REVIEW ARTICLE

Anatomic site consideration in placement of TADs: a literature review

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Abstract

Temporary anchorage devices (TADs) are the devices that are temporarily fixed to bone for the purpose of enhancing orthodontic anchorage either by supporting the teeth of the reactive unit or by obviating the need for the reactive unit altogether, thereby providing skeletal anchorage. Our aim in this article is to present a comprehensive review of the literature about the possible anatomical sites for placement of TADs.

Keywords: Temporary Anchorage Devices, Anatomical sites, Absolute anchorage

Introduction

Orthodontists have traditionally used teeth, intra and extra oral appliance to control anchorage minimizing the movement of certain teeth, while completing the desired movement of other teeth. However, because of Newton's third law, i.e, for every action there is an equal and opposite reaction, there are limitations in our ability to completely control all aspects of tooth movement. Probably, TADs are the "boldest brush strokes on the orthodontic canvas". TADs are a time tested modality and the philosophy behind the skeletal anchorage is that, if the reactive forces can be absorbed by skeletal structures, tooth movement can accomplish the desired therapeutic goals and the undesirable reactive side effects can be prevented entirely.[1]TADs have gained profound application in contemporary orthodontics protocol to treat almost every genre of malocclusion; be it arising from dento-alveolar component, from the skeletal or combination of both. The ability to have bone anchored growth modulation devices has expanded the envelope of growth modulation. The possibility to treat even adult patient's conventionally indicated for surgery by TADs supported appliance assemblies has introduced the term "**ORTHOGNATHIC LIKE ORTHODONTICS**" into the orthodontic glossary.

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Various anatomical sites have been suggested for the safe and reliable placement of TADs. Potential sites (1) for mini-screw placement in the maxilla include the inter-radicular sites (alveolar areas) and extra-radicular sites like the mid-palatal and paramedian sites, the infrazygomatic crest, and the maxillary tuberosities. Similarly, for the mandible, apart from the inter-radicular sites various extra radicular sites proposed are retromolar, buccal shelf, ramal,symphysis and para-symphyseal region.[2-3]Factors to be considered during placement of TADs are as follows;

1. ANATOMIC STRUCTURES IN THE VICINITY OF THE SITE OF PLACEMENT

During placement of TADs, the roots of the teeth, nerves and blood vessels, the bone and sinuses in the vicinity of the intended site of placement are all vulnerable to perforation. Particular care needs to be taken while placing TADs in the buccal and lingual alveolar bone and the paramedian areas of the palate. In contrast, there are no critical anatomic structures in the midpalatal region, the maxillary tuberosity and the retromolar pad area, except for the incisive canal in the palate.

2. BONE CHARACTERISTICS

The stability of TADs depends on the quality and quantity of the cortical bone. Moreover, the thickness and density of the bone varies between different anatomic sites in the same patient and between patients. According to the Misch classification,[5] the maxillary alveolar bone is mostly composed of porous bone, corresponding to D3 or D4, whereas the mandible has dense bone classified as D2 and D3 (Fig.1). The anterior area tends to have denser bone than posterior areas. The maxillary cortical bone is thicker in the palate than on the buccal surface.[6]The palatal cortical bone thickness at 4 mm or more apical to the cementoenamel junction is uniform throughout (Fig. 2).[6,7] In contrast, the

mean cortical thickness of the mandibular buccal alveolar bone increases towards the ramus (Fig. 3).[8]The midpalatal region is composed of cortical bone of good quality with sufficient volume for placement of TADs. The retromolar pad area in the mandible is also composed of dense cortical bone.

3. SOFT TISSUE CHARACTERISTICS

The quality of the soft tissue, much like that of the bone, is an important factor in determining the success of anchorage derived from TADs. Ideally TADs should be placed in attached gingiva as it is resistant to inflammation (Table.1).[9]Irritation of the installation site by oral mucosa may cause unfavorable conditions, including compromised stability. Therefore, the insertion site must be carefully selected to minimize potential soft-tissue irritation or inflammation; firm attached gingiva is usually preferable to movable mucosa.

Amount of keratinisation	Mucosal site	Prognosis
Non-keratinized mucosa	Alveolar mucosa	Greater Failure rates
Gingiva (thin keratinized)	Dentoalveolar (or) mid paltal region	Ideal
Thick keratinized mucosa	Paltal slope	Are less likely to obtain adequate bony stability.

