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Original Research Article

Three-dimensional morphometric analysis of maxillary and mandibular molars and bilateral correlation in North Indian population

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ABSTRACT

Aim: The aim of this study was to evaluate and compare the anatomical landmarks of maxillary and mandibular molar pulp chambers and evaluate bilateral symmetry between contralateral molars using CBCT.

Materials and Methods: CBCT scans of 200 molars from 157 patients were selected for the study. A total of nine measurements - A (Distance from the cusp tip to the roof of the pulp chamber) B (Distance from the cusp tip to the floor of the pulp chamber) C (Distance from the cusp tip to the furcation) D (Distance from the floor of the pulp chamber to the furcation) E (Distance from the roof of the pulp chamber to the furcation) F (Height of pulp chamber) A1(Distance from the central fossa to the roof of the pulp chamber) B1 (Distance from central fossa till the floor of pulp chamber) C1 (Distance from central fossa to furcation) were done.

Results: Statistical analysis was done using the ANOVA and Post hoc tests and statistical significance was set at $p<0.05$. Significant differences in maxillary and mandibular molars were noted in the measurements of- D, E, B and C1. Bilateral symmetry was also observed between the pairs of maxillary and mandibular molars.

Conclusion: Maxillary first and second molars do not differ much from each other. However, mandibular first and second molars differed in various anatomic parameters from each other. Contralateral molars (maxillary and mandibular) pulp cavities, in general, exhibit matching symmetry in terms of their morphological and anatomical landmarks.

1. Introduction

The preliminary step in performing endodontic therapy is establishing an ideal access to the root canals. This permits not just the localization of the orifices, but also the adequate cleaning, shaping, disinfection, and three-dimensional obturation of the root canal system. Iatrogenic errors commonly occurring during access cavity preparations are either, due to failure in following the guidelines, or due to the lack of understanding of the external and internal morphology of the tooth. Perforation being one such error can reduce the success rate of a root canal treatment by 30%.[1]

Pulp space in the teeth often show considerable variations in their anatomy due to age changes, disease processes like caries, and trauma. These could result in receding of the pulp horns, smaller pulp chambers in height than in width, and calcifications in the pulp chamber space. In such cases, gaining an access to the root canal orifices could be challenging for the clinicians, and relying on crude

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techniques like the "drop effect" or the "dip effect" may not assure success.[2] Thus, the need for more scientific landmarks and their correlation to studying the internal morphology of the pulp chamber is desired to minimize the occurrence of iatrogenic perforation during access cavity preparation.

Khojastepour[3] suggested that undesirable accidents like dentinal gouging, incomplete de-roofing, perforation, and missed canals could be minimized with detailed knowledge of anatomy and skilful therapeutic intervention. Hence, a more comprehensive understanding of the location of the anatomical landmarks in the teeth serves as a prerequisite for an ideal access cavity with maximum tooth structure conservation.

Several researchers in the past have studied the dimensions of molar pulp chambers and have found consistent results like smaller pulp chambers in mandibular teeth as compared to maxillary teeth, the average distance between the cusp tip to pulp chamber ceiling being 6 to 7 mm, and absence of sex predilection.[4–9] However, what is common in the above-mentioned studies is that they evaluated the landmarks by IOPA and bitewings which provide information only in two dimensions.

With the advent of advanced digital three-dimensional radiographic techniques like Spiral Computed Tomography (SCT) and Cone Beam Computed Tomography (CBCT), the limitations of 2D imaging have been overcome. CBCT has proven to be a valuable tool in the field of endodontics and it may provide us with precise anatomic information across three different planes before root canal treatment.[10] Thus, the aim of this study was to evaluate and compare the anatomical landmarks of maxillary and mandibular molar pulp chambers and evaluate bilateral symmetry between contralateral molars using CBCT.

2. Materials and Methods

This observational study was conducted in Meerut, representing India's northern population. Upon receiving the ethical clearance from Institutional Review Board, patients (both male and female between the age group of 19-64 years) requiring CBCT scan due to diagnostic requirements were included in the study. Before the commencement of data collection, verbal and written consent were obtained from all the participants. Patients with missing, restored, carious, attrided molars and molars with varied anatomy (C-shaped canals and Taurodontism) were excluded. Two hundred molars (50 each of maxillary 1^{st} and 2^{nd}, mandibular 1^{st} and 2^{nd} molars) from 157 patients were selected for the study.

