

MORPHOLOGICAL CHARACTERISTICS OF MAXILLARY MOLARS INTERRADICULAR SEPTUM AND CLINICAL IMPLICATIONS -WHAT DO WE KNOW SO FAR?

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ABSTRACT

The interradicular septum describes area in the root furcation that separate alveoli of multi-rooted teeth. The shape and dimension depend of the topography of the extraction socket, the geometry of residual root and anatomy of molars alveoli. The clinical implications of this anatomic structure may be used in oral surgery resection procedures, periodontology and implantology. There is an opinion from the surgical and prosthodontic side that center of interradicular septum may be adequate place for immediate implantation. The aim of this study was to investigate morphological characteristics and clinical implications of upper molars interradicular septum. The studies showed that interradicular septum is important for success of resection surgery procedures: hemi-section, bisection and root amputation. It's reported that furcation involvement in periodontal disease is clinical sign for severe bone loss. By reviewing the available literature for immediate implantation, it's reported the clinical implications for diagnostic plan (pre-intervention), presurgical (pre-instrumentation) and intraoperative evaluation of interradicular septum for immediate implantation. The cone beam computed tomography analyze study presented mean values of septum height and wide for hypothetical plan of immediate implant placement. The presurgical studies evaluate how to assure preservation of septum and safe implant position in center of septum. The research showed varies therapy modalities that can be used, and how to choose right therapy according the socket type and initial septum width classification. According to observation of studies results, other researches should be considered for CBCT anatomical structure analyze and measures of interradicular septum for immediate implantation planning.

Keywords: interradicular septum, maxillary molars, clinical implication, immediate implantation, cone beam computed tomography- CBCT.



MORPHOLOGICAL CHARACTERISTICS OF MAXILLARY MOLARS INTERRADICULAR SEPTUM

The first upper molars consist of three wide alveoli, which are separated with septa (interradicular septa). The „Interradicular septum“, „interradicular bone“ or „septal bone“ are synonyms that are used to describe a broad area that starts in root furcation and becomes thicker in the periphery of the alveoli. The alveoli of the second upper molar are closer to each other, so the septum is not so widespread. The first and second lower molars have two roots separated with strong and regular interradicular septa. However, in the region of the second molar may be one compartment in the periphery of alveoli that divides into two segments. (1)

The area between tooth root is rich blood supplied (1). The appliance of interseptal and interosseus technique of terminal anesthesia through medullar bone, according to branched vascularization, provides pain control and hemostasis to the bone, soft tissue, and root structure in the region of infusion (2). These technique advantages are less dose, quick onset, limited duration, minimal collateral anesthesia, minimize bleeding during the surgical procedure and it's successful both in upper and lower molars (2,3).

In the mandible, the first and second molars septum have 2 roots; mesial, and distal, that are similar in size and dimension, so the shape of interradicular septum is rhomboidal with a narrow mesiodistal dimension (1,4,5). The interradicular septum of the first and second teeth of maxillary molars is surrounded by 3 roots: bucco mesial, bucco distal, and palatal (6), which provides a triangular shape and wider dimensions of the septum. The average width of mandibular molars is 9 mm buccolingual and 9 mm mesiodistal, relative to maxillary 10 mm buccolingual and 8mm mesiodistal, which explains the triangular shape and wider interradicular septum (4).

The type of bone in the posterior mandible region (second premolar and molars) is described by Misch et al., and presents usually as D3 bone, while the posterior maxilla region (molar region) usually as D4 bone, still in cases of sinus grafting it may have D3 bone 6 months after grafting. “D3 bone describes fine trabecular bone surrounded by thin porous cortical bone until D4 bone is fine trabecular bone with almost no cortical bone” (7).

Forming the interdental and interradicular bone is closely related to tooth eruption in postnatal life. Studies reported that forming of interradicular bone starts in primordial dental development, at the same time bone as the alveolar ridge expand. The bone crypts around dental primordial development are constantly exposed resorption process. In the developmental grooves deep on the root occurs a septal spine that developed during the roots divide, while interradicular septum is formed when roots are entirely divided. (1). Results of study Radlanski et al. on mice showed that dental crypts, interdental and interradicular bone are forming with the combination of resorptive and appositional processes (8, 9).

