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Review Article

Infra zygomatic crest (IZC) and mandibular buccal shelf (MBS) bone screws: A comprehensive updated review

Mohsin Aslam Wani[1,*], Diptiman Shukla[2], Mohd. Amir[3], Shiraz Siddiqui[4], Sana Mehtab[5], Mohd Saeedul Jafar[5], Md. Anas Husain Khan[6], Maisa Rasool[7]

[1]*Dept. of Orthodontics and Dentofacial Orthopaedics, Embrace Orthodontic and Implant Centre, Srinagar, Jammu & Kashmir, India*
[2]*Dept. of Orthodontics & Dentofacial Orthopaedics, Banaras Hindu University, Varanasi, Uttar Pradesh, India*
[3]*Dept. of Orthodontics & Dentofacial Orthopaedics, Care Dental Clinic, Pryagraj, Uttar Pradesh, India*
[4]*Health Gulf Polyclinic, Tabuk, KSA*
[5]*Dept. of Orthodontics & Dentofacial Orthopaedics, Career Post Graduate Institute of Dental Sciences & Hospital, Lucknow, Uttar Pradesh, India*
[6]*Dept. of Oral and Maxillofacial Radiology, H.M.S. Memorial Hospital, Banda, Uttar Pradesh, India*
[7]*Dr. Qaiser's Dental Clinic, Srinagar, Jammu & Kashmir, India*

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ABSTRACT

The definition of anchorage is the opposition a body exhibits to being displaced. In orthodontics, the body is used to simulate a tooth, and forces that can be either light and continuous or heavy and intermittent are used to propel it around. When natural tooth motions are to be performed in greater amounts, they must be fastened against an anchor that, if feasible, is fairly enduring. This is when anchoring is required in orthodontics.

1. Introduction

The concept of skeletal anchorage was first introduced more than 70 years ago, as mentioned by Papadapolus.[1] Reactionary forces are generated with each orthodontic force application and, in accordance with Newton's third principle, will induce tooth movements in the reverse direction, which is undesirable for the majority of orthodontic biomechanics. Gainsforth B. L. and Higley L. B. in 1945 inserted Vitallium screws in the ascending ramus of the mandible of dogs and proposed that in the future anchorage for orthodontic movement can be obtained by inserting metallic screws into the bone. They have since been employed as temporary anchoring for canine retraction, anterior segment retraction, dental intrusion, distalization, mesialization, and other procedures.[2] Creekmore and Eklund utilised a Vitallium bone screw implanted in the anterior nasal spine to manage a case with a profound overbite in 1983, which was the first therapeutic application recorded in the empirical studies. A mini-implant designed exclusively for orthodontic usage was reported by Kanomi in 1997, while a screw with a bracket-like head was introduced by Costa et al. in 1998.[1] Thereafter, many studies were

* *Corresponding author*.
E-mail address: mohsynaslam@gmail.com (M. A. Wani).

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conducted to develop a simple protocol for mini-implant insertion, increase the success rate, and introduce skeletal anchorage in clinical practice.[3] For decades, traditional extraoral appliances have been used to assist maxillary molar anchoring or for distalization. The main downside of an extraoral technique, unfortunately, is a low level of patient compliance. To address this adverse implication, researchers have been urged to employ Temporary Skeletal Anchorage Devices (TSADs). The use of mini-plates and mini-screw implants as anchoring allows for distal translation of anterior or posterior teeth (or both) without anchorage compromise.[4] As a result of the necessity for maximum anchoring control, while requiring little patient participation, implant-aided orthodontic therapy has seen widespread use and development.[5] In spite of being frequently inserted in portions of the alveolar process situated between the roots of consecutive teeth, referred to as Inter-radicular (I-R) sites, newer locations referred to as Extra-alveolar (E-A) or Extra-radicular sites, have been advocated as implant location for extra-radicular bone screws such as Infra-zygomatic Crest (IZC) and Mandibular Buccal Shelf (MBS) Implants.[6] The following advantages have led a number of researchers to suggest the infrazygomatic crest and the mandibular buccal shelf area as potential locations for establishing an effective and secure anchoring system, and improving therapeutic boundaries:

1. Reduces the possibility of unintentional root injury.
2. More cortical bone at the implant site.
3. No obstruction of a tooth or a set of teeth's mesiodistal movement.
4. The acquired anchoring allows for retraction or mesialization of the complete dental arch as well as dentition.
5. There is a low failure rate when equated to standard mini-implants.
6. Requires fewer implants to tackle difficult problems.[6]

Important osseous features, such as the availability of denser cortical bone, which enables strong primary stability, may be found in the infra-zygomatic area.[7] The objective of this literature review is to encompass and discuss the development, usability, efficacy and scope of implant-assisted orthodontics, specifically Infra-zygomatic crest (IZC) and Mandibular Buccal Shelf (MBS) implants in the contemporary orthodontic treatment modalities.

