MIMICS program, which is the same program we did segmentation in it in Figures 2-4.

Automatic-segmentation of the maxillary sinuses (200 MS, F = 122, M = 78) was also done to see if there is a difference in its volume in the impacted and non-impacted sides. First, we used the dynamic region grow (which allows growing a mask from a selected point without having to threshold) in MIMICS, followed by some steps until we obtained accurate borders of the maxillary sinuses as shown in Figure 5. The Materialise
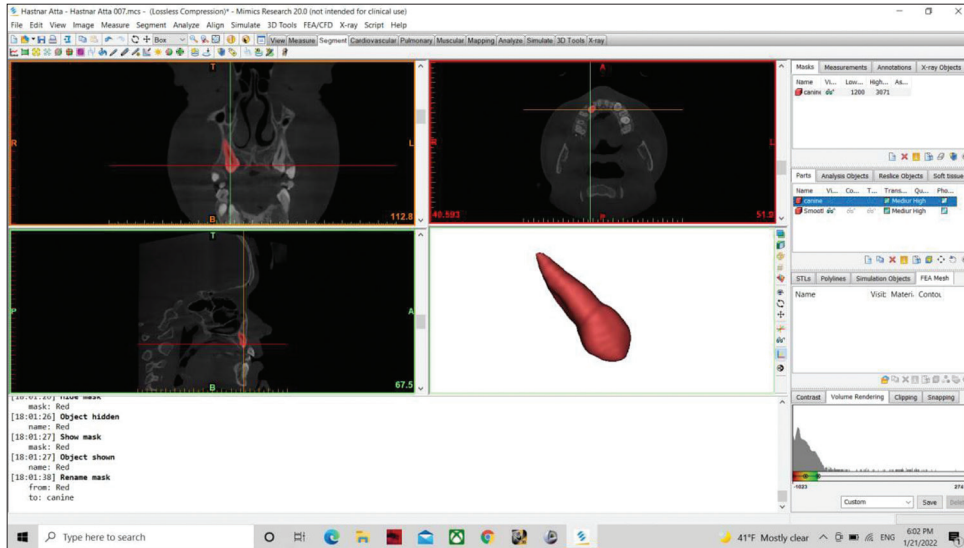

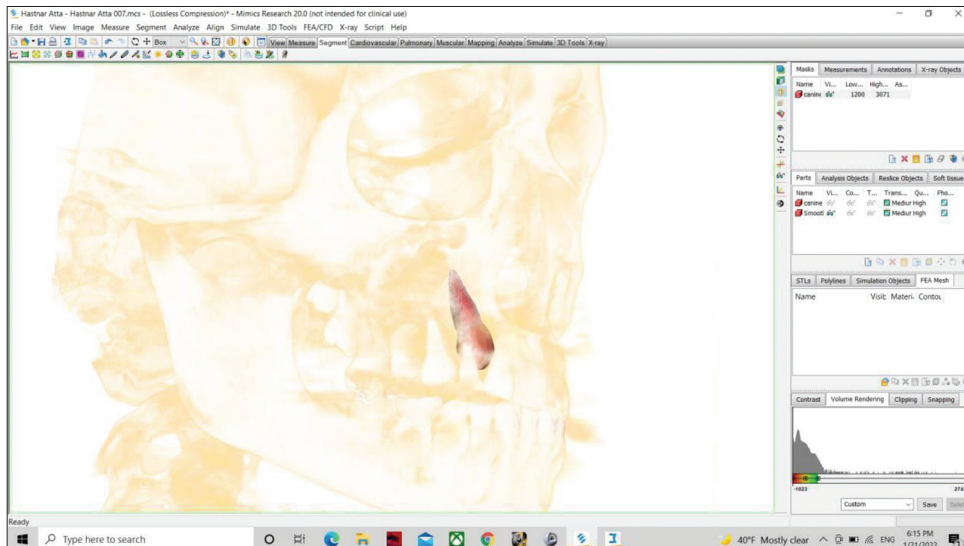**Figure 2:** Creation of the three-dimensional tooth model by MIMICS from CBCT