CBCT imaging was done using the Orthophor SL 3D (Sirona Dental System, GmbH Fabrikstra Be31, 64625 Benshein, Germany) with an effective radiation dose of 15-273μm, isotropic voxel edge size of 0.16mm and exposure time of 2-5 sec with 11x10 imaging volume of maxillary and mandibular arches.

All scans were performed by experienced oral radiologists following the manufacturer's instructions. The morphological and anatomical landmarks were measured in the coronal plane. Two reference points: the cusp tip and the central fossa were used in this study.

Total of 9 measurements were taken (Figures 1 and 2).

A- Distance from the cusp tip to the roof of the pulp chamber in mm

B- Distance from the cusp tip to the floor of the pulp chamber in mm

C- Distance from the cusp tip to the furcation in mm

D- Distance from the floor to the furcation in mm

E- Total distance (pulp chamber + furcation) in mm

F- Height of pulp chamber in mm

A1- Distance from the central fossa to the roof of the pulp chamber in mm

B1- Distance from central fossa till the floor of pulp chamber in mm

C1- Distance from central fossa to furcation in mm

These 9 different landmarks were calibrated and measured with the help of the measuring tool in the software, Sidexis 4 Digital dental imaging software [Sirona Dental System, Benshein, Germany]. To eliminate the operator bias, these measurements were made by two oral radiologists, excluding those who scanned the data. In case of disagreement, the measurements were redone to reach a common consensus.

Statistical analysis of the data obtained was done using Windows PC-based "SPSS Statistics software" (version 12.0, SPSS Inc; IBM Corporation, United States). For multiple comparisons against groups, ANOVA and post hoc tests were used. A p-value <0.05 was considered statistically significant for each measurement.

3. Results

The mean, standard deviation, and p value for each measurement are presented in Tables 1 and 2. The mean measurements of different anatomic landmarks in maxillary and mandibular molars were compared using the Analysis of Variance (ANOVA) test. Significant differences (p<0.05) were noted in the measurements of- distance from the floor of the pulp chamber to the furcation (D), the total distance from the pulp chamber to the furcation (E), distance from the central fossa to the floor of the pulp chamber (B1) and distance from the central fossa to the furcation (C1).

On multiple comparisons between the maxillary (first and second) and mandibular (first and second) molars by post hoc tests (Tables 3 and 4), a significant statistical difference was found between maxillary first and second molars in the measurement of D landmark (p value 0.000) and in the measurements of A (p value- 0.000), B (p value- 0.000), C (p value- 0.000), F (p value- 0.006), B1 (p value- 0.002) and C1 (p value 0.041) between mandibular first and

Table 1: Mean measurements of different anatomic landmarks in maxillary and mandibular first and second molars.

	Mean ± Standard Deviation				
Landmarks	**Maxillary first molars**	**Maxillary second molars**	**Mandibular first molars**	**Mandibular second molars**	**P value**
A	5.71±0.88	5.49±0.91	5.29±0.92	6.11±0.71	0.00
B	7.82±0.91	7.97±1.2	7.21±0.96	8.48±0.89	0.00
C	10.68±1.07	10.27±1.44	9.63±1.03	10.88±0.99	0.00
D	2.82±0.55	2.31±0.50	2.45±0.63	2.30±0.72	0.00
E	4.95±0.90	4.86±1.21	4.34±0.70	4.63±0.89	0.006
F	2.09±0.67	2.42±0.82	1.88±0.59	2.34±0.65	0.00
A1	3.90±0.83	3.95±0.66	3.63±0.70	4.00±0.85	0.084
B1	6.14±0.86	6.44±1.16	5.53±0.85	6.25±1.08	0.00
C1	8.93±0.89	8.77±1.44	8.00±1.00	8.62±1.24	0.001

Table 2: Mean measurements of different anatomic landmarks in maxillary and mandibular molars.

	Mean ± Standard deviation		
Landmarks	**Maxillary molars**	**Mandibular molars**	**P value**
A	5.60±0.98	5.70±0.91	0.449
B	7.90±1.06	7.85±1.12	0.751
C	10.47±1.28	10.26±1.19	0.217
D	2.56±0.58	2.37±0.67	0.035
E	4.97±1.02	4.48±0.81	0.002
F	2.26±0.75	2.11±0.66	0.149
A1	3.92±0.75	3.81±0.80	0.317
B1	6.29±1.03	5.89±1.04	0.006
C1	8.85±1.19	8.31±1.16	0.001

Table 3: Comparison of mean measurements of different anatomic landmarks in maxillary first and second molars.