CLINICAL IMPLICATIONS OF MORPHOLOGICAL CHARACTERISTICS OF MAXILLARY MOLARS INTERRADICULAR SEPTUM

ORAL SURGERY

The anatomic area of the multi-rooted tooth with divergently positioned roots, by periodontal terms, define as root furcation (10). In the clinical situation as an extensive vertical bone loss of one root of multi-rooted teeth, furcation destruction (11), should be considered to use some of the nonsurgical and surgical mechanic debridement, furcation plasty, tunneling procedures, hemi-section, root resection, and regenerative procedures to retain teeth (12). Tooth resections procedures preserve the maximum teeth structure, rather than sacrifice the whole tooth (13). Hemi-section is a useful alternative surgical procedure extraction of one root of multi-rooted teeth, as shown in Table 1., in case no other surgical and endodontic therapy approach is available. Other root stays with his crown part, and after proper endodontic therapy, uses to attain the fixed prosthesis (14). Before the decision of resection procedures, it should be considered a vertical bone loss or furcation destruction, anatomy and morphology of molar teeth, such as root concavities, development grooves on the root; cervical enamel projection, and interradicular ridges (12), remaining bone for stabilizing remain teeth structure (13), which can affect on procedure decision.

Bisection is the surgical procedure that separates the crown, of two-rooted teeth to the furcation, and creates two independent teeth. It's used for lower molars (13). Amputation is the procedure of removal of affecting root, with a minimum reshaping of the crown, and it can be used to all multiple-rooted teeth (12,13).



Table 1. Clinical implication of interradicular septum in oral surgery resection procedures

Author/Year	Origin	Sample size	Results	Type of research
Mokbel N et al. 2019	Beirut, Lebanon	Total of 1.012 publications were screened. A total of 22 studies met the inclusion criteria.	Survival rate and follow-up times differed widely: survival rate ranged from 40.3% to 100% and follow-up from 6 months to 23 years. Half of the studies had a survival rate > 90% with a follow-up period ranging from 5 to 23 years Root resection and hemi-section are associated with high survival rates, making it a reliable option for treatment of furcated molars that should be considered before every extraction and implant placement.	A systematic review
Falakaloglu S et al. 2016	Diyarbakir, Turkey	2 patients	Success results are possible to teeth that failed to endodontic treatment. Hemi-section is a suitable alternative approach.	A Case report
Sahoo S et al. 2016	Uttar Pradesh, India	1 patient	Bisection/ bicuspidization of the decayed molars can be a practicable treatment option when there is vertical bone loss involving root/roots with furcation defect.	A Case report
Babaji P et al. 2015	Rajasthan, India	1 patient	The case presents hemi-section technique.	A Case report

PERIODONTOLOGY

The „furcation involvement“ presents a clinical symptom of severe periodontal disease that involves interradicular bone of multi-rooted teeth (14,15). The clinical evidence of furcation destruction is a symptom of advanced periodontal disease and those teeth have an undesirable prognosis (16). It's a higher incidence of tooth loss in periodontal disease where bone destruction is under furcation level (17). The study reported that loss of only 1 mm bone in furcation indicates the decay of interdental bone loss around 4 mm (18).

IMPLANTOLOGY

The interradicular septum is considered to be the best option for immediate implant placement in the molar sector, according to best implant survival and favorable 3D position (19). A loss of one or more molars is very common in the adult population, so immediate implantation is a suitable procedure to substitute hopeless teeth (20). The concept of immediate implantation has been accepted for single-rooted teeth since 1989 (21,22), and today has been widely used in the molar sector (19,23-27). Immediate implantation refers to implant placement in a fresh socket after the teeth extraction



(28). The advantage of this procedure is the reduction in the number of surgical procedures (29,30), preservation of esthetics and the bone height and width (30,31), improved quality of life, and increase patient comfort and satisfaction (32). The fresh post-extraction socket provides the wider implant-bone contact, that's the precondition for successful osseointegration, compared to edentulous healed bone (21,23,33-35).

The studies showed the opposite success of immediate implantation, while a result of the study showed a higher failure rate of immediate implantation (33), other systemic and meta-analyses didn't present differences of failure rate between immediate and delayed implant placement (34). Studies showed the survival rate of implants in latero-posterior sites from 90-100% (23, 35-37). It's suggested that immediate implantation in the center of interradicular septum may be sufficient to achieve enough primary stability (41). Also, interradicular septal bone is presented, from the prosthetic point of view, as an ideal site for implant position, that

assures the esthetic outcome of fixture prosthetics (39-42). Placing the implant in the root socket doesn't provide an adequate esthetic outcome and may compromise implant survival (43-45). In the molar region, the primary stability of implants is achieved from interradicular bone and apical threads (46). Studies report that's a necessary minimum of 3 mm, the width of interradicular septum, and 2-3 mm of subcrestal bone, to provide initial primary stability (47). An ideal position of the implant placement that provides primary stability may be difficult to determine according to the topography of the extraction socket, the geometry of residual root, anatomy of residual molars alveolus, and reduced thickness of interdental septum (4). The socket size of the upper molar is large, so the use of standard implants diameter may have a consequence remaining gap between the bone-implant surface. That gap can affect implant primary stability (26). A different measure in planning, pre-instrumentation, and pre-implant placement of immediate implantation, as shown in Table 2, are investigated.