2. Anatomical Characteristics of Infra-zygomatic Crest (IZC) Region

Anatomically, the infrazygomatic crest (IZC) is the site on the maxillary bone near the zygomatic process of the maxilla, situated between the first and second molars, ideal for the placement of an orthodontic miniscrew or miniplate. Clinically speaking, it is a perceptible curvature of the osseous crest that runs between the maxillary alveolar and zygomatic processes. Because of its thicker bone, the IZC is often employed as an insertion site for orthodontic skeletal anchoring. More miniscrew biting depth, increased bone interface, and improved primary stability are all made possible by thicker bone.[8] Misch and Kircos claim that the IZC region's bone density is higher than that of the maxillary alveolar ridge (D2/D3 vs. D3/D4).[8] The buccal cortical plate and the sinus floor are the two cortical plates found in the IZC area. Its anatomical benefit permits bi-cortical fixation and may help to improve the miniscrew's main stability.[8–10] The infrazygomatic crest (IZC), is the site that De Clerck et al. chose for the insertion of the skeletal anchorage system.[9] Aline Rode Santos et al. discovered that the infrazygomatic crest's mean thickness in males was 3.55mm when assessed from 2mm (M1) above the distobuccal root of the permanent maxillary first molar and 2.84mm when assessed from 4mm, compared to 2.37mm and 2.24mm in females (Figure 1), with no statistically sizeable variations between the sexes.[9] However, Infrazygomatic crests were observed to be diagnostically thicker in male patients than in female patients, according to Lee et al. Similar to this, Baungaertel and Hans noted that there is significant individual variation in infrazygomatic crest thickness.[9,11] Also, the skeletal Class III group has thicker cortical bone than the skeletal Class I group.[12] According to Lin et al., the infrazygomatic crest is located above and to the side of the first and second molar regions. They chose to position the bone screws closer to the first molar's mesiobuccal root in the first and second molar regions. In young people, it lies between the second premolar and the first molar, however, it is above the maxillary first molar in adults.[10,13] In contrast, Chang et al. proposed that the ideal location to place extra-alveolar miniscrews in the maxilla is buccal to the first molar's mesiobuccal roots.[13,14] The optimal location of the IZC for screw placement, according to another study, must adhere to the spatial orientation of the second molar's mesiobuccal root, as the area possesses thicker, denser bone.[13]

3. Anatomical Characteristics of Mandibular Buccal Shelf (MBS) region

The mandibular buccal shelf (MBS) is an osseous depression located lateral to the mandibular molar region in the posterior jaw (Figure 2). Its anatomical borders are located between the masseter and temporalis muscle attachments in the back and the buccal frenum in the front. Buccal to the molars, there is a thick cortical plate.[15] Yet there are certain concerns, particularly with regard to variability in anatomic and osseous thickness, in this area. The bone thickness in the MBS grew transversely and vertically in the distal and apical sections, meaning that the more posterior the buccal shelf, the thicker the bone was, according to the research by Eduardo et al. A minimum thickness of 4 mm buccal to the distal root of the mandibular second molar was present in over 75% of the samples. This shows that the buccal to the distal root of the mandibular second molars is the ideal location to place extra-alveolar miniscrews in the mandibular arch.[14] For safe mini-screw insertion, 5 mm of buccal bone thickness is regarded as the minimum base value for the buccal extension of the MBS (1.7 mm of root safety distance, 1.6 mm of screw thickness, 1.7 mm of cortical buccal bone safety distance). The second molar's distal root location has much denser bone than the mesial root, indicating that the distal root is a more reliable area for insertion than the mesial root.[16] In addition to the horizontal bone thickness characteristic, it's crucial to assess the corono-apical (vertical) bone height measurement of the MBS in order to choose the right screw length. The mesial and distal root scans of the mandibular second molars show a large standard variation of vertical bone dimensions at 6 mm buccal to the CEJ, indicating a high topographical deviation of the MBS.[16] The anatomical makeup of the MBS has a significant impact on how well the treatment mechanic's work. Considering these features of the MBS, the most logical and secure insertion location for the distalization of the complete mandibular dentition is the area between the distobuccal root of the first molar and mesiobuccal root of the second molar (L6db-L7mb).[17] Parinyachaiphun et al. examined the cortical bone thickness at the first and second molar contact points and the mesial aspect of the second molar in the jaw. They came to the conclusion that the cortical bone thickness at the second molar's mesial aspect was greater than that at the first and second molar intersections. Whilst the mandibular buccal shelf provides enough osseous structure in both the quality and the quantity for bone screw insertion, if the mandibular buccal shelf is shallow and sparse, as is frequently the case in the Indian population, orthodontic bone screws can also be inserted on the external oblique ridge.[10] According to Chang et al., the mandibular buccal shelf's slope flattens from the anterior to the posterior area, facilitating the implantation of orthodontic anchoring screws. He concluded that the mandibular buccal shelf is a suitable location for explicit attachment to retract teeth for the treatment of class III malocclusion and mandibular crowding without extraction.[10] Both the infra zygomatic crest (IZC) and the mandibular buccal shelf (MBS) regions are regarded as the safest zones since they lack any significant anatomical features like dental roots, nerves, etc. The bone in the IZC/MBS areas is of sufficient quantity and quality to offer appropriate primary stability, with the D1 bone type (> 1250 HU), the bone density is likewise high.[18] Furthermore, in both these sites, the thickness of bone varies with high-angle patients having thinner bone cortices in the IZC region as well as the MBS region.[14,19]

4. Metals/Alloys Used in the Manufacturing of IZC and MBS Implants

Nearly all of these orthodontic implants are made with a uniform texture to avert the advance of osseous ingrowth and are mechanically retained by the interlocking instead of establishing a histopathologically visible ankylotic junction with the bone that makes the retrieval procedure more difficult.[1,3] Stainless steel (bio-tolerant) and type IV or type V titanium alloy (bio-inert) make up the majority of orthodontic implants.[1,3] According to Chang et al., both stainless steel (SS) and titanium alloys (TiA) are clinically potentially suitable for IZC and BS Implants since the total success rate was 93.7%. There were no appreciable variations in the osseous reaction between SS and TiA (Ti) when compared in vivo for use as bone screws. SS (7.0%) and Ti (5.7%) make up a failure rate that is 6.3% overall (Figure 3). Clinical significance was not reached (P =.07) despite the 1.3% difference between SS and Ti (TiA).[20] Even though titanium does not exhibit immune-mediated responses or malignancy growth, it is regarded as a non-reactive substance. Regrettably, the fatigue strength of pure titanium is lower.[18] As the titanium alloy constructed of titanium, aluminum, and vanadium (Ti-6Al-4V), is stronger than pure titanium and can withstand common issues like fractures and distortions, it is utilized instead of pure titanium.[5] The incidence of fracture during placement is significantly reduced by the unique structural characteristics of stainless-steel bone screws, such as their exceptional flexural strength and shear resistance.[21,22] Due to the stainless-steel bone screw's pointed tips, predrilling is not necessary prior to their insertion.[21] Despite their many variances, titanium alloy and stainless steel both offer equal effectiveness in meeting the primary biomechanical criterion of stability.[5]