Figure 3: Using the volume rendering to show the 3D impacted canine tooth model
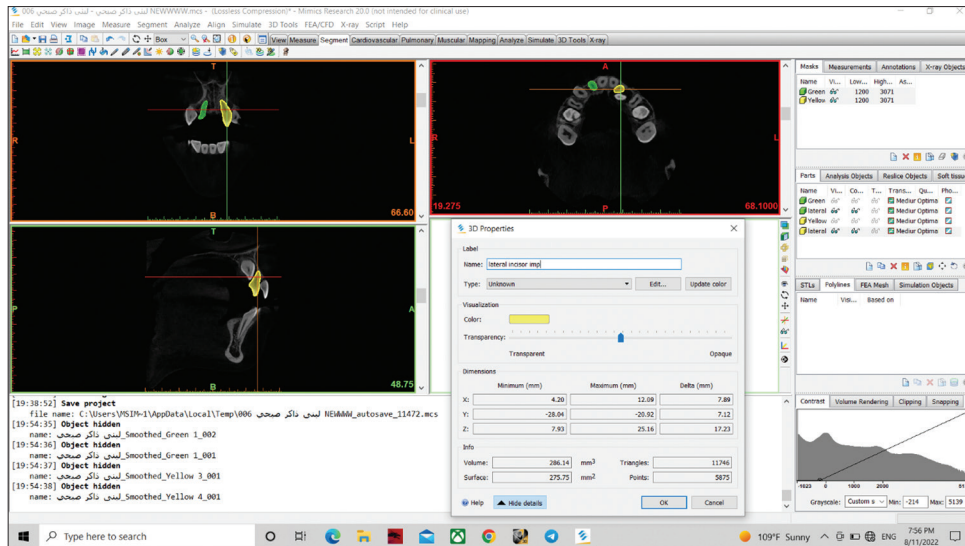
Figure 4: Measuring the volume of the Lateral incisor in the impacted side using MIMICS
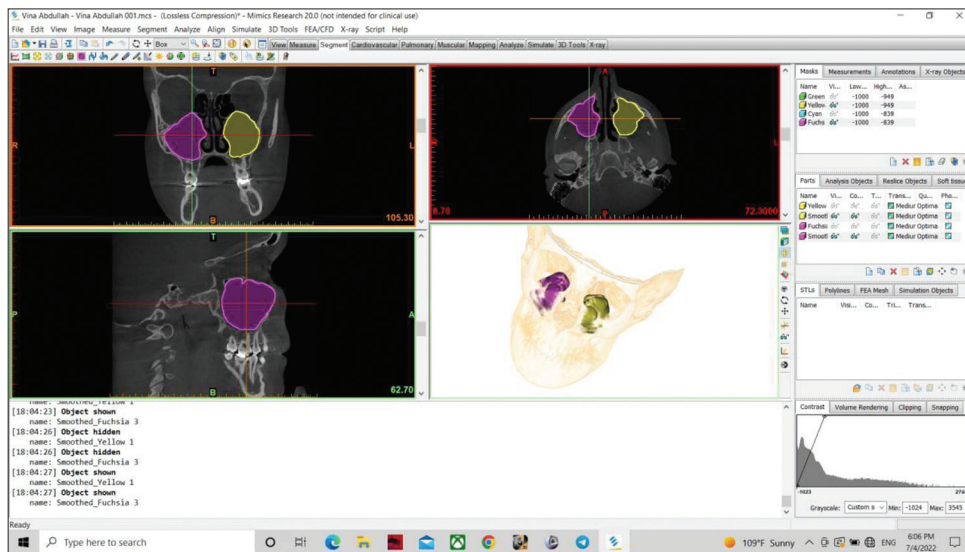

Figure 5: The three-dimensional Maxillary sinus model via MIMICS from CBCT

interactive medical image control system (MIMICS) tool was used to determine the volume of the sinus models after the three-dimensional sinus model was finished. Since manual segmentation takes a lot of time and requires a lot of operator skill, it is not a procedure that can be done in a routine clinical setting. Manual threshold selection is still needed for semi-automatic segmentation algorithms. Furthermore, the manual changes of segmented structures take a lot of time and could result in operator errors.[11]

Virtual Grid was founded in 2003 and developed VR Mesh, an advanced 3D point cloud, and mesh processing software tool. The MIMICS software was used to convert the DICOM file into stereo lithographic or standard tessellation language (STL), because the DICOM files are not recognized by the VR Mesh application as in

Figure 6. V R Mesh covers point cloud classification, feature extraction, and point cloud meshing. In the present study, VR Mesh software was being used to calculate the tooth and sinus volumes; the development of this software was carried out by an American company (Bellevue, Washington), and it is used in many fields involving dentistry as in Figure 7.

