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Biomechanics Involved In Treatment with Temporary Anchorage Devices

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Abstract

Temporary anchorage devices (TADs) which are used to improve anchorage during routine orthodontic therapy have become popular mode in contemporary orthodontic therapy. Our aim in this article is to present a comprehensive review of the literature about anchorage consideration using temporary anchorage devices in correction of sagittal, transverse and vertical discrepancies, a brief overview of various intra-radicular & extra-radicular mini-implants, indications and contraindications.

Keywords: Temporary Anchorage Devices, Anchorage, Miniscrews

INTRODUCTION

Temporary anchorage devices (TADs) used to improve anchorage during routine orthodontic therapy have become popular in the modern era. A temporary anchorage device is temporarily inserted into the alveolar 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 and which is subsequently removed after use. Reasons for the increased interest in using such devices for anchorage include their commercial availability, the ease of placement, the lack of necessary patient cooperation and the possibility of achieving better anchorage control during mechanotherapy.[1,2] As orthodontic forces are applied to move teeth, anchorage is required from teeth in the same or opposing arch to achieve differential tooth movement. TAD's can be located trans-osseously, sub-periosteally or endosteally and they can be biocompatible & fixed to bone either mechanically (cortically stabilized) or biomechanically (osseo-intregated). By using temporary anchorage devices for orthodontic purposes we are able to obtain zero anchorage loss. In 1945, Gainsforth and Higley first introduced the concept of skeletal anchorage using vitallium in ramal screws in dogs. Since then, there has been evolution of TAD s for orthodontic anchorage.[3]

SITES OF PLACEMENT OF TADs:[4,5]

During placement of a miniscrew, 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 when considering placing implants in the buccal and lingual alveolar bone and the paramedian areas of the palate.

MAXILLA	MANDIBLE
Buccal/palatal alveolar area	Labial and buccal alveolar bone
Midpalatal region	Retromolar pad

Maxillary tuberosity	Buccal shelf
Zygomatic arch	

INDICATION:

A. Correction of anterior-posterior discrepancy: [6,7]

In extraction cases requiring maximum anchorage, miniscrews are placed in the posterior region for incisor segment retraction.

1. In case of increased overbite cases adjunctive intrusion of the anterior teeth using additional anterior mini-implants is advised. In reduced overbite case, second molars should be bonded (if fully erupted) during the alignment phase so that they can be actively intruded during space closure, by virtue of the rotational effect of oblique traction on the arch.
2. If there is sufficient height of attached gingiva then the mini implant may be vertically sited at a relatively apical level, but with the potential effect of producing an oblique (steep) vector of traction and consequently molar intrusion (Fig.1 a).

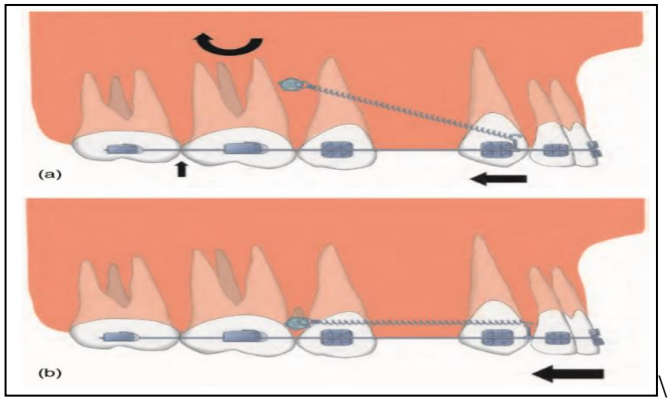

Fig-1 Buccal implant inserted at (a)apical and coronal level resulting in oblique and horizontal vectors of traction

4 Indirect anchorage, involves force application on the fixed appliance molar hooks. This means that biomechanical effects are similar to conventional straight wire approaches. (Fig-2)

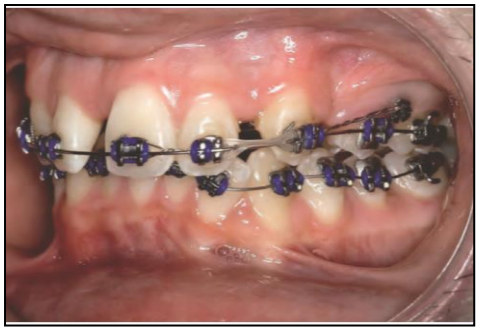

Fig-2: Indirect anchorage using a stainless steel ligature from the posterior mini implant to the canine bracket, enabling active traction from canine to retract the adjacent incisors.