Table 1 Comparision of musocal site and prognosis

4. PATIENT COMFORT

Patients rarely complain of pain after routine TADs placement. The placement procedure itself causes little or no discomfort. If there is any discomfort it typically lasts for a day or two at the most. However, the protruding TADs head or the orthodontic attachments (e.g. elastic chain) on it can cause discomfort. (Fig.4).

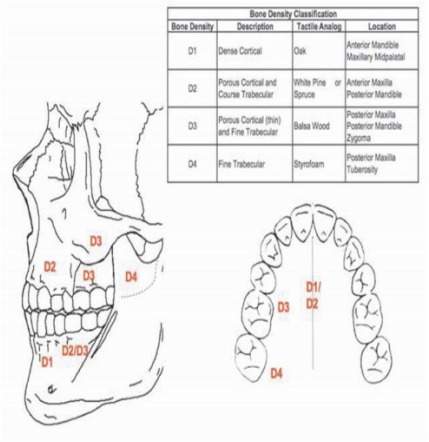

Fig.1Bone density

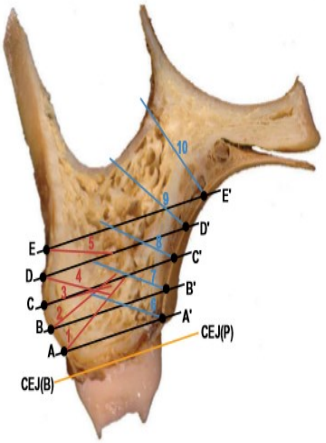

Fig.2 Cross- section of the maxillary bone showing the thickness of the buccal and palatal cortical bone at different levels from the CEJ

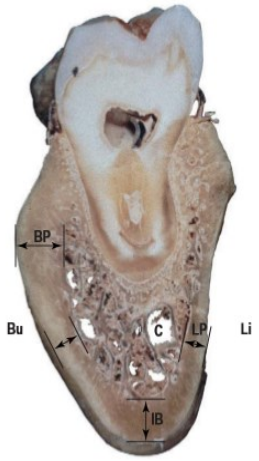

Fig.3 The mandibular buccal bone thickness tends to increase toward the ramus

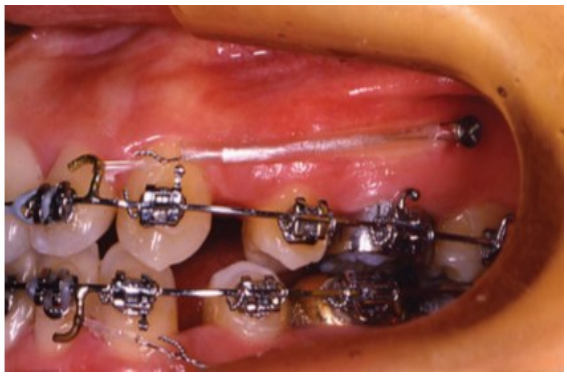

Fig.4 During space closure using sliding mechanics elostomeric module may imping on gingiva

INTER-RADICULAR SITES

Only a narrow corridor of bone is suitable for inter-radicular insertion of TADs. From cervical to apical, appropriate sites fall between the clinically invisible crestal bone margin and the clinically visible mucogingival border (Fig.5).[10]Various studies have proposed that at least 3mm of inter-root space would be required for safe placement of TADs. In the buccolingual dimension, not the whole buccolingual dimension, but the safety depth (at least 4mm) was measured to assess the available space, since most mono-cortical TADs do not reach the other side of the cortical bone of the alveolus (Fig.6). Suitable placement sites should meet at least one of the following requirements; the narrowest inter-radicular space must be larger than 3mm, and the overlying bone thickness on the narrowest inter-radicular area must be sufficient to accommodate the length of bone penetration in the TAD.[11]Poggio et al[12] provided an anatomical map of safe location to assist in placement of TADs between dental roots (Fig. 6 and 7).