5. Difference between Bone screw and Mini-implant

While both extra-radicular bone screws (IZC, BS) and mini-implants are categorized as temporary skeletal anchoring devices (TSADs), bone screws are positioned distant from the roots in the infra-zygomatic regions of the maxilla and the buccal shelf regions of the mandible (extra-radicular). Bone screws are often bigger in size, varying from 10 to 14 mm in length and a minimum thickness of 2 mm. Similar to mini-implants, bone screws are offered with short or long heads, and based on the anatomical position and the functional context, they can also have short or long collars. The form of their heads can also differ, with the mushroom design being the most prevalent. Apart from the fact that they cannot be inserted between teeth due to their greater size, orthodontic bone screws can be utilized in practically all clinical situations where a mini-implant is employed.[22]

6. Biological Limits of Distalization with Orthodontic Bone Screws

There is a posterior anatomic threshold across which orthodontic tooth movement may very minimally be accomplished, irrespective of the anchoring unit utilised for distalization. The maxillary tuberosity serves as the maxillary arch's profound posterior boundary.[23] Rickett's criterion, or age-dependent and sagittal distance from the pterygoid vertical, is used to determine the boundaries of distalization in the maxillary arch. Third molars that have fully emerged should preferably be sacrificed to make room and facilitate the distalization procedure. For teenagers with unerupted wisdom teeth located below the cement-enamel junction of the second molars, distalization without their extraction is achievable to some extent if certain conditions are met. But, later in the course of therapy, extractions are advised to stop relapse.[22] In the case of the mandibular arch, two types of anatomical constraints for orthodontic tooth movement are seen at the crown level and root level, respectively. The ramus, which is associated with the distalization of mandibular molars, is the sole anatomic component that can be met at the crown level during orthodontic tooth movement in the mandibular arch. Pressure necrosis results only after the enamel of a tooth's crown comes into direct touch with the cortical bone.[23] However, the posteriorly accessible space in the mandible is less at the root level than at the crown level and the cortical layer of the alveolar bone at the level of the root restricts the tooth mobility, showing that the lingual cortex of the mandibular body, rather than the anterior boundary of the ramus, served as the posterior anatomic limit. Therefore, the distance between the second molar roots and the lingual cortical plate, as governed by the Angle of Inflection, defines the boundaries of distalization in the mandibular arch (Figure 4). Removal of the third molar is nearly always necessary for distalization in the mandibular arch. The periodontal coverage may be compromised if the tooth shifts far enough towards the outer cortex due to root exposure, gingival recession, and erosion of the alveolar ridge.[22,23]

7. Stability - Success and Failure of Orthodontic Bone Screws

The stability of non-osseointegrated TSADs under load is a significant issue. This is due to the fact that when utilised as orthodontic anchoring, they have the potential to slip in relation to the basal bone. Bone labeling for loaded TSADs in primates showed that hard, non-osseointegrated screws migrated inside bone via a bone-modelling and bone-remodeling process that was comparable to tooth movement (Melsen B. and Roberts W.E., unpublished data).[20] Mechanical adherence and biological responses so affect the stability of mini-implants and bone screws. Primary stability is a biomechanical phenomenon influenced by the kind and volume of bone, the configuration of the implant, and the method of implantation. Bone remodelling and modelling at the implant-bone interface lead to secondary stability.[5] The effectiveness of orthodontic implants is determined by an array of parameters that directly affect their stability, including cortical bone (quantity and quality), mandibular plane angle, type of implant (thickness, length, and form), implant location (angle), gingival tissue surrounding the implant, the patient's age (as the quantity and condition of bone decreases with age), root adjacency, and the amount of force applied, etc.[2,3,24] The principal implant stability is also increased by the deeper insertion depths to prevent significant tipping moments at the osseous margin.[5] Comparing the mandibular buccal shelf to other implant sites on the jaw, the cortical thickness is relatively higher and will offer significantly improved primary stability.[10] An implant thread diameter of 1.0 mm or smaller has been shown to be related to instability. Also, because of the thin cortical bone, people with steep mandibular plane angles have greater risk of implant failure and results in reduced survival rates of just 72.7%.[1,3,7] According to a systematic review by Schatzle et al., orthodontic miniscrews with a diameter > 2 mm had a roughly two-fold reduced rate of failure than those with a diameter of 1.2 mm. Maintaining proper oral hygiene is crucial for the implant's durability and, consequently, for improved anchoring.[21] Extra-alveolar mandibular buccal shelf (MBS) bone screws inserted in the movable mucosa or attached gingiva were compared for their preliminary failure rates by Chris Chang et al. According to him, although buccal shelf implants should always be put in connected gingiva, numerous patients only have a narrow strip of gingiva attached buccal to the molars, therefore more than 75% of buccal shelf screws that were properly positioned entered moveable mucosa. He proposed that because oral hygiene is made easier when the screw head is elevated (5 mm or more above the soft tissue level), this location is probably a key element in successfully keeping the screws in moveable mucosa (Figure 5).[25] When used in attached gingiva or moveable mucosa, MBS bone screws are equally successful due to ample soft tissue clearance.[15] The drawback of this strategy is that a larger (12mm) screw is needed.[26] However, non-keratinized gingiva has been suggested to be a contributing factor for implant failure due to its reduced resilience against the effect of plaque and the likelihood of developing an inflammatory response.[7] The methodological delicacy of the treatment and perhaps other uncontrollable epigenetic factors like chewing and brushing habits were blamed for the inconsistencies in failures on the left side (9.29%) compared to the right side (5.12%). Moreover, a right-handed practitioner may find it more challenging to place buccal shelf miniscrews on the contralateral side.[25] According to research by Flavio Uribe et al., IZC bone screws had a little lower success rate (78.2%) than the typical mini-implant. In contrast, recent research by Chang et al. found that mini-implants placed in this area had a 93% success rate, while Liou et al. found that they had a 100% success rate.[7,20,26] Inadequate bone quality, early implant loading, closeness to the sinus floor, and implantation in moveable mucosa are among the major causes of implant failure, according to Chang et al. Moreover, if an IZC bone screw was maintained to deliver the expected anchoring, movement inside the bone tissue was not considered to be an indication of failure.[20,26] The angle of insertion and the direction of the loading force in implants put in the IZC area are two significant factors that might affect the failure rate. In fact, Perillo et al. discovered using the finite element analysis (FEA) approach in a recent study that the stress on the bone is significantly influenced by the angle at which the orthodontic implant is inserted, and the thrust being applied.[7]