Results

The male represents (39%) (of 39 patients) while female patients signify (61%) (of 61 patients), the mean age for male patients was 16.30 ± 2.27 years while for female patients 15.23 ± 1.33 years, 47 (47%) of unilateral palatally impacted canine in the left side of the patient while 53 (53%) in the right side as shown in [Tables 1 and 2].
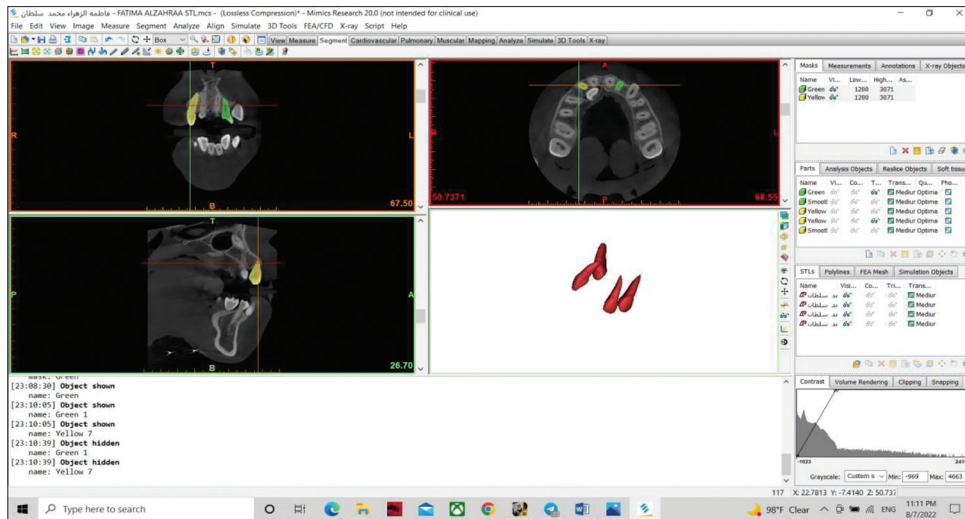
Figure 6: Converting DICOM files into STL using MIMICS
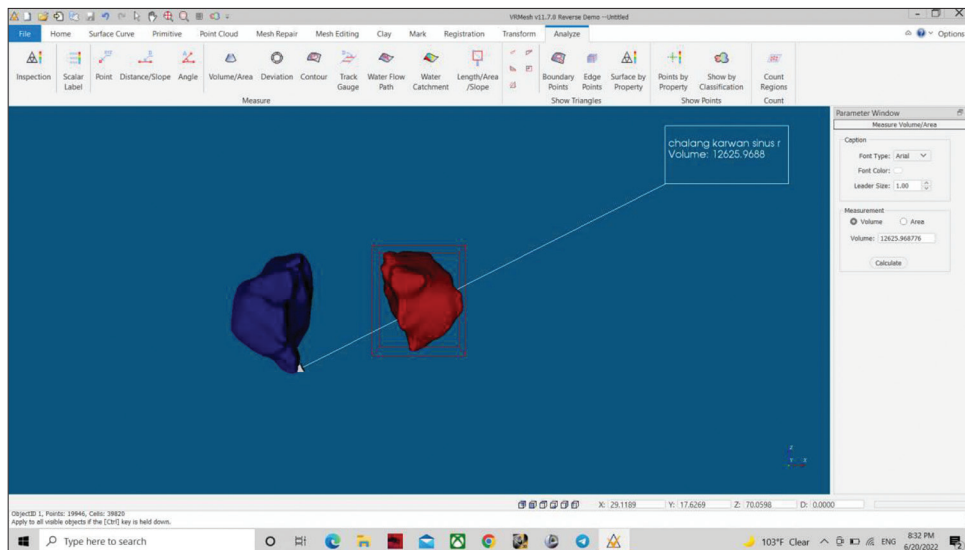
Figure 7: Measuring sinus 3D models volume using VR mesh

Table 1: Descriptive statistics of right- and left-impacted maxillary canine

Side	n (%).	Impacted canine							P
		Age	Mean	SE	SD	Minimum	Median	Maximum	
Left side	47 (47%)	20.000	15.000	14.00	1.486	0.217	15.553		>0.05
Right side	53 (53%)	25.000	16.000	14.00	2.368	0.325	16.170		