Fig.5 Ideal insertion site for interradicular mini-implant placement (blue circle)

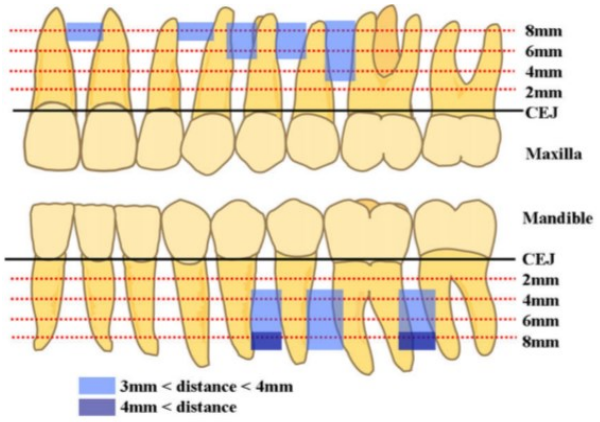

Fig.6 Areas with interradicular space greater than 3mm

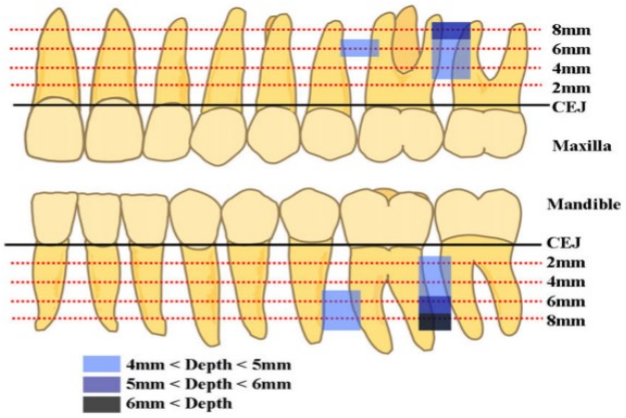

Fig.7 Areas with safety depth greater than 4mm

The order of the safer sites available in the inter-radicular spaces of the posterior maxilla and mandible is as follows:

MAXILLA

- On the palatal side, the inter-radicular space between the maxillary first molar and second premolar, from 2mm to 8mm from the alveolar crest.
- On the palatal side, the inter-radicular space between the maxillary second and first molars, from 2mm to 5mm from the alveolar crest.
- Both on buccal or palatal side between the second and first premolar, between five and 11mm from the alveolar crest.
- Both on buccal or palatal side between the first premolar and canine, between five and 1mm from the alveolar crest.
- On the buccal side, in the inter-radicular space between the first molar and second premolar, from 5mm to 8mm from the alveolar crest.
- In the maxilla, the more anterior and the more apical, the safer the location becomes.

MANDIBLE

- Inter-radicular spaces between the second and first molar.
- Inter-radicular spaces between the second and first premolar.
- Inter-radicular spaces between the first molar and second premolar at 11mm from alveolar crest.
- Inter-radicular spaces between the first premolar and canine at 11mm from the alveolar crest.

Among the more important factors for placement in the buccal cortex are soft tissue anatomy, inter-radicular distance, sinus morphology, nerve location and buccolingual bone depth.[13-15]As far as bone density is concerned placement of TADs in D4 bone is not recommended due to the reported high failure rate.[16-18] Similarly for soft tissues, the general recommendation is to place mini-implants in attached gingiva,[19-21]yet as apical as possible since the inter-radicular distance increases in the apical direction, reducing the risk of root damage.

EXTRA RADICULAR SITES

PALATAL SITE

Anterior palate is a good insertion site because it allows TADs with larger dimensions and greater stability[22-23]to be placed in a region with high bone quality, thin overlying soft tissue, and a nearly negligible risk of root damage or interference with teeth.[24]Both the midsagittal[7],[25-27] and paramedian[28] regions of the hard palate have been proposed for implant placement. These are easily accessible and offer excellent peri-implant conditions because they are covered by attached mucosa. Because the bone volume is reduced in the lateral and posterior areas of the palate,[29-30] only a median insertion is possible in the posterior palate. Additionally, the proximity of such structures as the incisor roots and the incisive canals must be considered. Therefore, insertion of TADs directly within the palatal rugae can be challenging. The area immediately posterior to the palatal rugae referred to here as the "T-Zone", is a more suitable region for insertion of palatal mini-implants due to the available bone volume (Fig.8 and 9). As a general rule, TADs should not be inserted directly into the anterior area of the palatal rugae, but posterior to the third palatal rugae within the T-Zone. Ludwig et al[31] reviewed radiographic landmark studies and demonstrated that the thickest vertical bone repositories are located 3-4mm distal to the incisive foramen and 3mm paramedian to the palatal suture (Fig.10). Bernhart and colleagues found a mean bone thickness of only 2.94mm at the suture and, therefore, recommended an insertion site 3-6mm paramedian to the suture and 6-9mm distal to the incisive foramen.[32]