	Mean ± Standard deviation	
Landmarks	**Maxillary 1^{st} and 2^{nd} molars**	**P value**
A	0.225 ± 0.173	.562
B	0.146 ± 0.200	.885
C	0.414 ± 0.230	.278
D	0.511 ± 0.121	.000
E	0.086 ± 0.189	.969
F	0.329 ± 0.139	.087
A1	0.044 ± 0.154	.991
B1	0.304 ± 0.200	.430
C1	0.165 ± 0.232	.893

Table 4: Comparison of mean measurements of different anatomic landmarks mandibular first and second molars.

	Mean ± Standard deviation	
Landmarks	**Mandibular 1^{st} and 2^{nd} molars**	**P value**
A	0.814 ± 0.173	.000
B	1.277 ± 0 .200	.000
C	1.254 ± 0 .230	.000
D	0.153 ± 0 .121	.590
E	0.296 ± 0 .189	.402
F	0.459 ± 0 .139	.006
A1	0.366 ± 0 .154	.085
B1	0.725 ± 0 .200	.002
C1	0.622 ± 0 .232	.041

Table 5: Mean measurements of different anatomiclandmarks in bilateral maxillary molars.

Variable	T16		T26		't' value	P value	Variable	T17		T27		't' value	P value
	Mean	± SD	Mean	± SD				Mean	± SD	Mean	± SD		
A	5.565	0.878	5.507	0.978	0.349	0.733	A	5.5925	0.84798	5.4667	0.90183	1.415	0.185
B	7.928	0.81478	7.634	1.0047	1.696	0.112	B	7.9733	1.12256	8.1333	1.25346	-0.832	0.423
C	10.7107	0.92787	10.4313	1.06414	1.197	0.251	C	10.4333	10.4542	1.14468	1.42366	-0.08	0.937
D	2.754	0.48271	2.802	0.65151	-0.347	0.734	D	2.5575	2.3417	0.40358	0.47147	1.206	0.253
E	5.1367	0.82116	4.9047	1.02186	1.14	0.273	E	5.0425	5.1958	1.11352	1.48291	-0.887	0.394
F	2.3253	0.79001	2.078	0.83222	1.705	0.11	F	2.4283	2.4283	0.9151	0.82471	0	1
A1	3.882	0.75193	3.9067	0.91566	-0.106	0.917	A1	4.0217	3.8308	0.59827	0.69178	1.638	0.13
B1	6.4167	0.80508	6.0993	0.99612	1.396	0.185	B1	6.3758	6.4067	1.16087	1.37854	-0.213	0.835
C1	9.1447	0.7887	8.7513	1.00734	1.876	0.082	C1	8.9467	8.7408	1.32868	1.6927	0.872	0.402

Table 6: Meanmeasurements of different anatomic landmarks in bilateral mandibular molars.

Variable	T36		T46		't' value	P value	Variable	T37		T47		't' value	P value
	Mean	± SD	Mean	± SD				Mean	± SD	Mean	± SD		
A	4.605	0.57204	4.6925	1.34765	-0.152	0.889	A	6.3313	0.92295	5.945	0.69525	1.231	0.258
B	6.8725	0.63442	7.0125	1.01612	-0.577	0.604	B	8.86	0.76644	8.3263	0.83922	2.768	0.028
C	9.1525	0.97103	9.3475	0.73595	-0.601	0.59	C	10.955	0.92523	10.9663	1.22264	-0.039	0.97
E	2.3125	0.40358	2.3925	0.47147	-0.288	0.792	D	1.9987	0.69004	2.6038	0.97188	-2.627	0.034
F	4.545	0.6481	4.7075	0.93032	-0.494	0.655	E	4.6637	1.25972	4.9125	0.97036	-0.698	0.508
G	2.2425	0.38483	2.2175	0.55949	0.057	0.958	F	2.7738	0.72732	2.39	0.65185	1.213	0.265
A1	3.4975	0.61256	3.54	0.63482	-0.19	0.862	A1	4.0888	1.02554	4.07	0.95582	0.086	0.934
B1	5.825	0.72528	5.8375	0.62404	-0.065	0.953	B1	6.665	1.32993	6.49	1.21163	0.531	0.612
C1	8.035	1.18202	8.265	0.55169	-0.678	0.546	C1	8.8975	1.62903	8.9463	1.44971	-0.139	0.894