Table 2: Representing the gender and age of the patients

Parameters	Male No. (%)	Female No. (%)	P
Gender	39 (39)	61 (61)	P<0.01
Age (year) (Mean ± SD)	16.30±2.27	15.23±1.33	P<0.01

Regarding the ADAHMLI and the AARHMLI, there were no statistically significant differences for both males and females ($p > 0.05$) in the impacted side with a Mean ± SD (M: 26.456 ± 1.067, F: 26.523 ± 1.127) and (M: 21.687 ± 0.950, F: 21.703 ± 0.970). But in the non-impacted side, ADAHMLI (M: 26.630 ± 1.093, F: 26.697 ± 1.151)

and the AARHMLI (M: 21.830 ± 0.951, F: 21.857 ± 0.970) showed no statistical significance ($p > 0.05$) between male and female patients as shown in [Table 3].

There were no significant differences in canine and lateral incisor volumes between male and female patients in the impacted side at $P > 0.05$, while the maxillary sinus volumes revealed a statistical difference ($P = 0.022$) between male (12642 ± 810) and female (12481 ± 650) patients in the impacted side. While in the non-impacted side, there was a statistical difference in the volume of lateral incisors and maxillary sinuses $P = (0.003)$, (0.001),

respectively, between male and female patients as shown in [Table 4].

When comparing the canine volume in impacted and non-impacted sides for male patients ($P > 0.05$), there was no significant difference, while it showed a statistically significant difference for the lateral incisors volume ($P = 0.002$), maxillary sinuses volume ($P = 0.002$) in impacted and non-impacted sides. For the female patients, the canine and maxillary sinus volumes showed no statistical significance ($P > 0.05$) between the impacted and non-impacted sides. The P value was (0.003) for the lateral incisors volume in the female patients, which means there was a statistical difference as shown in [Table 5].

The correlation coefficient among parameters (AARHMLI, ADAHMLI, the canine, the lateral incisors, and the maxillary sinuses volume) using Spearman's correlation coefficient as shown in [Tables 6-9]. A strong positive correlation was found between canine and lateral incisor volume for male

Table 3: Comparing ADAHMLI and AARHMLI between male and female patients

	Sex	Mean	SE	SD	Minimum	Median	Maximum	P
Impacted								
ADAHMLI	Male	26.456	0.107	1.067	24.600	26.300	29.100	>0.05
	female	26.523	0.144	1.127	24.600	26.400	29.100	>0.05
AARHMLI	Male	21.687	0.0950	0.950	20.000	21.700	24.000	>0.05
	Female	21.703	0.124	0.970	20.000	21.900	24.000	
Non impacted								
ADAHMLI	Male	26.630	0.110	1.093	24.300	26.450	29.300	>0.05
	Female	26.697	0.149	1.151	24.300	26.550	29.300	
AARHMLI	Male	21.830	0.0951	0.951	20.100	21.900	24.100	>0.05
	Female	21.857	0.124	0.970	20.100	22.000	24.100	

Table 4: Comparing the canine, lateral incisors, and maxillary sinus volume between male and female patients

	Sex	Mean	SE	SD	Minimum	Median	Maximum	P
Impacted								
Canine volume	Male	537.12	4.54	45.42	460.85	534.39	665.66	>0.05
	Female	538.63	5.14	40.16	467.61	540.20	611.20	
Lateral incisor volume	Male	312.44	2.33	23.28	244.12	309.35	404.09	>0.05
	Female	314.23	2.46	19.19	286.16	310.20	385.09	
Maxillary sinus volume	Male	12642	81.4	810	11029	12477	15212	0.022
	Female	12481	83.3	650	11393	12289	14198	
Non impacted								
Canine volume	Male	542.32	4.61	45.84	465.72	542.73	660.61	>0.05
	Female	543.47	5.27	40.83	472.30	545.71	615.70	
Lateral incisor volume	Male	363.81	3.94	39.41	282.14	366.30	578.20	0.003
	Female	372.35	5.57	43.46	297.35	370.50	578.20	
Maxillary sinus volume	Male	12914	79.4	790	11393	12743	15452	0.001
	Female	12698	82.7	646	11656	12487	14422	

Table 5: Comparing the canine, lateral incisors, and maxillary sinus volume between impacted and non-impacted sides for male and female patients separately