Table 2. Clinical implication of interradicular septum in immediate implantation

Author/Year	Origin	Sample size	Results	Type of research
<i>Diagnostic procedure</i>				
Agostinelli et al. 2018	Pescara, Italy	CBCT scans of 100 patients	Mean height of interradicular septum: first molar: 4.51±3.58 mm, second molar: 3.24±3.82 mm. The extension of the interradicular bone septum was first molars: 9.00±5.98 mm in second molars: 4.14 ± 4.96 mm	-CBCT retrospective analyze Evaluation the morphology of a hypothetical post extractive site in the upper molars area to diagnose the possibility of immediate post extraction implant placement.
<i>Intraoperative evaluation of interradicular septum</i>				
Smith et al. 2013	New York, USA	/	Classification of dental extraction sockets -A,B,C type of socket	Classification of Molar Extraction sites for immediate dental implant placement – A technical note
Acocella et al. 2010	Florence, Italy	68 patients 68 teeth	All implants restored with single crowns were monitored for 36 months; 3 implants failed cumulative survival rate of 97.96% Use the retained tooth to insure interradicular septum preparation for implant placement	-A Clinical trial
Rebele FS et al. 2013	Munich, Germany	2 patients	5 months follow up 100% success osteointegration	-A Case report



Author/Year	Origin	Sample size	Results	Type of research
			Use the retained tooth to insure he interraderic septum preparation for implant placement	
Haddad El E et al. 2015	Torino, Italy	1 patients	Use the retained tooth to insure he interraderic septum preparation for implant placement	-A Case report
<i>Presurgical (pre-instrumental) evaluation of interraderic septum</i>				
Bleyan S et al. 2021	Pittsburg, USA	131 patients 90 women, 41 men Mean age 52 years	The mean follow-up was 36 months mean overall septum width: -at baseline: 3.3 mm, the mean osteotomy diameter (post instrumentation): 4.65 mm after expansion with osseodensification. Classification of septum width Presurgical evaluation of interraderic septum for osseodensification appliance	-Clinical retrospective study

CONE BEAM COMPUTED TOMOGRAPHY (CBCT) IN PRESURGICAL EVALUATION OF INTERRADICULAR SEPTUM

The radiograph analyses are required diagnostics procedure in everyday dental practice, and also are used in the treatment plan and follow-up the results of therapy (48). The conventional 2D radiographic have multiple visual limitations (49) as are magnification, distortion, and superimpression, which altogether may lead to misrepresentation of anatomical structures (48,49). The triumph of CBCT is his capability to gather patients' information of volumetric jaw bone imaging, which can be used for preoperative field review and treatment plan (50). The equipment that's included in CBCT is a viewing software, containing 3D database, and a wide range of extensive tools that provide analysis of images (51,52,53). The software tools that are usually used in pre-surgical implant placement are: oblique slicing (nonorthogonal)- which creates 2D image at any angle by cutting across a set of axial images; curved slicing (panorama like view), cross-sectional (oblique coronal) view provide images in thickness and spacing, that's important for evaluation of morphometric characteristics of alveolar bone for immediate placement, and others like ray sum and volume rendering (51). Using 3D CBCT in implantology is possible to fully integrate the preoperative transfer to the surgical field, virtual implants placement, and preoperative transfer to the surgical field with further prosthetic rehabilitation (50,54,55).

The study showed that CBCT is reliable in morphometric analyses of the anterior maxilla, to notice interconnections

between the structure measures, and preliminary examination for implant planning (56). Moreover, another studies using CBCT in anterior maxilla analyze that detection of various anatomic structures, may be useful in the prevention of complications during surgical intervention, as implant placement (49,57). Still, the morphological observed algorithms of the anterior maxilla may offer detailed information that can be used for planning orthodontic teeth movement (58). The justification of CBCT for preoperative implant plan is based on accurate information about vital structures, height, and width of bone, bone density, and alveoli profile (51,59,60). The European Association for Osseointegration in 2011, and the American Academy of Oral and Maxillofacial Radiology 2012, represented the guidelines of using CBCT in implant dentistry (59,61).