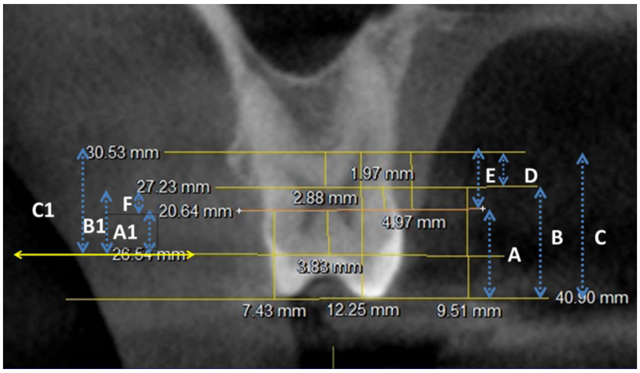

Fig. 1: CBCT image of the maxillary molar showing the nine measurements (A, B, C, D, E, F, A1, B1, C1) taken in this study.

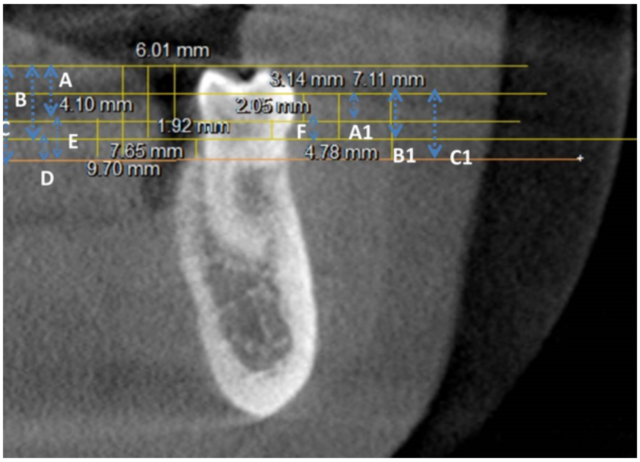

Fig. 2: CBCT image of the mandibular molar showing the nine measurements (A, B, C, D, E, F, A1, B1, C1) taken in this study.

second molars.

Comparison of both maxillary and mandibular molars with their contralateral partners revealed no statistical difference except for mandibular second molars for landmark B and D (Tables 5 and 6).

4. Discussion

Thorough knowledge of the morphological landmarks of the pulp chambers of teeth is essential to avoid iatrogenic errors that could commonly occur during the initial steps of root canal treatment. Gaining access to the pulp chamber, locating the root canal orifices, and thus conserving the remaining dentin without gauging, or perforating into the furcation could be possible only for the knowledge and understanding of these landmarks. Therefore, it is essential to prudently analyse the size, and shape of the pulp chamber before performing root canal treatment.

Laws of access opening have been well established by Krasner and Rankow.[11] Although these guidelines are universal, there exist variations in the root canal anatomy and pulp chamber morphology amongst different ethnic groups. This makes it essential to conduct studies in different populations and to do an in-depth analysis of the pulp chamber morphology with as many landmarks as possible to supplement the knowledge with scientific evidence.

Studies done in the past have evaluated morphological landmarks of pulp chambers in both molars and premolars using two-dimensional radiographs.[3,4,6,12–14] Research on the Indian population by Vijaykumar et al[15] and Selvakumar et al [12] although utilized spiral CT however their studies were conducted on primary, not permanent teeth. Bovino et al evaluated the pulp chamber thickness in the primary teeth of the Brazilian population by CBCT.[16]The use of CBCT provides better accuracy and yields more information than intra-oral periapical radiographs, bitewings.[17] To the best of our knowledge, this is the first 3D CBCT search to analyse the morphological landmarks in the North Indian population.

Permanent mandibular molars are the most commonly endodontically treated teeth and also the one with the most frequent procedural errors. The least endodontically treated teeth are the permanent third molars.[18]Therefore, only the first and second molars were analysed in this study. Two points, the cusp tips, and central fossa were utilized as reference points because the cusp tips of molars are the most stable, reproducible, and commonly referred landmarks and the central fossa is often the area from which access is initiated. This is in accordance with the study by Azim et al.[10]The coronal plane was used for the visualization of the morphological landmarks in this study. This allowed the complete visualization of the teeth longitudinally from cusp tips to the furcation and even to the periapical areas. The best coronal section was selected by adjusting the axial and sagittal views. Moving the axial view corona-apically and apico-coronally, the desired landmarks were selected accurately.