2. Molar distalization & Uprighting: [8,9,10]

In case of molar distalization, the choice of mini-implant site depends on the planned amount of maxillary molar movement and on whether the mid-palate area is easily accessible. For molar distalization in mix dentition stage, mid palatal area

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is chosen for miniscrews because of thickness of cortical bone & elevated nasal floor toward the midline. The most central sutures area may not be ossified during pre-pubertal growth, so it is helpful to place the miniscrews on the para-sagittal area about 2-3mm apart from the central suture line,to utilize the nasal crestal bone. Miniscrews reinforced Nance holding arch & Pendulum appliance is used for molar distalization. (Fig-3)

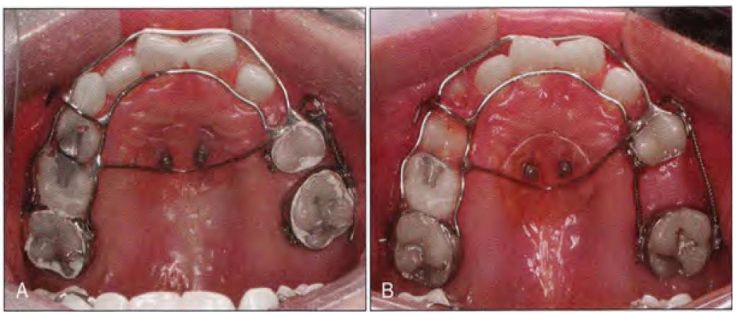

Figure-3: Unilateral molar distalization using Nance holding button with miniscrews

In permanent dentition, a variety of appliances are used for molar distalization as well as the line of force should be established at the adequate level at C_{res} of the molar.

a) Midpalatal miniscrew combined with transpalatal lever arm and horse shoe shaped transpalatal bar: 2 miniscrews are inserted along the midpalatal sutures and a lingual sheath is bonded on the head with light cure resin. A horse shoe type TPA with soldered hooks connecting both molars is retracted by elastic chains engaged to the hooks of the transpalatal lever arm. This system generates a constant line of force that runs through the C_{res} of molars, inducing translation without tipping.

b) Miniscrew on the palatal slope & a horse shoe type TPA: Midpalatal miniscrews often generate a force above the level of C_{res}, leading to a root movement rather than translation. Here,the height of insertion site is determined from the lateral cephalogram by drawing a line through the C_{res} of the molars.

c) Miniscrew on the buccal alveolar bone combined with an archwire and an open coil spring: Miniscrews are inserted between the second premolar and the first molar. Distalizing force is applied indirectly by the open coil spring between the premolars and molars, while the forward tipping is prevented by the elastic chain engaged to the first premolar.(Fig-4)

Fig-4: Molar distalization using buccal miniscrews

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In case of molar uprighting, if the space mesial to the molar is to be closed, a microimplant should be inserted between the roots of the premolars or between the roots of the canine and first premolar. In this procedure, a laceback can be tied between the microimplant and the molar crown to prevent the later from distalizing as the tooth uprights with straight wire. (Fig-5)

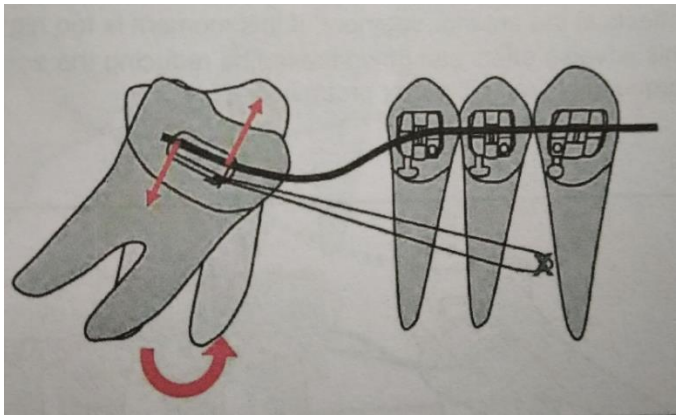

Fig-5: Mandibular molar uprighting

Molar protraction: [11,12]

Protraction of molar can be done by using buccal alveolar mini-implant anchorage (direct or indirect) in either arch, palatal alveolar mini-implant (direct) anchorage. Mesial tipping of molar teeth causes archwire binding and consequently frictional problems (Fig.6), then possibly protraction (mesial shunting) of the entire dental arch and incisor intrusion. This manifests as a reduction in overjet and overbite.