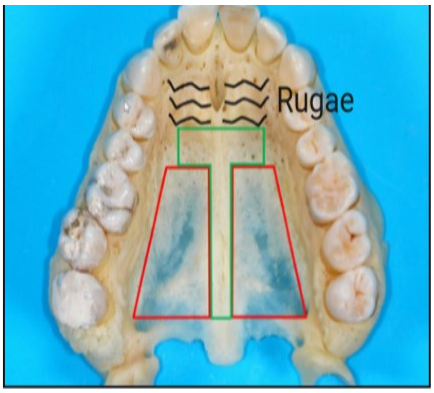

Fig.8 Recommended insertion site posterior to palatal rugae ("T-Zone")

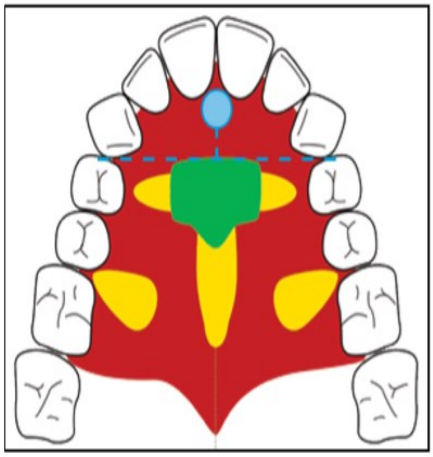

Fig.9 Suitability of potential TADs insertion sites in palate (green = optimal; yellow = restricted due to individual variability in bone thickness; red = unsuitable because of thick mucosa or vascular bundles; blue dot = incisive foramen)

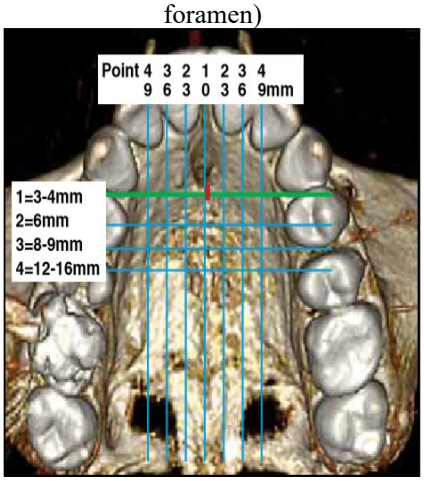

Fig.10 Palatalvault grid used in analysis of radiographic and clinical landmarks (green line indicates anterior limit for favorable palatal TADs insertion; red square shows distance from incisive foramen to reference line)

