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Original Article

Criteria for Classification of Inter-Radicular Septum Shape in Maxillary Molars with Clinical Importance for Immediate Implant Placement

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ABSTRACT

Objective: To explore the use of Cone Beam Computed Tomography to evaluate morphometric properties of the Inter-Radicular Septum in maxillary first and second molar region.

Study Design: Cross-sectional study.

Place and Duration of Study: Armed Forces Institute of Dentistry, Combined Military Hospital, Rawalpindi Pakistan, from Jul to Dec 2023.

Methodology: Cone Beam Computed Tomography scans of 177 patients, recruited via consecutive sampling technique were obtained and analyzed using NEWTOM software. Patients falling in the age range of 18-65 years, having first and second maxillary molars were included. The Inter-Radicular Septum morphometric properties of maxillary first and second molars were evaluated in coronal and axial plane. Inter-Radicular Septum widths and areas of M1 and M2 were compared at different levels by applying ANOVA/Kruskal Wallis test based upon data normality

Results: Out of 177 patients, 118(66.7%) were males, while 59(33.3%) were females with mean age 40.49±1.33 years. Frequency of arrow shape of molars (M1&M2) was highest [119(67.2%) and 136(76.8%) respectively]. Mean difference of Inter-Radicular Septum widths across all levels was significantly varied with respect to shapes of Molar 1 and Molar 2 as well (p<0.05). Boat shape of molar 1 & 2 had greatest furcation angle (60.14+12.85 and 56.12+11.01 respectively) and the mean difference was significant across different IRS shapes (p<0.001 and p=0.034 respectively). Inter-Radicular Septum surface area required for implant placement was most prominent in buccal convergence shape in maxillary first molar and boat shape in maxillary second molar.

Conclusion: Cone Beam Computed Tomography image analysis can serve as a useful tool for anticipating conditions that significantly enhance the planning of immediate implant placement procedures in posterior maxilla.

Keywords: Cone Beam Computerized Tomography, Immediate Implant Placement, Inter-Radicular Septum.

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INTRODUCTION

The inter-radicular septum is described as an area in root furcation that separates alveoli of multi-rooted tooth.[1] The upper molars are usually multi-rooted teeth predominantly with three roots, so the septal bone between them usually expresses triangular shapes.[2] The primary area of available bone for immediate implant placement is inter-radicular septal bone of multi-rooted teeth.[3] In some cases, insufficient inter-radicular bone septum could compromise implant placement procedures.[4] In order to achieve more successful implant therapy using the inter-radicular bone septum as the implant place, Agostinelli and coworkers reported the importance of morphological characteristics of inter-radicular bone septum as the criteria determining the therapy.[5]

As the inter-radicular septum of the maxillary molars expresses significant morphometric variability (height and width) , preoperative radiological analyses are highly recommended.[6] CBCT provides a possibility to achieve detailed inter-radicular septum morphological characteristics in the region of the posterior maxilla, which may significantly impact the characteristics of implant. Inter-radicular septum width can be measured by CBCT analysis which can play important role in the prognosis of implant therapy success.

The ideal positioning of immediate implants in molar extraction socket often requires the osteotomy to be in the inter-radicular septum, which can be challenging in some cases, with traditional site preparation techniques.[7] Therefore, numerous studies aim to measure its architecture, Agostinelli in his

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study concluded that the mean available height of IRS was 7.43 and 7.07mm for the upper first and second molars.[5] For primary implant stability the recommended minimum length for implant is 10mm.[6] Moreover, inter-radicular septa with minimum 3mm width is important for providing initial stability to the implant, as this residual bone tend to have more volume towards the apical region.[8] In most cases of IRS width in region of maxillary molar is less than 3mm, this require additional surgical procedures, such as osseo-densification, to provide implant stability.

The existing literature provides various classifications based on the dimensions of the inter-radicular septum. Smith and Tarnow classification can be roughly utilized as a useful clinical guide for placing appropriate sizes of dental implants into the IRS.[9] However, there appears to be no published data to quantify IRS characteristics before extraction. Moreover, another classification of extraction socket width is determined according to implant diameter. This study proposed a new diagnostic classification based on the initial septal width prior to site preparation and implant placement.[7] However, there is a requirement of pre-clinical studies that can accurately assess inter-radicular morphometric characteristics before any intervention.