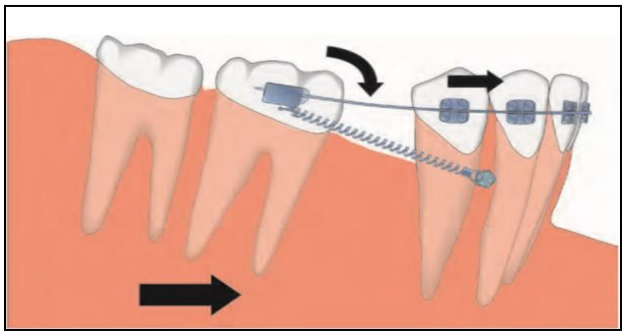

Fig-6 : Mesial tipping of molar

The use of a posterior power arm, to apply traction at the molar furcation level, assists bodily molar movement and unidirectional space closure. Powerarms may be free-sliding on the archwire although they provide better bodily control when attached directly to a molar crown.

B.CORRECTION OF VERTICAL DISCREPENCY: [13,14]

Vertical correction includes single or anterior segment intrusion, open bite correction. Miniscrew implant anchorage for intrusion of posterior teeth is indicated in patients with anterior open bite or vertical maxillary excess in whom reduction of lower anterior facial height is desirable.

Intrusion of the entire maxillary or mandibular dentitions either separately or simultaneously: An elastic chain is attached between hooks soldered to the arch and the miniscrews to generate the intrusive force (Fig-7). As the entire dentition is intruded, the anterior facial height is reduced and the chin point advances.

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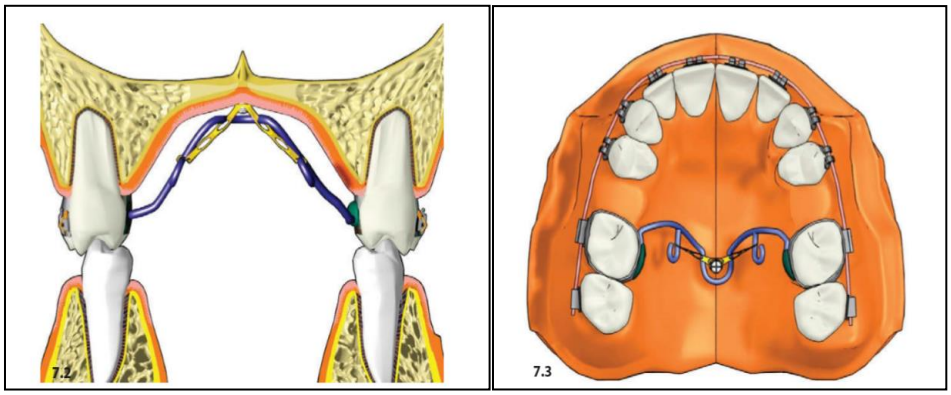

Fig-7 Elastic chain attached to hooks and miniscrews

Intrusion of entire lower dentition or lower posterior teeth: [5,15]

In the lower arch, miniscrews are inserted in the inter-radicular bone between the first and second molars for intrusion of the entire lower dentition or the lower posterior teeth. A rectangular archwire is engaged in the lower fixed appliance and a lingual arch is placed. An elastic chain is tied between the archwire and buccal alveolar miniscrews to apply intrusive force on the lower teeth.

A single miniscrews can be placed between the central incisor roots. In this design, since a single force is applied at the centre of the arch, a reverse smile line can be created as the incisors are intruded. To reduce the likelihood of this problem, two miniscrews can be placed instead, one on either side of the arch, between the lateral incisor and canine roots.

Molar intrusive movements, especially with traction applied distal to the second molars, may cause the entire dental arch to tip around its centre of rotation (in a clockwise direction in the maxilla), causing inadvertent incisor extrusion (Fig.8). This is countered by the use of segmental mechanics (separate buccal and labial segments) or the addition of a bite-opening curve to any steel archwires used during continuous arch mechanics.