8. Concepts and Methods for Placement of Bone Screws in the IZC Region of the Maxilla

The first location of penetration for bone screws is interdentally in the zone between the first and second molars and 2 mm just above the mucogingival boundary in the alveolar mucosa for implantation in the IZC area (1st and 2nd molar region). At this stage, the self-drilling screw is pointed 90 degrees away from the occlusal plane. The orientation of the bone screwdriver is altered downward by 55° to 70° towards the tooth (occlusal plane) after the first notch in the bone is made (Figure 6). This helps to securely route the screw inside the infra-zygomatic region of the maxilla while avoiding the teeth's roots. For the insertion of IZC bone screws, there is no need for pre-drilling, flap lifting, or a directional incision in the mucosa.[22] Instead of placing IZC bone screws in inferior places (like mid-root), Eric J. W. Liou et al. advised doing so in higher locations, like at or past the root apex, where the inter-septal bone is denser with a lesser risk of molar root damage and suggested that in the adult's infra zygomatic crest screw should be inserted at a height of 14 to 16 mm above the maxillary first molar and at an angular position of 55° to 70° to the maxillary surface in order to prevent bone stripping, damage to the mesiobuccal root of the maxillary first molar, engage adequate cortical bone thickness and abate irritation of the alveolar and buccal mucosa.[8,18,27,28] The feasible location for an IZC bone screw, according to John Lin, is either anterior to the anatomic ridge, buccal to the mesiobuccal root of the maxillary first molar (MBR of U6) or distal to the anatomic ridge, buccal to the mesiobuccal root of the maxillary second molar (MBR of U7). These implantation areas are referred to as IZC 6 (Maxillary First Molar) and IZC 7 (Maxillary Second Molar).[26] When generalising the diameters of bone screws, soft tissue clearance, attached gingiva, and cortical bone at 1.5mm each, John Lin proposed that 8 to 12mm long IZC bone screws enter nearly 3.5 to 7.5mm into the medullary bone or sinus floor. Therefore, in most practical situations, an 8mm bone screw length is sufficient to contact a sufficient cortical plate to ensure satisfactory primary stability.[26] To promote maximum buccal bone engagement, Liou proposed positioning screws 55°-70° inferior to the horizontal plane, however, it was unclear whether the IZC of the first or second molar area was the optimum anatomical spot. Despite an increased angulation of 55-70° (Liou's IZC 6), the alveolar bone is too fragile to implant a bone screw buccal to the mesiobuccal root of the first molar.[26] Nevertheless, John Lin recommended inserting an IZC screw lateral to the mesiobuccal root of the second molar (Lin's IZC 7) to produce a more reliable extra-radicular location for maxillary arch retraction. The IZC site of the second molar is generally the preferable position for bone screw implantation since the alveolar bone is firmer on the buccal surface of the second molar. Additionally, Lin's therapeutic alliance with orthodontic bone screws inserted in the IZC of the first and second molar locations demonstrated that maxillary arch retraction was more frequently attained using bone screws in the IZC region of the second molar position instead of the first molar position.[26]

9. Concepts and Methods for Placement of Bone Screws in the MBS Region of the Mandible

The initial position of insertion for bone screws in the buccal shelf region of the jaw (2nd molar region) is interdentally between the 1st and 2nd molars and 2 mm below the mucogingival junction. At this stage, the self-drilling screw is angled 90 degrees to the occlusal plane. Following a few rotations with the driver, the bone screwdriver direction is adjusted by 60°-75° towards the tooth, upward, which assists in avoiding the roots of the teeth and guiding the screw to the buccal shelf zone of the mandible (Figure 7). Nevertheless, in the mandible, pre-drilling or a vertical cut in the mucosa may occasionally be warranted if the bone mass is too high; elevation of the flap is never essentia.[22] To maximize osseous engagement and reduce the chance of root injury, Park et al. recommended setting the screws at an acute angle to the surface of the bone. The use of relatively large screws that may be placed along the axial inclination of molars and, as a result, not infringe on the tooth roots is made possible by positioning the devices in an E-A site like the MBS.[15,25] A self-drilling treatment entails a procedure whereby the bone screw is inserted into the bone perpendicular to the occlusal plane without piercing the site first or reflecting the soft tissue flap. In order to ease oral health access and prevent soft tissue discomfort, the screw head must be no less than 5 mm above the level of the soft tissue post-placement.[15]

10. Distalization snd Retraction with Bone Screws in the IZC and MBS Areas

Traditional mini-implants can be used to distalize the whole arch, but there are restrictions since they are positioned inter-radicularly, increasing the likelihood of root encounter during the distalization procedure provided segmental (two-step) distalization is performed before the screw is repositioned for retraction). Extra-radicular bone screws offer more stability and are relatively safe when complete arch distalization is performed.[22] The point of application of force is more parallel and near as possible to the occlusal plane because of how the bone screws are positioned, which lowers the risk of occlusal plane rotation, the advancement of a posterior open bite, or an anterior deep bite, which are frequently linked to the mini-implant assisted retraction. The absolute control over the occlusal plane is still determined by the height of the hook and the force axis from the bone screw.[22] The likelihood of molar rolling-in is higher since the force produced by the bone screw is from a more buccally positioned anchoring unit and it must be adjusted with an extended arch form or a torque in the wire, depending on which is appropriate for the clinical circumstance. Mini-screws, however, do not have these adverse effects because of their inter-radicular location.[22]