This study aimed is to validate previous findings and establish a quantitative method that clinicians can employ for a quicker and more reliable plan for immediate implant placement in the maxillary molar area. Hence the objective of this study is to assess the morphometric characteristics of the inter-radicular septum of M1 and M2 using CBCT images.

METHODOLOGY

A cross-sectional study was conducted after Ethical approval by the Ethical Committee of Armed Forces Institute of Dentistry (IRB Form No. 905/Trg-ABP 1K2). CBCTs of 177 patients were obtained from the department of Prosthodontics, during the study period of July 2023 to December 2023. Sample size of 42 was calculated by using WHO sample size calculator based upon the 97.2%[10] maxillary molars, 95% confidence level and 5% margin of error. However, we collected data from 177 patients presented with healthy molars.

Inclusion Criteria: The study included patients falling in the age range of 18-65 years, having first and or second maxillary molars.

Exclusion Criteria: Patients having dental or maxillo-facial pathology in the area of maxillary molars i.e. inter-radicular resorption, peri-apical lesions, cysts, tumor, trauma, bone grafts, bony surgical intervention, dental implants and patients having systemic disease were excluded.

Prior to data collection and patient examination, informed consent was obtained from patients. The maxillary molars inter-radicular septum morphometric characteristics were evaluated using NNT Viewer software. In coronal plane, the following linear measurement were marked and recorded: (as shown in Figure-1) IRS width 2mm from the inter-radicular furcation,- IRS width at midpoint of IRS height, IRS width 2mm from the IRS base,IRS width at IRS base, IRS height—h (the distance between the inter-radicular furcation and IRS base); The distance between IRS base and sinus floor—H and Inter-radicular furcation angle.

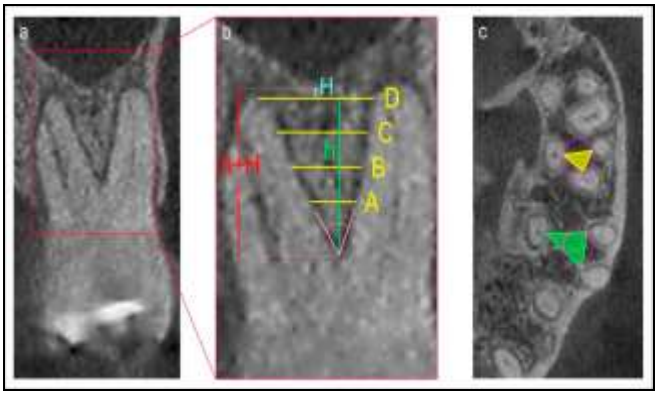

Figure-1: CBCT Scans of the Maxillary Molar Region in the Coronal View. a) CBCT Image b) Landmarks of CBCT Image c) Axial View

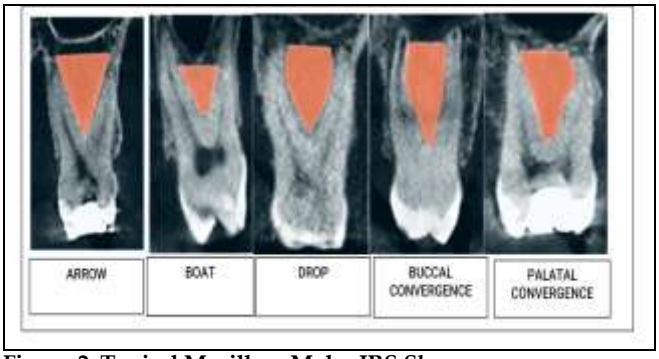

Figure-2: Typical Maxillary Molar IRS Shapes

In Axial plane, after radiological construction, surface area of inter-radicular septum was calculated using Heron's formula. IRS shapes were identified and systematic criteria was applied to IRS shape in maxillary molar region. Based on the numerical criteria, especially the diameter of IRS at D level and

IRS furcation angle as outlined in Table-I and visually represented in Figure-2, a classification system for IRS shapes is used as proposed by Pavlovic.[6] This classification comprises of five different categories: arrow, boat, drop, buccal convergence and palatal convergence.

