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Review Article

Extra-Alveolar Temporary Anchorage Devices and Considerations of Adjacent Anatomical Structures-A Review

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Abstract

Extra-alveolar TADs offer the orthodontist elaborate tooth movements like en-masse distalization, expansion, mesialization etc. with an added advantage of preventing root damage. Although these TADs are placed away from roots, they are in close proximity to the adjacent anatomical structures at the area of placement. The most commonly used extra-alveolar TADs are the infra-zygomatic crest screws, the buccal shelf screws, palatal, retromolar and symphseal screws. For the IZC screws, the main anatomical structure to be considered is the maxillary sinus where up to 2mm of penetration is acceptable and more than 2mm can cause its significant damage. Similarly, for the buccal shelf screws, the inferior alveolar nerve is to be considered to avoid damage because the buccal shelf area shows ethnic variation in terms of thickness ad width. Similarly, the retromolar, symphseal and palatal screws also have their adjacent anatomical structures to be kept in mind before their placement and use. This review aims to elaborate ideal sites of placement of extra-alveolar TADs and anatomical considerations of the adjacent anatomical structures to be kept in mind while placing them to prevent the injury and failure of the implants

Keywords: Extra-Alveolar; Anchorage; Anchorage; TADs; Maxillary Sinus

Introduction

Modern day orthodontics has evolved through its natural course of time in terms of bracket prescription, anchorage control and the biomechanics used. Although the use of basal anchorage has been emphasized routinely in the past by authors like Gainsforth and Higsleys, temporary anchorage devices which primarily take support from the basal bone, have now become common in routine orthodontic practice [1]. Numerous studies and case reports using TADs for anchorage have necessitated innovations and hence there is an advent to use extra-alveolar TADs for complex tooth movements which would have otherwise needed surgical treatment. Extra-alveloar TADs now offer the orthodontist elaborate tooth movements like en-masse distalization, expansion, mesialization etc with an added advantage of preventing root damage. Although these TADs are placed away from roots, they are in close proximity to the adjacent anatomical structures at the area of placement [2-5]. These considerations have to kept in mind to prevent any iatrogenic damage and promote faster tooth movement which is desirable to both the clinician as well as the patient. This review hence aims to elaborate ideal sites of placement of extra-alveolar TADs along with anatomical considerations of the adjacent structures to be kept in mind while placing them.

Anatomical considerations for various extra-alveolar tads

Infra-zygomatic screws

Anatomy of maxillary sinus

It is the largest of the paranasal sinuses and is pyramidal in shape which is bounded anteriorly by the facial surface of the

Common extra alveolar sites	Uses
Infrazygomatic crest	Distalization, Mesialization, Intrusion, Guiding impacted canine, Expansion
Buccal shelf	Distalization, Mesialization, Intrusion, Guiding impacted canine, Expansion
Ramal screws	Up righting molars
Sympheseal	Anchorage for maxillary protraction
Maxillary tuberosity	Distalization
Palatal	Expansion, Intrusion

Table a: Common sites for Extra-alveolar screws and their clinical applications [6,7].

maxilla, posteriorly by the infratemporal surface of the maxilla, superiorly by the thin triangular orbital floor, a medial wall which separates the sinus and the nasal cavity, laterally it extends to the zygomatic bone and forms the zygomatic recess (Figure 1), inferiorly by alveolar and palatine process which spans from the mesial of the 1st bicuspid to distally to the third molar [10]. Posterior dentition and the sinus floor are separated by a thin cortical bone. Maxillary molar root tips lie at a close proximity to the sinus floor as compared to the premolars. Mean distance of the posterior teeth and sinus floor is about 1.97mm [10].

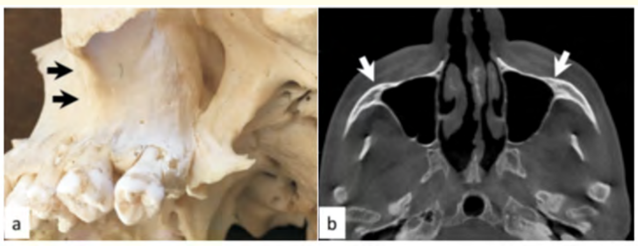

Figure 1: Maxillary sinus and zygomatic process- dry skull and CT images.