Sex variables	Impacted/non-impacted	Mean	SE	SD	Minimum	Median	Maximum	P
Male	Impacted	537.12	4.54	45.42	460.85	534.39	665.66	>0.05
Canine volume	Non-impacted	542.32	4.61	45.84	465.72	542.73	660.61	
Male	Impacted	312.44	2.33	23.28	244.12	309.35	404.09	0.002
Lateral incisor volume	Non-impacted	363.81	3.94	39.41	282.14	366.30	578.20	
Male	Impacted	12642	81.4	810	11029	12477	15212	0.003
Maxillary sinus volume	Non-impacted	12914	79.4	790	11393	12743	15452	
Female	Impacted	538.63	5.14	40.16	467.61	540.20	611.20	>0.05
Canine volume	Non-impacted	543.47	5.27	40.83	472.30	545.71	615.70	
Female	Impacted	314.23	2.46	19.19	286.16	310.20	385.09	0.003
Lateral incisor volume	Non-impacted	372.35	5.57	43.46	297.35	370.50	578.20	
Female	Impacted	12481	83.3	650	11393	12289	14198	>0.05
Maxillary sinus volume	Non-impacted	12698	82.7	646	11656	12487	14422	

Table 6: Spearman's correlation coefficient among these parameters (ADAHMLI, AARHMLI, the canine and lateral incisors, and the maxillary sinuses volume) in non-impacted male

	ADAHMLI (non-impacted side)	AARHMLI (non-impacted)	(Non-impacted) canine volume	Lateral incisor volume (non-impacted)	Maxillary sinus volume (non-impacted)
ADAHMLI (non-impacted side)					
r	1.000	−0.273	−0.115	0.085	0.077
P		0.093	0.488	0.608	0.639
n	39	39	39	39	39
AARHMLI (non-impacted					
r	−0.273	1.000	0.076	−0.232	0.109
P	0.093		0.646	0.155	0.509
n	39	39	39	39	39
(Non-impacted) canine volume					
r	−0.115	0.076	1.000	0.420**	−0.149
P	0.488	0.646		0.008	0.365
n	39	39	39	39	39
Lateral incisor volume (non-impacted)					
r	0.085	−0.232	0.420**	1.000	−0.073
P	0.608	0.155	0.008		0.658
n	39	39	39	39	39
Maxillary sinus volume (non-impacted)					
r	0.077	0.109	−0.149	−0.073	1.000
P	0.639	0.509	0.365	0.658	
n	39	39	39	39	39

Table 7: Spearman's correlation coefficient among these parameters (ADAHMLI, AARHMLI, the canine and the lateral incisors, and the maxillary sinuses volume) in non-impacted female

	ADAHMLI (non-impacted side)	AARHMLI (non-impacted)	(Non-impacted) canine volume	Lateral incisor volume (non-impacted)	Maxillary sinus volume (non-impacted)
ADAHMLI (non-impacted side)					
r	1.000	−0.050	−0.021	0.185	0.066
P		0.701	0.870	0.154	0.612
n	61	61	61	61	61
AARHMLI (non-impacted)					
r	−0.050	1.000	0.035	0.319*	−0.033
P	0.701		0.792	0.012	0.803
n	61	61	61	61	61
(Non-impacted) canine volume					
r	−0.021	0.035	1.000	0.011	0.006
P	0.870	0.792		0.933	0.965
n	61	61	61	61	61
Lateral incisor volume (non-impacted					
r	0.185	0.319*	0.011	1.000	−0.140
P	0.154	0.012	0.933		0.283
n	61	61	61	61	61
Maxillary sinus volume (non-impacted)					
r	0.066	−0.033	0.006	−0.140	1.000
P	0.612	0.803	0.965	0.283	
n	61	61	61	61	61

patients in the non-impacted (r = 0.420**, P = 0.008) and impacted sides (r = 0.334*, P = 0.038). Also, a positive correlation was found between ADAHMLI and lateral incisor volume for female patients in the impacted side (r = 0.296*, P = 0.021) as shown in [Table 10].

The calibration of the inter-examiner between the two observers revealed a statistically no significant difference as shown in [Tables 11 and 12].