11. Biomechanics of IZC Bone Screws

As the total maxillary arch is distalized, the infra zygomatic crest (IZC) implants create a retraction force system that produces intrusive and extrusive forces in the incisor and molar regions, respectively. This clockwise rotation of the maxilla around the centre of resistance (CR), which is situated between the premolars is brought on by the line of force of action passing beneath (occlusal) the maxillary CR (Figure 8). Hence, it is reasonable to predict incisor extrusion, which may not be advantageous for individuals with deep bites. On the other hand, this occlusal plane movement in a clockwise direction encourages concurrent Class II correction and open bite closure.[6] It is recommended that in addition to two IZC bone screws, two additional mini-implants be placed between the central and lateral incisors in order to counteract the maxillary occlusal plane's clockwise rotation and the anterior extrusion while causing the whole maxillary dentition to intrude and favouring gingival smile improvement.[6] Moreover, by altering the height of the hooks in the anterior region and the direction of the force, the biomechanics of retraction may be altered. Clinically, similar differential motions can be replicated on the anterior teeth when using mechanics with extra-alveolar implants by altering the line of action of force by variations in hooks/power arm length.[6,29] When utilising short hooks, the retraction force delivered passes underneath the CR, increasing the propensity of clockwise spin of the anterior teeth, which causes torque loss and a vertical extrusion force on the incisors. Increased hook length mesial to the canine permits the force action line to approach very near the incisor's centre of resistance. Because of this technique, the anterior moment is likely to be balanced out, and incisor torque can be preserved during retraction with minimal disturbance in the occlusal plane. The hook/power arm length must be increased during the distalization of the whole arch in order to cause the force line to pass well above centre of resistance, producing an anticlockwise moment on these teeth and an extrusive force on the incisors. Park et al. made reference to the necessity of using arch wires with long hooks however there is a chance of damaging the patient's oral mucosa, it is, therefore, crucial to note that in clinical practice, such a circumstance may be more challenging.[6] In a comparative finite element analysis (FEA) study, Sneha Sanap and colleagues found that, when compared to IZC bone screws inserted posteriorly, the degree of anterior segment intrusion was greatest when miniscrews were positioned between the upper first and second premolar teeth and between the upper second premolar and first molar. The outcomes were statistically noteworthy. In all FEM models, there was no bucco-palatal rotation caused by changing implant placements.[19]

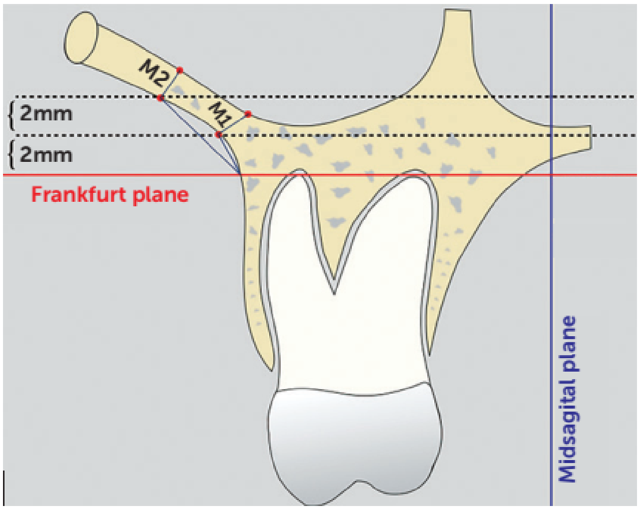

Fig. 1: Overall mean thickness of theinfrazygomatic crest, measured at M1 and M2.

12. Biomechanics of MBS Bone Screws

By using two bone screws in the buccal shelf, a full-size rectangular archwire, and NiTi coil springs to apply a continuous force of 200g (Figure 9), Roberts et al. illustrated a reliable system for retraction of the whole mandibular dentition that is deemed "statically determinate" and is based on biomechanics. In addition, the authors hinted at the presence of three essential conditions for the mechanics

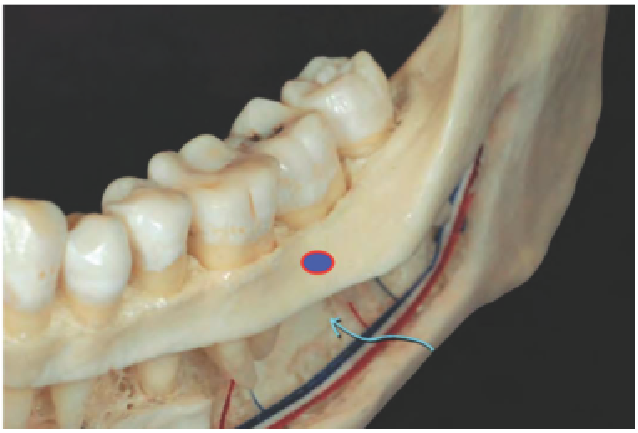

Fig. 2: Cutaway preparation of the posterior mandibular arch with a blue arrow marking theendosseous space available for E-A bone screw in the MBS. The blue oval with a red outline marks the preferred site for bone screw insertion.

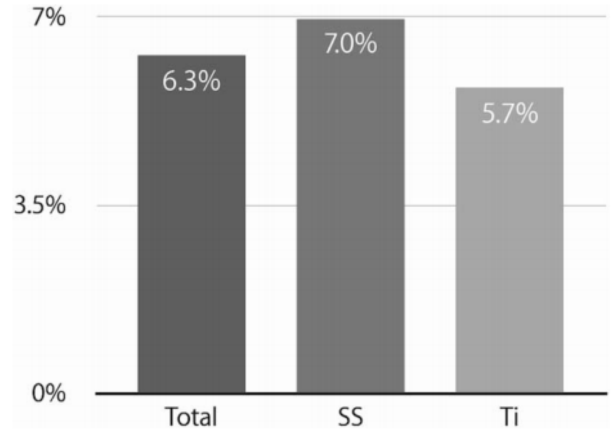

Fig. 3: Overall and partitioned failure rate of stainless steel and Titanium bone screws.