Vascular supply is through branches the maxillary artery: the posterior superior alveolar, the infraorbital artery, and the posterior lateral nasal artery.

Nervous supply is by the maxillary branch of trigeminal nerve, of which the posterior superior alveolar branch plays the large part of sensory innervation.

Boundaries of IZC area

The buccal border is formed by the exterior side of the zygomatic process of maxilla and the apical border of the alveolar process. The superior border is formed by the floor of the maxillary sinus and nasal cavity; the medial border by the palatal root of the maxillary first molar and the anterior and posterior border by the mesial and distal buccal roots of the first maxillary molar [7].

Age change

The maxillary sinus usually measures about < 7.0 mm in depth antero-posteriorly, < 4.0 mm in its height, and < 2.7 mm in width at birth. The development of the height of sinus is dependent on numerous factors like the amount of pressure from eyeballs when pushed against the orbital wall, the traction force experienced by the lower part of the maxilla by muscles of the face, and also the eruptive force of the permanent dentition. The full adult size of the MS is achieved between the ages of 18 and 21 when the third molars erupt. The adult MS has a mean volume range of 5.0 to 22 ml with12.5 ml being the mean. The length, width and height are usually 27.96 mm, 19.57 mm, and 25.33 mm viz [10].

Sinus thickness and relation to intraoral tissues [15]

The maximum membrane thickness in various arch forms was observed in square-shaped arch form bilaterally. When the membrane thickness was checked for different gingival biotypes, the thicker types showed more as compared to thinner biotypes at the Central Incisors as well as and Molars bilaterally.

Growth pattern and sinus thickness [16]

In general, Lower limit of maxillary sinus (LLMS) was least in hypodivergent compared to hyperdivergent and average growth pattern. In general, the cortical bone thickness was more in hypodivergent growth pattern and least in hyperdivergent growth pattern and it was more at and above the LLMS than below LLMS in all 3 groups (Figure 2).

IZC and maxillary sinus considerations

Bi-cortical penetration is attained by using IZC screws, through the buccal alveolar cortical plate and the maxillary sinus floor. The bi-cortical penetration aids in primary stability but this factor may also lead to loosening of the TAD and cause severe discomfort to the patient. There is also no consensus on the use of sinus wall cortex for mini-screw stability. Perforation of the Schneidrian membrane and entering the of antrum is the main challenge faced by the clinician during placement of IZC screws [11,12].

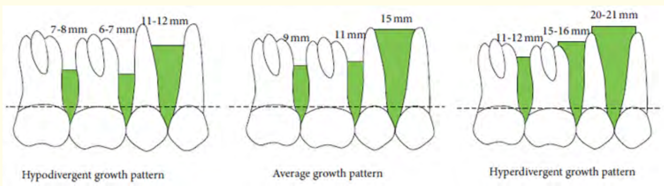

Figure 2: Lower level of maxillary sinus and cortical bone thickness in different growth patterns.

Due to the highly interconnected trabecular networks in the maxilla, the cortices are very thin and this can influence the muscle physiology and the growth pattern. To increase the cortical bone contact, angulating the screws has been advised but this holds a risk of maxillary sinus damage. High placement of the mini screw between the roots of the 2nd premolar and 1st molar and the between 1st and 2nd molars is usually done with minimal 3D measurement of the thickness of the bone and the maxillary sinus floor [13]. Small perforation into the sinus floor will heal over time in most cases, but severe perforation may lead to sinusitis, inflammation and other complications [14].

Ideal placement

Lin and Liou have suggested a level of 12 - 17mm above the occlusal plane at an angle of 65 - 70 degrees of the distobuccal root of the first molar [8] (Figure 3) For the Indian population Murugasan's study showed that 9 - 11mm length of screw can be inserted without sinus perforation [9].