When the tooth and sinus volumes were calculated using the VR Mesh program, it was discovered that, with the

Table 8: Spearman's correlation coefficient among these parameters (ADAHMLI, AARHMLI, the canine, and lateral incisors, and the maxillary sinuses volume) in impacted males

	ADAHMLI (impacted)	AARHMLI (impacted)	(Impacted) canine volume	Lateral incisor volume (impacted)	Maxillary sinus volume (impacted)
ADAHMLI (impacted)					
r	1.000	−0.265	−0.079	0.129	0.075
P		0.102	0.633	0.435	0.649
n	39	39	39	39	39
AARHMLI (impacted)					
r	−0.265	1.000	0.044	−0.093	0.092
P	0.102		0.791	0.572	0.580
n	39	39	39	39	39
(Impacted) canine volume					
r	−0.079	0.044	1.000	0.334*	−0.060
P	0.633	0.791		0.038	0.716
n	39	39	39	39	39
Lateral incisor volume (impacted)					
r	0.129	−0.093	0.334*	1.000	0.059
P	0.435	0.572	0.038		0.723
n	39	39	39	39	39
Maxillary sinus volume (impacted)					
r	0.075	0.092	−0.060	0.059	1.000
P	0.649	0.580	0.716	0.723	
n	39	39	39	39	39

Table 9: Spearman's correlation coefficient among these parameters (ADAHMLI, AARHMLI, the canine, and lateral incisors, and the maxillary sinuses volume) in impacted females

	ADAHMLI (impacted)	AARHMLI (impacted)	(Impacted) canine volume	Lateral incisor volume (impacted)	Maxillary sinus volume (impacted)
ADAHMLI (impacted)					
r	1.000	−0.065	−0.006	0.296*	0.051
P		0.617	0.964	0.021	0.696
n	61	61	61	61	61
AARHMLI (impacted)					
r	−0.065	1.000	0.040	0.133	−0.038
P	0.617		0.762	0.306	0.771
n	61	61	61	61	61
(Impacted) canine volume					
r	−0.006	0.040	1.000	−0.212	−0.004
P	0.964	0.762		0.101	0.975
n	61	61	61	61	61
Lateral incisor volume (impacted)					
r	0.296*	0.133	−0.212	1.000	−0.109
P	0.021	0.306	0.101		0.404
n	61	61	61	61	61
Maxillary sinus volume (impacted)					
r	0.051	−0.038	−0.004	−0.109	1.000
P	0.696	0.771	0.975	0.404	
n	61	61	61	61	61

exception of a few tiny decimals, they nearly had the same value.

Discussion

In the current study, 1:1.5 male-to-female ratios of palatally impacted canines coincide with the

1:2 male-to-female ratios (out of 1333 cases) reported by Moreira Telmo *et al*.[12] The prevalence of maxillary canine impaction in (x) population was (6.78%), and in terms of the investigated sample's gender, the number of impacted canines was higher in females than in males and also reported that the impaction occurred more unilaterally than on both sides that agrees with our findings.[13] The intensity and direction (positive or negative) of a relationship between two variables can be summarized using Spearman's rank correlation coefficient. The answer will always be between 1.0 (a perfect positive correlation) and −1.0 (a perfect negative correlation). Spearman's correlation coefficient was used instead of Pearman's correlation coefficient, because most of the parameters included in our study were not normally disturbed. A strong correlation was found between canine and lateral incisor volume in the impacted side, which coincides with the correlation

Table 10: Positive Spearman's correlation coefficient was found between these parameters

Parameter A	Parameter B	R	P
(Non-impacted) canine volume/male	Lateral incisor volume (non-impacted)/male	0.420**	0.008
AARHMLI (non-impacted)/female	Lateral incisor volume (non-impacted)/female	0.319*	0.012
(Impacted) canine volume/male	Lateral incisor volume (impacted)/male	0.334*	0.038
ADAHMLI (impacted)/female	Lateral incisor volume (impacted)/female	0.296*	0.021

Table 11: Test of normality comparing between the first and after a week of reading among these parameters (the canine, lateral incisors, and the maxillary sinuses volume) in the impacted and non-impacted sides