According to the knowledge of CBCT usage, the study of Agostinelli et al. investigate the bone morphology of the first and second maxillary molar, to analyze bone measures for protentional immediate implantation. This study aimed to prove is the interraderic bone predictive ideal site for implant placement. The CBCT scans of 100 patients were used to measure interraderic septum, in axial, paraxial, and panorex sections. Parameters that were used in the measure were: numbers of alveoli, the average number of bony walls in each alveolus, number of root sites with 4 bony walls, interraderic septum, the extension of the interseptal bone area, mean thickness of buccal and palatal plate, buccopalatal and mesiodistal width of the alveolus. The axial and paraxial section was used to measure septum height, from most coronal furcation points of view to the line that virtually



connected buccal and palatal root points. Extension of the interseptal bone observed the axial section of roots to determine width in the interradicular area, 2 mm apical to furcation. The most interpoint of roots on the axial section were connected with lines between them, so it was measured formed triangle. "The sum of 3 sides of the triangle contributes the parameter of the interseptal bone." Results of the study showed that interradicular septum was present in 74% of first and 44% of second upper molars. The interradicular septum mean height of the first molar was 4.51 ± 3.58 mm, and for the second molar was 3.24 ± 3.82 mm. Those results showed that interradicular septum cannot be considered a safe site for immediate implantation (20). The authors used the same methodology to evaluate the septum of lower molars (62), however, there is no other research considering using CBCT for presurgical evaluation of upper molars interradicular septum for immediate implantation.

Other studies tried clinical evaluation of interradicular septum after extraction to estimate the possibility for immediate implant placement (26). According to Smith et al., the primary area of the available bone for immediate implants placement are septal bone of multirooted molars, and the periphery of the socket, of molars with fused or converging roots. The interradicular septum is considered as an ideal site for implant, otherwise, the implantation in the palatal socket may cause implant angulation too far palatal, which affects the esthetic and prosthodontic outcome. The implantation in the buccal socket also is not a solution, however, it's known that buccal ridge remodels horizontally and vertically, which may cause pocket between the implant and soft tissue where food will be trapped, so the outcome of implantation should be compromised (26). For the success of immediate implant placement is necessary lateral or apical bone stabilization (22). Influence to three-dimensional implant position has tooth width at the cement-enamel junction, roots length, truck length, and root divergence degree. The most coronal aspect of the septal bone, at the base of the root furcation, fits for vertical implant position. The length over the root furcation determines the length and depth of the safe zone for immediate implantation, while beyond the apices of roots is the danger zone (compromised by anatomic structures of maxillary sinus).

The outcome of immediate implantation can be determined by 3 different types of extraction sockets: "Type A - the implant is completely within the septal bone, without gaps between the implant and the socket walls; Type B - the implant has enough but incomplete septal bone, leaving gaps; and Type C - insufficient septal bone, thus the implant engages the periphery of the socket" (26). At type A socket, the coronal proportion of implant is surrounded with bone, so is stabilized. There is no gap and no need for graft. The grafting can be used only in the remaining parts of the socket or if the buccal plate is absent. It's suggested that is a necessary minimum of 3-5 mm apically bone for primary stabilization. Type B of the socket means that the implant is stabilized, still, there is a gap between the implant and alveoli socket (26). The study suggested that in cases the gap is <2 mm, the site

should be grafted, while according to others, grafting is necessary only if the gap is >2 mm (63,64). If one or more buccal plate is missing, implantation should be delayed. In the type C socket, there is no septal bone, so primary stability may be achieved using the wider diameter implant (26).

Several studies demonstrated that using ultrawide implant diameter have predictable outcome (65,66,67). On the opposite, the systemic review found the use of ultrawide implant diameter has a higher implant failure rate (68). The study showed that gaps filled with grafting material, rather than uses of wider implant diameter, improve the postoperative healing process, and lower consequential bone resorption (20).