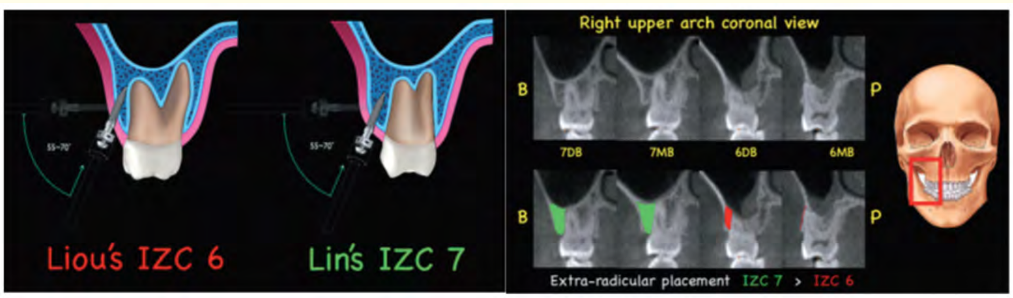

Figure 3: Liou's 6 and Lin's 7 technique.

- Presence of a 5mm space between roots of the upper second premolar and mesio-buccal root of upper first molar. This helps to prevent any interference of TAD with the root during retraction.
- In patients with a small oral cavity or restricted mouth opening, placement at site 6 much more feasible than at site 7.
- Presence of a thick buccal frenum near the insertion area may cause inflammation further leading to failure of the TAD; but for the most part a buccal frenum is not present at 6 sites.
- 4. Presence of a 5mm width attached gingiva

Sinus perforation and its management

The perforation of the Schneiderian membrane is a commonly occurring phenomenon. It occurs when the thin, lateral wall of the maxillary sinus is punctured from the buccal aspect during some procedures [12]. Perforation lesser than 2mm are self-healing without presenting many complications [14]. Branemark [17] and Ardekian [18] through their studies showed that when immediate loading of dental implants, there are chances of perforation into the maxillary sinus and the nasal floor but did not hinder with implant stability (Figure 4). However, Baumgaertel and Hans [7] and Kravitz and Kusnoto [14] from their studies showed that there was not need to removal or to halt the orthodontic treatment unless the patient present with sinusitis or mini screw instability to a point that no orthodontic force can be applied from it.

There have been numerous viewpoints concerning the perforation of Schneiderian membrane. Certain authors have claimed that no difference is observed in formation of bone as well as the

Figure 4: Diagrammatic representation- perforation of IZC screw into the sinus floor.

survival of implant. Other authors have noted more complications postoperatively like sinusitis and failure of the graft along with reduced implant survival [19,20]. Barone explained through his study that perforation of the membrane can cause graft migrating accompanied by infection of the sinus. He also gave proof that having an intact membrane ensures superior vascularity of tissues along with greater graft stability and complete maturation of the bone graft [20].

Also, osteoprogenitor cells present in the Schneiderian membrane help in speeding up the good clinical outcome. It has been observed in certain studies that the thickening of sinus membrane thickening is generally more for the mini implants which have a penetration depth greater than 1 mm into the maxillary sinus [21]. The typical reaction of the maxillary sinus membrane to different depths of penetration is illustrated in figure 2. The buccal bone resorption was more in value as well as incidence in those sites where penetration depth exceeded 1 mm [22].

Buccal shelf screws

Boundaries of buccal shelf

Bounded medially by the alveolar crest, distally by the retromolar pad, mesially by buccal frenum and laterally by external oblique ridge. Width of the buccal shelf is measured parallel to the occlusal plane in the buccolingual direction from buccal most point of the alveolar bone to the root of the mandibular molar root (Figure 5) The exact the site and placement may vary according to the individual factors presented by the patient [6].

The major anatomic consideration while placing the buccal shelf screw is the Inferior alveolar nerve proximity. The normal variation in the course, curvature and direction of the nerve has to

Figure 5: Buccal shelf area and related anatomical structures.

examined by using 3D diagnosis methods. Morphological variation in the buccal shelf area is seen with different ethnic origins like the excess of brachycephalic facial pattern in Asian patients [23].