Data analysis was done through Statistical Package for Social Sciences (SPSS) version 23:00. Means and standard deviations were used to express quantitative data. While for qualitative data frequencies and percentages were calculated. IRS widths and areas of M1 and M2 were compared at different levels by applying ANOVA/Kruskal wallis test based upon data normality. *p*-value <0.05 was kept statistically significant.

RESULTS

This study was performed on CBCT images obtained from 177 patients (118 males and 59 females), with a mean age of 40.49±1.33 years.

Frequency of arrow shape of molars (M1 & M2) was higher in study participants 119(67.2%) and 136(76.8%) respectively) followed by boat shape 32(18.1%) in M1 and drop shape 16(9.0%) in M2. Lowest percentage of patients had drop shape of M1 (2.3%) as shown in Table-I.

The quantitative criteria for maxillary molar inter-radicular septum shape classification is developed to allow analysis of individual parameters depending on visually identified IRS shapes i.e. Arrow, Boat, Drop, Palatal convergence, Buccal convergence as shown in Table-I.

The estimation of coronal views for the maxillary molars revealed that IRS shape significantly affects the dimensions of IRS at all levels. The length determined at level A was significantly lower in drop when compared with other shapes. Boat shape have highest value at B, C, and D in M1 among other shapes. In M2, Boat and palatal convergence have highest values at all levels (Table-II).

Findings of Table-II showed that widths of molars were comparatively higher at D-level. Mean difference of IRS widths across all levels was significantly varied with respect to shapes of Molar 1 and Molar 2 as well (p<0.05). Boat shape of molar 1 & 2 had greatest furcation angle (60.14+12.85 and 56.12+11.01 respectively) and the mean difference was significant across different IRS shapes (p<0.001 and p=0.034 respectively).

Table-III presented IRS areas at each level and revealed statistically insignificant difference of means of areas for first as well as second molar (p>0.05). However, highest areas were found at D-level of each type of IRS shape with greatest area of buccal convergence (11.11±3.20 mm2) in case of first molar and of boat shape Med (IQR)=6.58(4.75-8.96) for second molar.

Table-I: Distribution of Furcation Angle and IRS Length at D Level of M1 and M2 (n=177)

Inter-radicular Septum Shape	Frequency (%)		Furcation Angle		IRS Length at D level	
	M1	M2	M1	M2	M1	M2
Arrow	119(67.2)	136(76.8)	>50	≤50	>6	≥6
Boat	32(18.1)	11(6.2)	>50	>50	>6	≥6
Buccal Convergence	4(2.3)	6(3.4)	>50	≤50	>6	≥6
Palatal Convergence	16(9.0)	8(4.5)	>50	>50	>6	≥6
Drop	6(3.4)	16(9.0)	≤50	≤50	≤6	<6

IRS=Inter-radicular Septum

DISCUSSION

The current study showed significant difference in distribution of IRS shapes in first and second maxillary molars. Specifically, the arrow shape was predominant in both first and second maxillary molars, while buccal convergence was consistently least frequent. In dental and maxillofacial radiology, CBCT is established as standard radio graphic imaging technique, with a wide variety of applications in this field.[11] It is used in pre-surgical diagnosis, pre-operative planning and per-operative transfer for oral implant rehabilitation.[12] The main indications for CBCT use are assessment of anatomical structures and implant sites, determination of root canal morphology, visualization of impacted teeth, tooth alignment and localization, suspected cysts or tumors, evaluation of temporo-mandibular joint disorders and many other reasons.[13] To obtain morphological and morphometric properties of inter-radicular septum in posterior maxilla CBCT scan were used. IRS morphometric properties were analyzed according to methodology devised by Regnstrand and colleagues who described this relationship between maxillary molars and maxillary sinus with a 3D approach.[14] It was identified that each IRS shape is characterized by unique morphometric properties observable in both coronal and axial views. Accordingly, the arrow, boat, buccal convergence and palatal convergence shaped IRS, the length at D level was above 6mm, whereas only the drop shaped IRS width at the D level was below 6mm in both first and second maxillary molars. Interestingly, the IRS furcation angle showed more

variations according to IRS shape in the first maxillary molars when compared to second maxillary molars.