INFRA-ZYGOMATIC REGION

Due to the relatively long distance from the root region, TADs in the IZC region do not interfere with tooth movement, thereby reducing the risk of contact with natural tooth root. Moreover, in clinics the IZC site has been used successfully for space closure, anterior retraction, posterior intrusion, and molar and even maxillary dental arch distalization.[34]Anatomically, IZC is a pillar of cortical bone at the zygomatic process of the maxilla (Fig.11). Clinically, it is a palpable bony ridge running along the curvature between the alveolar and zygomatic processes of the maxilla. It is located between the maxillary second premolar and first molar in younger subjects, whereas it is found above the maxillary first molar in adults. It is a rectangular osseous volume that is limited by certain distinct borders. The buccal border of the IZC space is represented by the course of the outer surface of the zygomatic process of the maxilla and the most apical regions of the alveolar process. The cranial border is characterized by the floor of the maxillary sinus and/or the floor of the nasal cavity. The medial border is limited by the lingual root of the maxillary first molar, the lingual surface of the alveolar process and the surfaces of the nasal cavity. The caudal border extends to the mesio-buccal and disto-buccal roots of the first permanent molar.[35]The ridge of bone extends 2cm or more superiorly to the zygomatic-maxillary suture, and the inferior portion can be subdivided into the IZC 6 and IZC 7 areas, respectively. Soft tissue irritation is a common problem if the inferior aspect of the screw platform is contacting or near the mucosa. To control this problem the IZC TADs are placed in attached gingiva with ~1.5mm of clearance from soft tissue to the base of the TADs platform. The average thickness of the attached gingiva in the maxillary first molar is about 1.0mm and the cortical bone thickness is about 1.1-1.3mm.[36] Generalizing the widths, for soft tissue clearance, attached gingiva and cortical bone at 1.5mm each, reveals that 8-12mm IZC screws penetrate the medullary bone or sinus from 3.5-7.5mm. Under most clinical conditions, an 8mm screw is adequate to engage the cortical plate and secure primary stability [37](Fig.12).Liou[38] suggested orienting screws about 55-70° inferior to the horizontal plane to achieve maximal buccal bone engagement, but it was not clear whether IZC 6 or 7 was the preferred site from an anatomic perspective (Fig.13). Because the alveolar bone is thicker on the buccal surface of the second molar, the IZC 7 site is usually preferable for TADs. For clinical convenience and the advantage of attached gingiva, the preferred IZC bone screw sites are considerably inferior to the anatomic zygomatic crest.

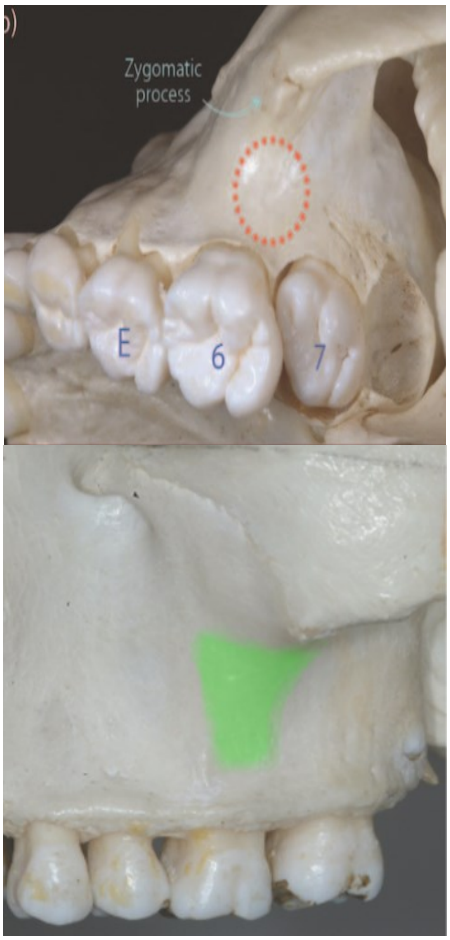

Fig.11 Topographical location of the infrazygomatic crest

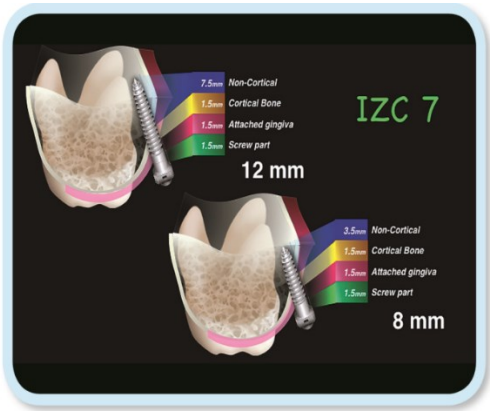

Fig.12 An IZC anchorage screw penetrates about a 3mm thickness of attached gingiva and cortical bone. The clearance of the screw head to the soft tissue should be ~1.5mm, so there is a distance about 4.5mm between the base of the screw and the inner surface of the cortical bone. Thus, screws of 8-12mm length will extend into the non-cortical bone space (medullary bone or sinus) about 3.5-7.5mm