Growth pattern and buccal cortical bone thickness

It has been observed that a low-angle or horizontal grower has a thicker buccal cortical bone as compared to a high-angle or vertical grower at all sites. Literature supports that subject with brachycephalic/short and broad faces with reduced s mandibular planes demonstrate thick cortical bone when compared with subjects who showed average or even dolicocephalic/thin and long face groups. This Thickness of buccal cortical bone can be attributed to the masticatory function which is influenced by muscular patterns as well [25].

Hyperdivergent patterns generally show weaker muscular activities along with reduced bite forces with mastication. On the other hand, the hypodivergent patterns have a stronger bite force and stronger muscular [26]. Some animal experiments concluded that areas which undergo more strain/stress during masticatory function tend to develop thicker cortical bones [26]. It was also seen that dolicocephalic group showed the most difference in change of height in the mandible when measured from molars up till the symphysis. A much greater height was seen in in the symphysis area as compared to the other 2 face groups [25]. A study by Motoyoshi [27] found results which showed that buccal cortical bone thickness must be more than 1 mm to make sure there is adequate primary stability of implants along with nominal success rates clinically. A recent study on that variability of the buccal shelf area showed that the hypodivergent group had wider buccal shelf area but had reduced length when compared to the hyperdivergent group (vaibhav)

Buccal shelf screws and inferior alveolar nerve considerations

Elsbeiny., *et al.* [23] observed that in the White population, buccal screws had the most closeness near the infra-alveolar nerve at the buccal site (5.46 ± 1.63 mm). Kolge., *et al.* [24] on the other hand, studied the Indian population and concluded this proximity to be maximum at the disto-buccal cusp end of the lower second molar (7.22 ± 2.00), whereas at the mesiobuccal it was around (7.50 ± 1.95). Hence, they concluded from the study that the tip of the implant is usually well within safe distance from the nerve to cause any kind of iatrogenic damage. These studies arrive at the opinion that the buccal shelf area in the Indian population is more suited for screws compared to Caucasian populations.

Ideal location for placement

Gandhi., *et al*. have suggested the buccal region of the distal root of mandibular second molars as an ideal site for buccal shelf screw placement [24] (Figure 6). Nucera., *et al*. on the other hand suggest the buccal bone corresponding to the distal root of second molar, with screw insertion 4 mm buccal to the cemento-enamel junction [25]. Chang has advocated the site lateral to the first and second molars is inserted at ~30° about 5 - 7 mm below the alveolar crest as an ideal site for the placement of extra-alveolar buccal shelf screw placement [28].

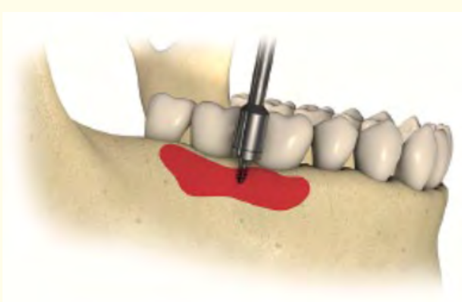

Figure 6: Insertion of mandibular buccal shelf screw.

Ramal screws

Ramal screws are now used mainly to upright impacted molars (Figure 7) The major anatomical consideration with the ramal screws is the proximity to the neuro-vasucular bundle in the mandibular canal and the muscle fibre attachment of both the medial pterygoid and temporalis. The ramal site usually provides a leeway of about 15 - 20mm from the neurovascular bundle, but examination of the post-operative radiographs of ramal screw used for correction of a horizontally impacted molar presented only 5 - 8mm space between the tip of the screw and the mandibular canal. In a clinical study done to assess the success rate of the ramal screw, it showed that only 2 out 40 screws failed and this was attributed to the hygiene maintenance of the patient leading to soft tissue hyperplasia. By following proper insertion technique and protocols, the clinician can achieve minimal complications while using ramal screws [30,31].

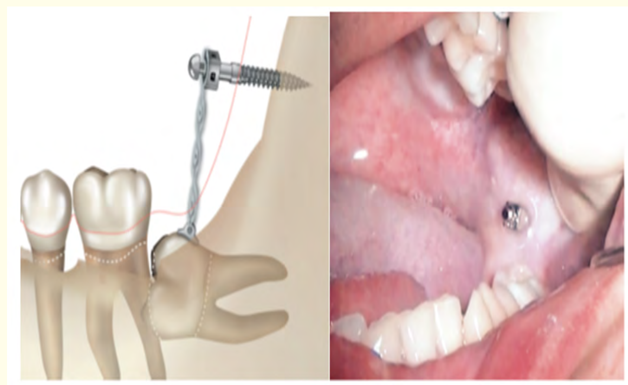

Figure 7: Uprighting second molars using ramal screws.