The current study showed significant difference in distribution of IRS shapes in first and second maxillary molars. Specifically, the arrow shape was predominant in both first and second maxillary molars, while buccal convergence was consistently least frequent. Milenkovik's study demonstrated comparable findings in the distribution of IRS shape, demonstrated comparable findings in the distribution of IRS shape, highlighting the predominance of the arrow shape and least prevalence of the drop shape.

To enhance our understanding of the clinical relevance of IRS shape classification, we performed horizontal linear measurement in the coronal plane. The critical IRS width for initial implant stability is 3mm.[15] Using this criteria, the drop shaped IRS exhibit insufficient width to achieve primary stability during immediate implant placement. According to Bleyan's classification of initial IRS width was established post extraction. It was determined that drop shaped IRS fall into the S III septum category, characterized by an initial width ranging from 2-3mm. Conversely, for the second maxillary molars, buccal convergence and drop shape at the level A categorized under S III septum classification.[7] Based on these findings, it can be inferred that the identification of the IRS shape serves as a reliable indicator for planning interventions that necessitate expansion of the inter-radicular septum, particularly when employing the osseo-densification technique. This information proves valuable in facilitating successful immediate implant placement within the inter-radicular septum.

In addition to assessing horizontal IRS width with the lowest level (A) being notably crucial, IRS vertical characteristics in coronal view were also analyzed. Two distinct parameters that contribute to vertical axis include the distance between the inter-radicular furcation and sinus floor, and the sum of these parameters. The clinical significance lies in representing the IRS height between the IRS furcation and sinus floor. This is essential for ensuring it meets the required implant length. Nunes *et al.,* noted that minimum bone height of 10mm is necessary to attain

Table-II: Variations in Inter Radicular Septum (IRS) Width at Different Levels and Furcation Angle of M1 and M2 (n=177)

IRS		IRS Width at Levels (mm) (Mean+SD)				Furcation Angle (Mean+SD)
		A	B	C	D	
M1	Arrow (n=119)	3.54±0.53	4.86±0.82	6.46±1.15	8.46±1.49	56.69+9.53
	Boat (n=32)	3.80±0.81	5.13±1.28	6.51±1.66	8.49±1.94	60.14+12.85
	Buccal Convergence (n=4)	3.88±0.51	5.02±0.80	5.75±1.20	7.62±1.42	54.40+5.00
	Palatal Convergence (n=16)	3.84±0.69	5.13±1.20	5.96±1.32	7.78±1.73	55.64+7.69
	Drop Shape (n=6)	2.25±0.34	3.31±0.61	4.96±1.04	6.25±1.31	39.36+4.77
***p*-value**		<0.001	0.001	0.031	0.009	<0.001
M2	Arrow (n=136)	3.19±0.54	4.12±0.94	5.37±1.40	6.93±1.74	49.46+9.91
	Boat (n=11)	3.43±0.65	4.54±1.16	5.97±1.84	7.83±1.93	56.12+11.01
	Buccal Convergence (n=6)	2.90±0.78	4.13±0.74	4.41±0.61	5.76±1.26	47.18+9.72
	Palatal Convergence (n=8)	3.58±0.37	4.81±0.90	5.83±1.28	7.30±1.93	51.78+6.16
	Drop Shape (n=16)	2.30±0.50	3.15±0.73	4.26±0.98	5.22±1.31	44.14+8.87
***p*-value**		<0.001	<0.001	0.005	<0.001	0.034

Table-III: Variations in Inter Radicular Septum (IRS) Area at Different Levels of M1 and M2 (n=177)