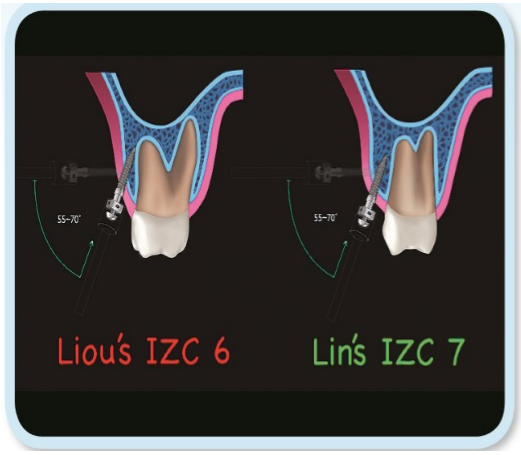

Fig.13 The alveolar bone is too thin to place a TAD buccal to the MBR of 6, even with an increased angulation of 55-70º

MAXILLARY TUBROSITY

Another, less commonly used anatomical site for the placements of TADs in the maxilla is the maxillary tuberosity. The maxillary tuberosity lies at the lower part of the infratemporal surface of maxilla. It is a rounded eminence, especially after the growth of the wisdom tooth; it is rough on its lateral side for articulation with the pyramidal process of the palatine bone and in some cases articulates with the lateral pterygoid plate of the sphenoid (Fig.14).[39] According to Lekholm and Zarb,[40]bone quality in the posterior maxillary region is usually type III or IV, characterized by thin cortical bone and low density trabecular bone. Further, in many situations the bone height in this region is insufficient for proper implant placement because of the presence of the maxillary sinus. These factors are detrimental to the achievement of high primary stability.[41]The bone quality in this region is relatively poor (Misch D3 or D4 categories), but there are no anatomic structures to avoid. As the soft tissue is thin in this area, a 6–7 mm long TADs can be used.Sung et al recommend using a relatively long mini-implant with a diameter of 1.3mm to 1.5mm in areas with a predominance of cancellous bone and low bone density,[42] such as the maxillary tuberosity.[43] The implants may be placed at an angulation of 20° to 40° (Fig.15) to the occlusal plane in a vertically directed manner.

MANDIBULAR BUCCAL SHELF AREA

Indications for the MBS as the insertion site are plentiful, but this site seems to be most useful for the correction of Class III malocclusions. Moreover, it is an appropriate skeletal site for extra-alveolar bone screws to retract molars for non-extraction treatment of mandibular crowding. The MBS is located bilaterally in the posterior part of the mandibular body, buccal to the roots of the first and second molars and anterior to the oblique line of the mandibular ramus (Fig.15).Nucera et al[44] concluded that insertion site of the MBS with the optimal anatomic characteristics is the buccal bone lateral to the distal root of the second molar, with screw insertion located 4mm buccal to the CEJ. However, for particular biomechanical needs, it is possible to consider an insertion site lateral to the mesial root of the second molar, but insertion will likely need to be more apical to attain adequate buccal bone thickness. Evaluation of cortical bone thickness before TADs insertion is appropriate since pre-drilling may be indicated in order to improve primary stability and to avoid excessive insertion torque and screw failure. The angulation of the MBS at the optimal TAD site is ~38 degrees which indicates that the bone screw should have the same angulation to the surface of the MBS to approximate the axial inclination of the molar.

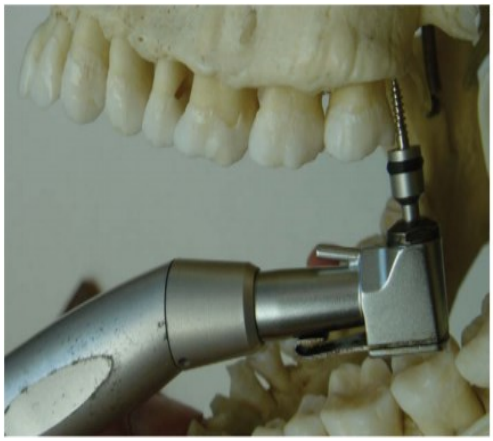

Fig.14 Orientation of the TADs is not exactly perpendicular to the bone surface

Fig.15 An occlusal view of a human mandible shows the available bone in the buccal shelf area (arrow)