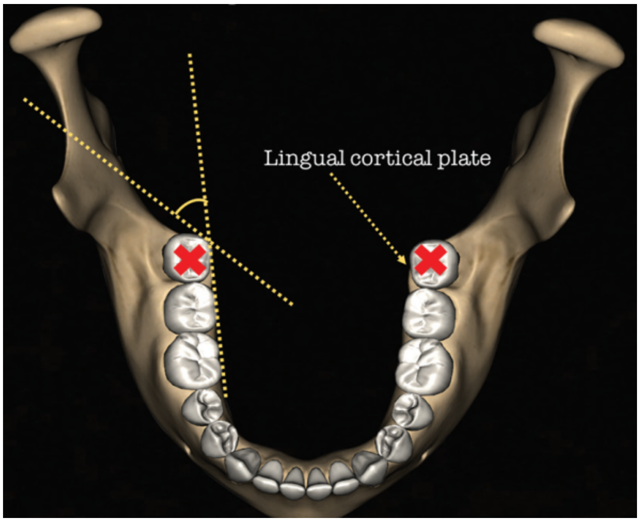

Fig. 4: Limits of mandibular distalization, angle of infliction.

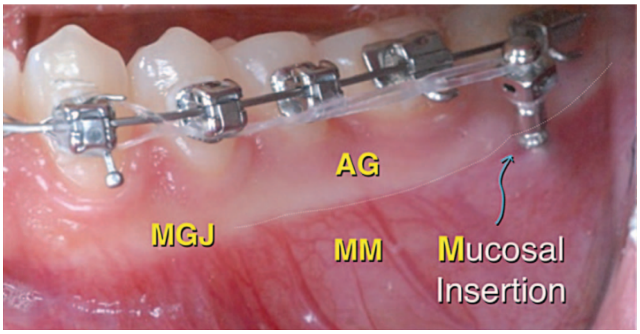

Fig. 5: Screw insertion point may penetrate AG or MM, but the head of the screw must be at least 5 mm above the level of the soft tissue.

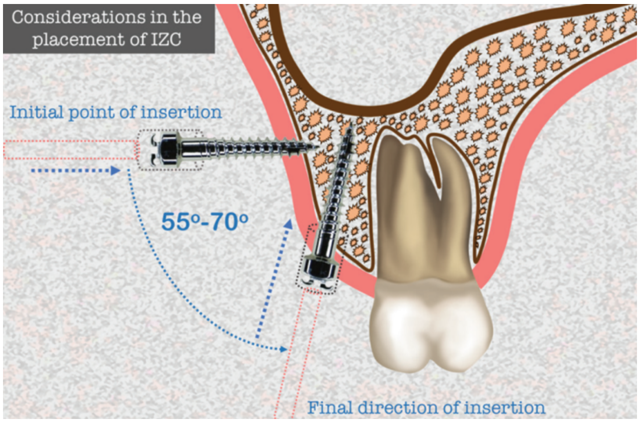

Fig. 6: Considerations in the placement of infra-zygomatic bone screws.

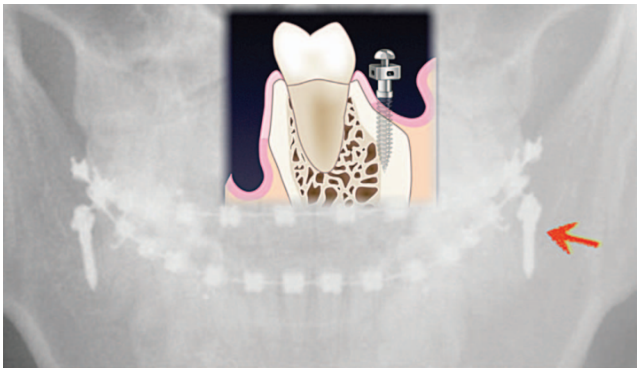

Fig. 7: A drawing superimposed on a radiograph shows that a properly positioned screw isbuccal to the molar roots.

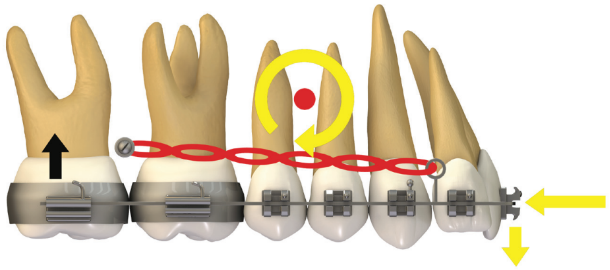

Fig. 8: Biomechanics produced by the IZC to retract the entire maxillary dentition in a single block.

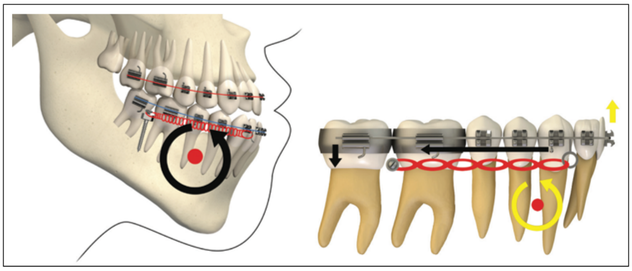

Fig. 9: Biomechanics of buccal shelf implant

to be regarded as statically determinate and capable of being explored using finite elements: the employment of a full-size rectangular arch with torque control during retraction, a constant relative force resulting from super-elastic NiTi coil springs, and a force directly applied to the arch.[6] Since the rotation of the mandibular arch, which results from the retraction force in the entire arch, produces intrusive forces in the molars and extrusive forces in the incisors, Roberts et al. considered this mechanics for mandibular teeth retraction anchored on two Buccal Shelf bone screws to be an incredible guide for the non-invasive and non-extraction treatment of Class III malocclusion with anterior open bite. Finite elements analysis (FEA) revealed that this anticlockwise rotation of the mandibular plane caused a 3mm molar intrusion and a 2mm incisor extrusion, promoting open bite closure and concurrent Class III correction.[6,30] A comparison between posterior mandibular or infrazygomatic anchoring and mandibular arch retraction showed that the inferior direction of traction (posterior mandibular) was superior to the infrazygomatic crest anchoring location for closing the open bite and reducing the vertical dimension of occlusion.[30]