IRS Shape		IRS Area at Levels (mm2) (Mean+SD)			
		A	B	C	D
M1	Arrow (n=119)	5.43±2.07	6.85±2.82	8.70±3.64	11.00±4.15
	Boat (n=32)	4.56±1.89	6.07±2.61	7.45±2.69	10.41±3.78
	Buccal Convergence (n=4)	5.10±1.83	6.35±2.01	8.83±2.72	11.11±3.20
	Palatal Convergence (n=16)	5.16±2.31	6.80±3.10	7.53±2.73	8.67±3.20
	Drop Shape (n=6)	3.90±2.20	5.41±3.98	6.69±4.84	9.09±6.95
***p*-value**		0.14	0.53	0.22	0.23
IRS Shapes		**IRS Area at Levels (mm2) Median(IQR)**			
		A	B	C	D
M2	Arrow (n=136)	2.46(1.79-3.71)	3.21(2.37-4.78)	4.07(2.68-5.97)	5.05(3.78-6.98)
	Boat (n=11)	3.80(1.99-4.68)	4.44(2.45-6.18)	5.02(3.62-6.02)	6.58(4.75-8.96)
	Buccal Convergence (n=6)	3.59(2.53-4.75)	4.26(3.58-5.78)	5.52(4.26-7.30)	5.70(4.45-8.35)
	Palatal Convergence (n=8)	3.29(2.91-3.70)	3.52(3.42-4.33)	5.21(4.30-5.47)	5.41(4.36-6.61)
	Drop Shape (n=16)	2.66(1.96-3.24)	3.19(2.69-3.75)	3.93(3.42-4.48)	4.43(3.64-5.62)
***p*-value**		0.93	0.18	0.19	0.24

IRS=Inter-radicular Septum

primary stability and resistance to occlusal forces.[16] Based on this criterion, our findings indicate that only buccal convergence and palatal convergence IRS shapes exhibit a 10mm height for both first and second maxillary molars. The clinical significance of presented data suggests that the immediate implant placement in second maxillary molar region may necessitate surgical procedure for buccal convergence and drop shape and in first molar region for drop shape. Moreover, the study's findings, particularly in relation to the vertical diameter of IRS based on its shape, enable predictions regarding the extent of contextual intervention needed to achieve implant stability.

The observed variations in the surface area based on IRS shape carry significant clinical implications, particularly in the context of prosthetic-driven immediate implant placement where horizontal diameters of IRS can be crucially impacted by implant width. Given that the most common implant diameter in the maxillary molar region is typically 4mm.[17,18] We employed a Heron's formula for calculating implant surface area and compared it with the surface area of the IRS. In the case of the first maxillary molars, the IRS with a drop shape have smaller area than the required for implant standard dimensions. Conversely, in second maxillary molars all shapes except the drop shape exhibit surface area sufficient for implant placement at level B, C and D while drop shape exhibited a horizontal diameter smaller than what is required for implants of standard dimensions.

While the IRS is considered an optimal site for prosthetic considerations,[19] current study's findings suggest that a detailed morphometric analysis of maxillary molars' IRS can serve as a predictive factor for the outcome of prosthetic-driven immediate implant placement. The initial differentiation of IRS shapes may serve as a crucial checkpoint in therapeutic planning, impacted both horizontal and vertical IRS characteristics in the maxillary molar region and influencing implant stability. Some authors[20,21] have proposed alternative implant sites to avoid IRS loss during drilling, but these approaches do not align with the criteria of the prosthetic-driven immediate implant placement concept.

To maintain adherence to the prosthetic-driven protocol and preserve the IRS as the preferred implant site, various treatment options have been suggested. Fugazzotto and colleagues[22] recommended using an appropriate angled bur in the IRS, while Sanz and collaborators[23] proposed closing the space between the implant and IRS through bone grafting procedures. In our pursuit of establishing an ideal implant site for prosthetic considerations through prosthetic-driven immediate implant placement, we introduced a classification of IRS shapes in the maxillary molar region. This classification suggest that specific IRS shapes come with characteristic horizontal and vertical diameters, aiding in better planning of implant placement procedures.

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CONCLUSION

CBCT image analysis can serve as a useful tool for anticipating conditions that significantly enhance the planning of immediate implant placement procedures in posterior maxilla. To enhance the reliability of predicting implant placement outcomes based on IRS shape, further insights could be gained by employing virtual implant placement methods in the posterior maxilla.

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Authors' Contribution

Following authors have made substantial contributions to the manuscript as under:

SK & MS: Conception, study design, drafting the manuscript, approval of the final version to be published.

AR & AA: Data acquisition, data analysis, data interpretation, critical review, approval of the final version to be published.

WA & NA: Conception, data acquisition, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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