Symphyseal screws

The sympheseal area of the mandible provides several advantages for anchorage preparation as it has both good quality and quantity of bone. The clinician can easily gain access to this site and associated anatomical complications are usually negligent as there are no adjacent nerves or vessels which could be possibly damaged while implant placement. The site is generally used as site for maxillary protraction in protruded mandibular and this has shown to produce similar results to that of orthopaedic appliances for the same correction [32].

Palatal screws

Palatal screws are becoming increasingly popular with their greater dimensions and superior stability for orthodontic tooth movement. The excellent quality of bone decreased soft tissue covering and least possibility of damage to adjacent roots or teeth makes the anterior part of the palate a good site for TAD insertion with minimal failure rates. The reduced amount of bone present in the posterior and lateral parts of the palate increases risk of breakage and tipping of the implant.

Anatomy of palate

Hard palate consists of the anterior 2/3rd which is immobile and formed by the two horizontal palatine plates. It forms the roof of the oral cavity and the floor of the nasal cavity and divides them into two parts. It consists of three major foramina: the incisive foramen found in the anterior palate directly behind the central incisors; greater palatine foramina found in the posterior palate distal to the second molar and the lesser palatine found posterior to the greater palatine foramina [33].

Thinner quality of the soft tissue makes it ideal for the palatal screw insertion. Even though the mucosa is thicker around the lateral sites, uniform thickness of 1 - 4mm of soft tissue is found between the mid-palatal suture lying distal from the incisive foramen. The anterior palate presents with lesser blood vessel density and has lower risk of inducing any iatrogenic injury. The greater palatine area on the other hand has a higher blood vessel density and mini-screw insertion in this area can lead to increased risk factors [33].

Becker., *et al*. from their study found that the total palatal bone thickness in the adult group ranged from 9.85 ± 2.04 to 1.87 ± 0.79 mm. In the adolescent group, it was found to be one-third of the incisor roots in the area 3 mm distal to the incisive foramen and 8 mm lateral to the mid-palatal suture. The cortical bone thickness in adults was thicker in the posterior para-median area as compared to adolescents [35].

T zone

T-zone is the area present behind the rugae that is considered an ideal site for the placement of palatal implants since it holds good quality and quantity of bone required for stability (Figure 8) Recent studies have shown that the T zone is narrower than what has been determined from previous studies. Adequate bone support in the para-median region is seen mainly in the first premolar region and for the median placement it extends till the second premolar region. For further posterior mini-screw placement slight anterior tipping was recommended. Similarly, for anterior placement slight posterior tipping was proven beneficial. Hourfar's study reported that the 3rd palatal rugae provides a stable and clinically identifiable landmark for the insertion of orthodontic Mis [36,37].

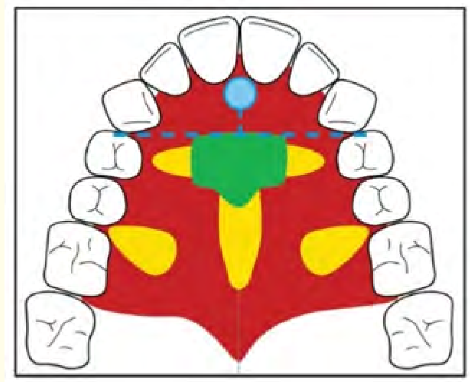

Figure 8: T-zone-ideal area of insertion of palatal screws.

Conclusion

Temporary anchorage devices are now of frequent use in everyday orthodontic practice. While the usage holds with it numerous advantages, associated anatomical considerations become important for the clinician to avoid injuries or failure of the implant. The ideal placements of extra-alveolar TADS along with their important adjacent structures hence is essential to the orthodontist.

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