Maxillary and mandibular molars showed a statistical difference in the mean measurements of D, E, B1, and C1. The clinical significance of difference in D and E between maxillary and mandibular molars is that the safety margin (Pulp chamber roof to furcation) to prevent furcation perforation after pulp chamber penetration is less in mandibular molars (4.48 mm) than maxillary molars (4.97 mm). Thus, the operators should be more careful while preparing access in mandibular molars.

According to the study by Deutsch et al, the mean distance between the pulp chamber floor to the furcation (D) in maxillary molars was 3.05 mm and 2.96 mm in mandibular molars.[4]This is in contrast to the values of 2.56 mm and 2.37 mm respectively found in this study. The reasons for these variations between the studies could be racial diversity. The difference in results of the present study and Deutsch et al reinforces the fact that for each ethnic group evaluation of different landmark measurements is necessary. Another reason of this difference may be due to the fact that Deutsch et al evaluated the landmarks by two-dimensional radiographs contrary to three-dimensional imaging used in the present study.

Reuben et al in their spiral CT study on extracted human mandibular first molars found the distance from the pulp chamber floor to the furcation (D) was 2.53mm and the height of the pulp chamber was 1.84 mm which are almost similar to the finding of the present study (2.45 mm and 1.88 mm respectively). However, the distance between the central fissure and the pulp chamber ceiling (A1) to be 4.19 mm while from the central fissure to the pulp chamber floor(B1) was 6.03 mm in Indian population.[19] These differences may be due to the differences in the racial population in South India (Dravidians) and North India (Aryans).

The distance from the cusp tip to the furcation (C) in maxillary first molars is approximately 1mm more than the mandibular first molar. This complies with the study done by Khojastepour et al, although they evaluated the landmarks on bitewing radiographs.[3]

Shreshtha et al measured the pulp chamber landmarks by radio-visio graphs and CBCT of maxillary premolars and found them to be comparable to each other.[13] However, differences in the measurements could be invariable due to the shortcomings of two-dimensional radiographs. We found similar results in comparing the present study to a previously conducted study in the same western UP region by Agarwal and Nikhil et al.[2] Although comparable, differences of approximately 0.5mm were observed in certain landmarks like "C" (cusp tip to the furcation) and "E" (pulp chamber floor to furcation).

Multiple comparisons between the maxillary molars (both first and second) and mandibular molars (both first and second) showed a significant statistical difference between them. Thus, establishing access in a maxillary tooth would be entirely different from a mandibular tooth as the pulp chamber anatomy differs completely. However, maxillary first and second molars do not differ much from each other, but the distance between the pulpal floor to the furcation (D) was different between the two. Which invariably suggests that one would encounter the furcation at different depths in both teeth. Thus, one needs to be meticulous in their technique of gaining access to the teeth.

There was also an attempt to check the bilateral symmetry between contralateral molars with an aim that in case there is any symmetry found, the availability of even contralateral CBCT can be helpful for guiding endodontic access of any molar. It was observed in the present study that there was the occurrence of bilateral symmetry amongst the maxillary first and mandibular first molars. This is a novel finding with respect to the investigations of the pulp chamber anatomy. Thirty-six pairs of teeth (15 pairs- of maxillary first molars, 12 pairs- of maxillary second molars, 8 pairs- of mandibular second molars, and 4 pairs- of mandibular first molars) showed non-significant differences among each other. This suggests that bilateral symmetry exists between them except for two parameters in mandibular second molars- "B" and "D". However, this finding cannot be extrapolated since the number of pairs of mandibular molars was less. Not much research has been done with regard to the bilateral symmetry of pulp chamber morphology of molars or any other tooth.

As this observational study was conducted using CBCT and not two-dimensional radiographs, the limitation of this study could be the bounded sample size. Future studies should also focus on the 3-dimensional analysis of bilateral pulp chamber symmetry with a greater number of sample size.

5. Conclusion

The study has three-dimensionally and quantitatively analysed the pulp chamber anatomy in detail, which is essential before the commencement of the endodontic treatment. Clinically, mandibular first and second molars identify differently and hence must be accessed differently. The burs should not extend beyond 10mm in maxillary and mandibular molars to avoid perforation in the furcation. Contralateral molar pulp cavities, in general, exhibit matching symmetry in terms of their morphological and anatomical landmarks.

6. Conflicts of Interests

The authors have no financial interests or conflicts of interests.

7. Source of Funding

None.

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