	Kolmogorov-Smirnova			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
(Impacted) canine volume	0.067	99	0.200*	0.971	99	0.030
Impacted canine after week	0.067	99	0.200*	0.971	99	0.030
(Non-impacted) canine volume	0.081	99	0.110	0.974	99	0.045
(Non-impacted) canine volume after a week	0.081	99	0.110	0.974	99	0.045
Lateral incisor volume (impacted)	0.157	99	0.000	0.905	99	0.000
Lateral incisor volume (impacted) after a week	0.157	99	0.000	0.905	99	0.000
Lateral incisor volume (non-impacted)	0.204	99	0.000	0.698	99	0.000
Lateral incisor volume (non-impacted) after a week	0.203	99	0.000	0.698	99	0.000
Maxillary sinus volume (non-impacted)	0.103	99	0.012	0.952	99	0.001
Maxillary sinus volume (non-impacted) after a week	0.103	99	0.012	0.952	99	0.001
Maxillary sinus volume (impacted)	0.522	99	0.000	0.079	99	0.000
Maxillary sinus volume (impacted) after a week	0.522	99	0.000	0.079	99	0.000

Table 12: Descriptive statistics between the first and after a week of reading among these parameters (the canine, lateral incisors, and the maxillary sinuses volume) in the impacted and non-impacted sides

	Mean	n	Std. Deviation	Std. Error Mean
Pair 1				
(Impacted) canine volume	536.9105	100	45.12070	4.51207
Impacted canine after a week	536.9229	100	45.11895	4.51189
Pair 2				
(Non-impacted) canine volume	542.5497	100	45.66561	4.56656
(Non-impacted) canine volume after a week	542.5516	100	45.66868	4.56687
Pair 3				
Lateral incisor volume (impacted)	312.4374	100	23.28548	2.32855
Lateral incisor volume (impacted) after a week	312.4401	100	23.28524	2.32852
Pair 4				
Lateral incisor volume (non-impacted)	363.8054	100	39.40814	3.94081
Lateral incisor volume (non-impacted) after a week	363.8090	100	39.41099	3.94110
Pair 5				
Maxillary sinus volume (non-impacted)	12913.9639	100	790.23589	79.42170
Maxillary sinus volume (non-impacted) after a week	12913.9695	100	790.23592	79.42170
Pair 6				
Maxillary sinus volume (impacted)	12649.8578	100	809.22079	80.92208
Maxillary sinus volume (impacted) after a week	12649.8636	100	809.22052	80.92205

that was done [14], and they found that the lateral incisor volume, buccolingual and mesiodistal width of the lateral incisor crown, root and the total lateral incisor length, the angulation of the lateral incisor to the midline, and the axis of neighboring canine were considered to be strong predictors for the impaction of the maxillary canine.

The findings of this study indicate favor for smaller volumes and shorter root lengths of maxillary lateral incisors in palatally displaced canines since it is able to have a significant local impact.[15] These findings support the guidance theory by showing that maxillary canine eruption is hampered by smaller maxillary lateral incisors, and it may be concluded that individuals who have smaller maxillary lateral incisor crowns, roots, and volumes are more susceptible to a deviated eruption of the maxillary canine.[14]) For the maxillary first premolars, canines, and central incisors, except for the length of the first premolar, there were no statistically significant differences in root lengths or volumes among the three groups,[15] which agree with our results in that there was no significant difference in the canine volume in the (impacted/non-impacted sides) for male and female patients.

CBCT is an effective and noninvasive diagnostic imaging modality in clinical dentistry due to its limited radiation exposure and ability of producing highly accurate life-size images. The constant overestimation of the volume may be explained by a number of factors that have an impact on the images produced by the used CBCT scanning. The voxel size, the field of view (FOV), scattered x-rays, and subjectivity in the segmentation process can be recognized as some of them.[16] It was determined that the CBCT is strong and accurate for measuring the tooth volume *in vivo* and was statistically comparable to measurements made *in vitro*.[17] Additionally, the manual segmentation steps have a certain amount of subjectivity built into them that can continuously skew the results in favor of a decrease or an increase in volume.[16] In conclusion, CBCT can be used to accurately reconstruct 3D tooth models for linear, volumetric, and geometric measurements.[18]

The volume of teeth depends on the threshold interval and segmentation methods, which are variable for each software as well as the operator.[19] Mimics software has more options for segmentation and has a slight learning curve.[19] In the present study, the segmentation was done semi-automatically and picked with the whole tooth 3D volume examination rather than merely dental roots that are apical to the cementoenamel junction (CEJ), because it is regarded as being more definitive.[20]