13. Force Magnitude

Because of its effect on anchoring stability, the scale of force utilized in an extra-alveolar mini-implant system is crucial for biomechanical effectiveness. For therapeutic procedures involving implants in the IZC area, the suggested magnitude ranges from 220 to 340g (8 to 12 oz), and for those in the MBS area, it ranges from 340 to 450g. It is important to note that such a force allows for the en masse retraction, or distalization, of the whole arch. The applied force must be modified to be between 150 and 200g for situations when a limited retraction is required, such as to retract canines and premolars.[6]

13.1. Indications

Orthodontic bone screws can be utilized in nearly all clinical settings where a mini-implant is appropriate, with the exception that they cannot be positioned between teeth due to their greater size.[22]

1. Because they enable better anchorage instantly after insertion (primary stability) into maxillary and mandibular buttress bone areas, they are also suitable for molar uprighting and mesialization, segmental, and full arch distalization, intrusion of single tooth to full arch, protraction and retraction of the dentition, as well as for any other anchorage requirements. Nevertheless, the two most definite needs would be full arch distalization of the maxillary and mandibular dentition to obscure a Class II or Class III malocclusion and for distalization of arches in re-treatment cases of anchoring loss, which would normally be challenging or time-consuming to complete with a conventional mini-implant.[22,29,31,32]
2. Asymmetry correction of the occlusal plane and midline deviation, anchoring for cantilever use in impacted canine traction or transposition, and preparation for surgical intervention in Class III patients are other reasons for using bone screws in the IZC,[6,42] eliminating marginal ridge discrepancies by axially inclining the buccal teeth.[33]
3. They can be used for Class III compensatory treatment, canine distalization in instances of severe mandibular crowding, mesial movement of the molar, intrusion of posterior teeth, adjustment of occlusal plane discrepancies, treatment of midline mismatch, anchorage for cantilever use in mandibular impacted canine traction, and orthognathic surgery.[6,18]
4. A severe scissors-bite malocclusion worsened by maxillary protrusion can be corrected with extra-alveolar bone screws by intruding the extruded maxillary molars and elevating the mandibular buccal segment with a mandibular buccal shelf bone screw on the side of the scissor bite.[33]

14. Complications of IZC and MBS Implant Placement

14.1. Inflammation, Infection, and Soft Tissue Irritation

Careful oral cleanness is essential, and any potential irritation or infection can be avoided and controlled by using dental floss soaked in 2% chlorhexidine or mouth rinses with 0.2% chlorhexidine. It is advisable to place the bone screw implants in keratinized gingiva and to stay away from frenum and muscle tissue.[1] The mandibular buccal shelf bone screws may potentially break if they are positioned too deeply in the buccal fold, irritating the soft tissues around and can be avoided by using lengthier screws that have at minimum 5 mm of space between the head and the soft tissue implant site.[30]

14.2. *Injury to adjacent structures*

The patient often exhibits pain on percussion and chewing in cases of periodontal injury signs, and intolerance to hot and cold in instances of root damage. Damage to nearby roots, periodontal ligaments, nerves, and vasculature may also occur. The bone screw implant should be withdrawn right away in such cases.[1] As a result, by using the right IZC screw driving inclination, care must be given before or following the implantation of IZC bone screws to prevent injury to the tooth root.[18] Avoid touching the distal root surfaces of any teeth in the buccal segment when inserting IZC bone screws in the first molar area. When placing screws on the left side, right-handed physicians must take extra caution, and vice versa. Regardless of whether an appropriate IZC bone screw is inserted in the area of the second molar, iatrogenic ankylosis of the injured root may develop and inhibit retraction.[34] The closest precise positioning is achieved with CAD/CAM surgical guides, so as to aid in reducing the tooth damage around the implant area while providing accurate miniscrew head location for improved treatment efficiency.[35,36]

14.3. *Fracture of the implant*

If the collar of the screw is too thin, a fracture of the bone screw implant may happen upon withdrawal. It is advisable to utilize bone screw implants with a baseline thickness of 2 mm or more in order to prevent this issue.[1] Park et al. advised against using self-drilling bone screws in areas of compact and dense cortical bone, such as the mandibular buccal shelf (molar regions). Instead, they suggested using the self-tapping approach.[3]

14.4. *Maxillary sinus perforation*

The Schneiderian membrane, which is adhered to the maxillary sinus's surrounding bone, is distinguished by a periosteum layered with a fine layer of pseudo-ciliated stratified respiratory epithelium, serving as a crucial defence and shield for the sinus canal. For the sinuses to work normally, it must be intact. The sinus membrane becomes raised when implants reach less than 2 mm into the maxillary sinus, which promotes repair because it permits for the creation of a blood clot that acts as a supporting structure for bone growth in this area. The Schneiderian membrane gets punctured when the implant extends farther into the maxillary sinus, which may lead to the expulsion of bone debris inside the sinus and raising the risk of sinus infections.[9] Sometimes, a depressed sinus floor is seen between the roots of teeth, which is not ideal for an IZC implantation.[26] The architecture of the infrazygomatic crest must thus be thoroughly evaluated using specialized tests, such as CBCT, allowing for implants to be inserted into an appropriate bone surface.[9] Baungaertel and Hans et al. discovered that there is a higher risk of maxillary sinus breach when the bone screws are inserted in a more cranial orientation. They demonstrated that the median cross-section of the infrazygomatic crest is less when calculated farther from the root apex.[9] Kravistz and Kusnoto assert that because mini-screws have a smaller size, they should not be removed right away if they puncture the maxillary sinus membrane. To prevent the potential emergence of sinusitis and mucocele, orthodontic treatment should proceed, and the patient should be monitored.[9]