The planning of immediate implantation requires making extraction the least traumatic as possible, to preserve interradicular septum (69). The real challenge of immediate implantation of multirooted teeth is to assure the drill position into interradicular septum. Topography of extraction site and thickness of interradicular bone may lead that drill slips from preparation site, compromising the implant position and primary stability, and reflect on future occlusal and biomechanical complications (4). Another surgical approach of immediate implantation was presented to ensure the appropriate implant position in the maxillary and mandible inter-radicular site (4,69,70-72). The modification of this technique permits local sinus augmentation if is required, through the interradicular preparation site (70). This technique uses retained root complex to serve as an ideal emergence profile for positioning the implant among the axial line of the tooth. For this procedure, the first teeth are separated to expose the interradicular septum and make it visible and sectioned to further preserve minimally invasive extraction (72). A flapless atraumatic procedure that's used for tooth removal also influences the postsurgical preserve of bone, especially edges of the bone crest (72). The initial osteotomy is performed using a pilot drill in the center of interradicular septum along with the long axis of the tooth (4). A transurgical radiograph is used to assure the position of the implant. After the implant site is prepared, the retained tooth is atraumatic extracted. The study presented a technique on 15 clinical cases both maxillary and mandibular multi-rooted extraction sites, while 3 maxillary cases were treated with internal sinus floor elevation (70). The study of Guarinieri et al. on 30 patients analyzes the use of this technique at lower molars immediate implantation. The 3 years follow-up showed that there are no significant differences in vertical bone change on radiological measurements (71).

Bone density is also an important factor that affects implant stability (73,74). This is particularly important in the posterior maxilla, which according to Misch et al. (7), is D4 type, so it has a lower density compared to the mandible (75). Different drilling protocols may affect enhancing the bone density in the maxilla (76) and improving implantation success (75). An osseodensification (76) becomes a novel surgical technique that uses non-cutting drills to preserve interradicular-bone, contra clockwise direction to expand the



osteotomy, enhances bone plasticity, compacts the bone in trabecula space, and increase bone density (77-80). Increasing the implant-bone contact is associated with allografting compaction and the so-called “spring-back” effect (77), which stimulate bone grafted into trabecular space to accelerate bone regeneration and make implant healing time shorter (78-81). The ability of this technique to increase bone quantity and quality, and make it sufficient for implant stabilization was documented in vivo and clinical trials (78,82). Trisi et al. in implanted 5 mm implant diameter in 5 mm wide ridge of sheep iliac crest with adequate healing (78). Koutouzis and Huwais showed in the clinical controlled study on 21 patients, the success rate of 93% in 38 implants using the osseodensification technique (82). The studies also reported short and long success of dental implants in different clinical cases, regardless of implant micro and macro design; for immediate implantation (83-85) and implantation with crestal sinus graft (86-88).

The measures of septum it's done after molar extraction, recorded it's the narrowest width. Initial septum <2,5 mm was excluded. After the site instrumentation, the osteotomy diameter was measured and recorded. Used implants were length range 10-13 mm, range 4.2-6.4 diameter, conical, bone-level, and internal connection. The results of this study showed the mean septal width at baseline initially was 3.3 mm, after instrumentation was 4.65 mm, and used implant diameter was 4.96, to prove septum expansion. The follow-up period was mean 36 months. A total of 4 implants in the mandible and 6 in the maxilla were failed, 7 before and 3 after prosthodontic rehabilitation, resulting in a survival rate of 93.1% (73). The authors looked back to Smith and Tarnow (26) classification emphasis that type of socket is determinate after implant placement, not before, so the diameter of the implant may affect on socket type. Even more, the use of the osseodensification technique with socket extension can convert type B to type A, and type C to type B of the socket, which enhancing for adequate implant stability (73). This study proposed a new pre-instrumentation classification: S-I-initial septum width >4 mm, S-II-initial septum width >3-4 mm, S-III-initial septum width >2-3 mm, S-IV-initial septum width <2 mm. In the S-I, S-II, and S-III groups osseodensification is allowed immediate implantation with adequate implant stability, while S-IV is excluded for this technique (73).

CONCLUSION

The shape and the thickness of the interradicular septum depend on the numbers and angulation of teeth roots. The preoperative evaluation of interradicular septum, the possibility of making a gap, and measurement of gap dimensions could be useful in planning implant size and grafting procedure for immediate implantation. However, still cannot be considered appropriate, otherwise exposes the patient to the risk of unnecessary surgical intervention, if an operatively estimated interradicular septum is not of matching dimension. The CBCT evaluation of interradicular septum in the planning of treatment it shouldn't be taken for granted to completely analyze the septum. Analyses of septum width, not

only 2 mm from furcation, then in other aspects of axial view, is necessary to notice is the base width of septum quite to cover the whole implant with bone during the placement. Otherwise, is the angle of root divergently affects on width and high of interradicular septum. New research should be considered precise CBCT investigation of interradicular septum for planning immediate implantation.

ABBREVIATIONS

Cone beam computed tomography- CBCT

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