The purpose of the current study was to compare the dentoalveolar and skeletal dimensions of the maxillae

in a sample with unilaterally palatally impacted canines to the contralateral normal erupted side in order to assess the effectiveness of CBCT in volume measured using the (MIMICS) program and VR Mesh. Volumetric measurements can be made using a variety of computer applications, including Mimics, Dolphin, and ITK-Snap, among others. No previous studies measured the volume of the maxillary sinus in patients with unilateral palatally maxillary impacted canines using VR Mesh. The maxillary canine eruption occurs between 11 and 12 years of age, while the maxillary sinus reaches its maximum size between 12 and 15 years of age and it does not significantly increase in its volume after 12 years of age.[21] Therefore, in the current study, the maxillary sinus volume was evaluated in patients aged above 12 years with unilateral palatally maxillary canine impactions. They discovered that male patients had the considerably greater mean right, left, and total maxillary sinus volumes than female patients. The fact that the males have typically a larger physical form than the females in most dimensions can be ascribed to the disparity in maxillary sinus volumes between the sexes.[22] In contrast, the present study found that thesinus volume was greater in males than in females. Additionally, the results will not be altered by the existence of an impacted canine on either the right or left side because prior research found no discernible difference in the volumes of the maxillary sinuses on the right and left sides.[23] Dental impaction may be connected to a decrease in the maxillary sinus volume.[23] The maxillary sinus volumes increased statistically significantly in the non-impaction sides 12770.71 ± 1621.24 mm^3 compared to the impaction side 11377.17 ± 1386.87 mm^3,[6] which was similar to our results. In the current study, smaller maxillary sinus volume was observed on the impacted canine side than on the opposing side. This result agreed with that of Zeynep *et al*.[24] who stated that when the canine was impacted on the right side, the volume of the right maxillary sinus was substantially lower than that of the left side. On the other hand, Kalabalık and Tarım Ertas[23] observed no discernible variation between the right and left sides, leading them to conclude that unilaterally impacted teeth have no effect on the maxillary sinus volume. Zeynep A *et al*.[24] reported that a deeply impacted canine has an impact on maxillary sinus volume by measuring the distance from the canine cusp tip to the palatal plane in their research.

The results of the current study show that non-significant differences when the AARHMLI and ADAHMLI were measured ($p > 0.05$), which agrees with the D' Oleo-Aracena *et al*. study;[25] in that there were statistically negligible variations between the impacted and non-impacted sides in all of these dimensions. In the study of Tadinada *et al*.,[26] however, the results were different; the impacted side's alveolar bone

dimensions (from the nasal floor to the alveolar ridge) were substantially smaller than those on the non-impacted side. In this study, measurements were done in the canine region depending on the fact that incisor eruption occurs before canines, so we believe that the height of the incisors should not be affected. VR Mesh Reverse, which was used in the current study, is the unique technology that we have that helps you convert large point clouds to meshes quickly and accurately. And a comprehensive toolset is provided, including point cloud cleanup, mesh repair/editing, registration, inspection, and measurement.

Outlining the precise location of the impacted canine in three dimensions is critical in the planning of the treatment and offers good assessment-making that may permit uninterrupted access or traction and less time-consuming treatment and less invasive.[27] Furthermore, the treating orthodontist was able to quickly reposition the impacted canine into normal occlusion due to the precise 3D image of the affected tooth.[27]

The number of samples with a unilaterally impacted maxillary canine was relatively low, which makes it difficult to accurately quantify prevalence without using many samples. We think that more enquiries with bigger sample numbers are necessary to define the relationship between impacted canine and maxillary sinus volume in the general population.

Conclusion

The results of the current study show non-significant differences in the AARHMLI and ADAHMLI measured ($p > 0.05$). There is no significant difference in the canine volume in the (impacted/non-impacted side), but it showed a statistically significant difference for the Lateral incisor volume in the impacted and non-impacted side for male and female patients. The Maxillary sinuses volume revealed statistical differences between males and females in impacted and non-impacted sides.

Ethical approval

Dear Dr, On behalf of Research Ethics Committee, I can confirm that the committee has reviewed the above project and permission to commence has been granted on the basis described in the application form as well as on the understanding that the study is conducted in accordance with the research guidelines followed in the University of Mosul/College of Dentistry. REC reference no. is Uom.Dent/H.48/22.

Conflicts of interest
There are no conflicts of interest.

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