RAMAL AREA

Realizing the deficiency of TADs (retromolar and I-R) in managing horizontal impactions, Chang et al[45] expanded the TADS concept by developing a 2mm diameter stainless steel (SS) bone screw that was suitable for dense cortical bone sites, such as the mandibular buccal shelf (MBS). The MBS bone screw is placed lateral to the first and second molars, so it does not interfere with the retromolar location of horizontal impactions, or the path of tooth movement within the alveolar process. Theramus of mandible is quadrilateral in shape, and has two surfaces, four borders, and two processes. The optimal site for a direct line of traction without occlusal interference is midway between the external and internal oblique ridges of the ascending ramus, about 5-8mm above the occlusal plane.[46](Fig.16)

Fig.16 Ideal site for TADs Placement in Ramus

RETROMOLAR PAD

TADs are placed in the retromolar pad area when distal retraction of the whole mandibular dentition is planned.[47]It is a triangular area bounded by the temporal crest on the medial side, anterior border of ramus on the lateral side, and the posterior portion of the third molar area (Fig.17). The depressible mucosal elevation covering the retromolar triangle is called the retromolar pad or the piriformis papilla (Fig.18). It has an average length of 11.2mm and an average maximum transverse diameter of 7.9mm. Its shape can be ovular (53.1%), rounded (29.6%), or triangular (17.3%).[48]The appropriate location of the TADs is slightly buccal to the buccolingual center of the retromolar triangle (bull's eye). The lingual side of internal oblique ridge should be avoided as there is a substantial bony undercut and the lingual nerve and vessels run close by. Palpation of the outer oblique ridge helps to locate the optimal area for TADs placement.[49]

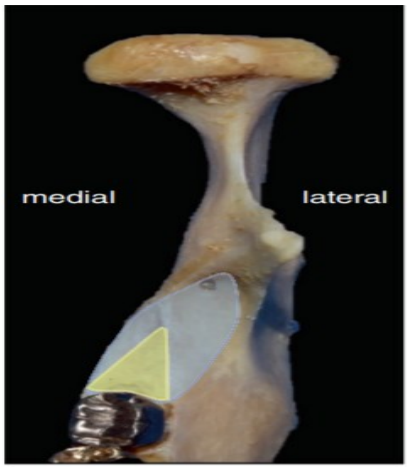

Fig.17 Superior view of the retromolarfossa (blue) and retromolar triangle (yellow)

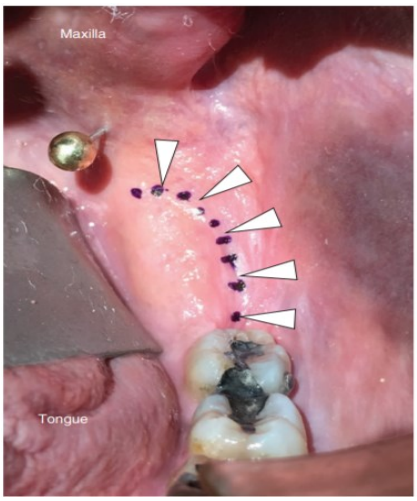

Fig.18 Retromolar pad (arrowheads)

SYMPSYSEAL AREA

TADs are inserted into the symphysis region to anchor fixed functional appliances in growing patients with skeletal Class II malocclusion, and also for Class III elastics and intrusion of mandibular incisors in patients with deep bite.The symphysis region is one of the best areas for screw insertion as the cortical bone is relatively thick and the area can be reached easily (Fig.19). Anteriorly, the upper external surface shows an inconstant faint median ridge, which indicates fusion of the halves of the fetal bone at the symphysismenti. Inferiorly, this ridge divides to enclose a triangular mental protuberance; its base is centrally depressed but raised on each side as a mental tubercle. The mental protuberance and mental tubercles constitute the chin. The mental foramen, from which the mental nerve and vessels emerge, lies below either the interval between the premolar teeth or the second premolar tooth.[50]

Fig.19 Positioning of a miniplate on the symphyseal region on an anatomical skull model

CONCLUSION

First adopters of TADs focused primarily on interradicular, buccal and posterior palatal alveolar insertion sites, within attached gingiva.[51]The disconcerting incidence of failure (loss) of TADs inserted between the roots in those buccal locations elicited caution and trepidation, preventing broad acceptance. Hence, many early adopters have now moved-on to more predictable and successful extra-alveolar sites in maxilla and mandible like palatal bone, infrazygomatic crest, aperturapiriformis mandibular buccal shelf, retromolar pad, sympyseal and parasympyseal area, ramal area.[52]

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