14.5. *Slippage of the implant*

The implant might accidentally roll underneath the mucosa along the periosteum if the surgeon doesn't firmly contact the cortical bone during implantation. Steep osseous surfaces in the alveolar mucosa, such as the zygomatic buttress, the retromolar pad, the buccal cortical shelf, and the maxillary buccal exostosis if prominent, are potential risk areas for implant sliding. To circumvent this, the practitioner can contact the bone with the screw at a more obtuse angle at first, then reduce the inclination of entry after the second or third rotation. Slippage of the bone screw is more likely with higher stresses.[37]

14.6. *Nerve involvement*

In the distal root of the second molar, the inferior alveolar nerve is located in the mandible's body at its greatest buccal location. Hence, the inferior alveolar nerve is most vulnerable to inadvertent injury when bone screws are put close to the mandibular second molar. The dento-alveolus soft-tissue shape might be deceiving; thus, a panoramic radiograph should be done to ascertain the mandibular canal's vertical location.[37]

15. Insertion Torque and Removal Torque

In order to assess the load-bearing capacity of implants, including mini-screws, the insertion torque is frequently utilized and this torque is a key determinant in defining the proper early or primary stability. In addition, it was proposed that high insertion torque, heat at the screw-bone boundary, and mechanical stress might result in bone deterioration at the implant-tissue interface.[38] According to Motoyoshi et al., self-tapping miniscrew stability requires between 5 and 10 N-cm of insertion force, and too much torque can lead to screw fracture or instability. The miniscrew stability may be assessed using the removal torque. Chen noted removal torques greater than 8.7 N-cm. The mandible had a substantially greater removal torque than the maxilla.[38] In an in-vitro investigation, Seon-A Lim came to the following conclusion: For both types of screws (cylindrical or tapered), the Maximum Insertion Torque (MIT) rose as a result of increasing screw length, increasing screw outer diameter, and increasing cortical bone thickness. However, the implanted site's closeness to the root should be considered.[38] Pre-drilling particularly in the mandibular buccal shelf area may be necessary to increase primary stability and prevent undue insertion torque and screw breakage.[16]

16. Advantages and Disadvantages of IZC and MBS Implants

16.1. Advantages

1. Unlike other alternative methods like orthodontic miniplates and on-plants that need surgical intervention, insertion and removal do not necessitate any specific surgical treatment.
2. Even the orthodontist may readily place bone screw implants chair side during a single consultation without the assistance of an oral surgeon.
3. To enable reliable and precise implant placement, complex clinical and laboratory processes are not required (such as the manufacturing of acrylic splints by taking impressions using extra implant copying devices to properly translate the implant location to cast models). All that is required of the operator is CBCT imaging, anatomical expertise, and thorough clinical evaluation.
4. Since there isn't any obligation to wait for osseointegration, bone screw implants may be loaded right away after being inserted into the bone, cutting down on the overall treatment duration.
5. The infra zygomatic crest (IZC), the mandibular buccal shelf (MBS), and the anterior border of the mandible's ramus (Retromolar/Ramal bone screws) are among the several sites that are appropriate for the placement of bone screw implants.
6. As a result of their provision of absolute anchoring, the teeth that would have otherwise been employed for anchorage purposes were spared from any negative repercussions.
7. Merely ensuring impeccable oral health requires patient commitment and cooperation.
8. Bone screw implants can be easily removed after they have served their purpose.

16.2. Disadvantages

1. They have a technique-sensitive insertion procedure.
2. Incorrect insertion potentially ends in root or neighbouring tissue injury.
3. Patients with poor dental hygiene may experience irritation or inflammation of the peri-implant tissues and subsequently lead to implant failure.
4. Higher risk of slippage and inadvertent harm to adjacent soft tissue spaces.
5. Relatively expensive than mini-implants and is a supplementary expense to the patient when the oral surgeon is needed for insertion (usually when drilling is necessary).
6. Not recommended for juvenile participants since they have a thin cortical bone.
7. Not indicated for individuals with vertical growth pattern, as the cortical bone thickness is reduced.

17. Conclusion

The advent of bone screws has opened up new treatment possibilities for orthodontic therapy by removing the old biomechanical obstacles, enhancing the level of service offered with the provision of accuracy, and improving treatment quality. Infra-Zygomatic Crest (IZC) and Mandibular Buccal Shelf (MBS) bone screws have made it feasible to conceal therapy by not requiring patient participation or extractions, with the exception of preserving as much excellent oral hygiene as possible. Extra-alveolar implants' biomechanics have made it possible for a diverse set of dental movements than has previously been possible in patient care. Hence, in order to develop more effective therapies, it is crucial to consider the countless opportunities in force delivery systems resulting from the usage of bone anchorages. Nevertheless, in order to achieve an ideal and acceptable outcome in patients reporting varied levels of malocclusion, it is important to choose the right cases and have the necessary expertise, comprehension, and professional abilities for correct positioning of the bone screws.

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19. Conflict of Interest

None.

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Author biography

Mohsin Aslam Wani, Consultant Orthodontist https://orcid.org/0000-0002-2522-0996

Diptiman Shukla, Chief Medical Officer (Dental)

Mohd. Amir, Consultant Orthodontist

Shiraz Siddiqui, Specialist Orthodontist

Sana Mehtab, Post Graduate Student (MDS)

Mohd Saeedul Jafar, Post Graduate Student (MDS)

Md. Anas Husain Khan, Consultant Dental Surgeon and Oro-Maxillofacial Radiologist

Maisa Rasool, Senior Dental Surgeon

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