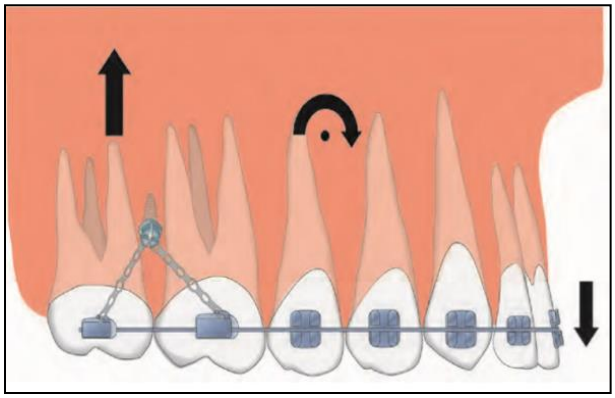

Fig-8: Molar intrusive movements

CORRECTION OF TRANSVERSE DISCREPENCY: Transverse discrepancy of the arches is expressed as unilateral or bilateral crossbite of the posterior teeth.

For dental midline correction: [11] Indirect mini-implant anchorage, e.g. stabilisation of a Nance palatal button so that unilateral traction can be applied from a molar band for dental midline correction .If there is

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sufficient height of attached gingival then the mini implant may be sited at a relatively apical ('high' vertical) level. This provides the option of supplementary vertical intrusive traction, although a powerarm may be required to prevent unwanted vertical side-effects due to an oblique vector of antero-posterior traction.

Transverse correction of ectopic tooth:

1. Direct traction is delivered using a traction auxiliary from the mini-implant to the tooth, or via a cantilever arm. The former may be used when there is both a stable insertion site and sufficient traction distance to allow for the tooth's movement towards the mini-implant. Alternatively, a cantilever arm may deliver traction from a more remote insertion site. (Fig-9)

Fig-9: Transverse correction of ectopic tooth

2. Indirect anchorage may involve a rigid auxiliary wire bonded onto an anchor tooth. This enables traction to be applied from this anchor unit to the ectopic tooth, e.g. from a buccally anchored maxillary first premolar to a palatally ectopic canine. Alternatively, the working archwire may be stabilised using a combination of an auxiliary wire and cross-tube.

Temporary anchorage devices (TADs) provide absolute anchorage systems that are highly useful in orthodontic clinics. Although they are frequently placed in interradicular alveolar bone, recent studies have suggested that they can also be placed in extra-alveolar bone to avoid root interference as teeth and dental arches are moved. There are three well-established intraoral anchorage sites: infrazygomatic crest (IZC), mandibular buccal shelf (MBS), and mandibular ramus which are the most commonly used extra radicular sites that provide efficient and secure anchorage system.[16]

Infrazygomatic bone screw: [17,18]

Anatomically, the IZC is a reinforced bone with thickening of the cortical layer which extends along the maxilla from the zygoma toward the molars. It is a palpable bony protuberance located anteriorly to the maxillary tuberosity.

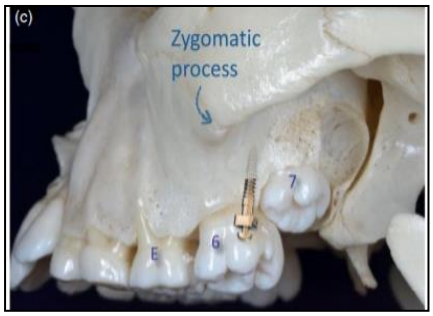

Fig :10 Anatomical localization of an IZC area

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Indication of IZC- (Fig-10)

1. Maxillary anterior teeth retraction, performed by segments or dentoalveolar en masse retraction of maxillary arch.
2. Canines and premolars distalization with sliding mechanics, in order to obtain anterior space.
3. Posterior teeth intrusion associated to retraction of the entire dental arch.
4. Patients requiring retraction of segments of teeth, in order to correct dental protrusion.
5. Asymmetry correction of the occlusal plane and midline deviation.
6. Anchorage for cantilever use in impacted canine traction.
7. Orthognathic surgery preparation in Class III cases.

The buccal shelf region corresponds to the bone plateau that lies between the buccal face of the lower molars and the mandibular external oblique line.(Fig-11) This plateau widens as it approaches the second and third molars. According to Chang et al. and Almeida the ideal area to position a TAD is in the buccal shelf between the first and second lower molars due to the thickness of the cortical bone and the reasonable amount of attached gingival.

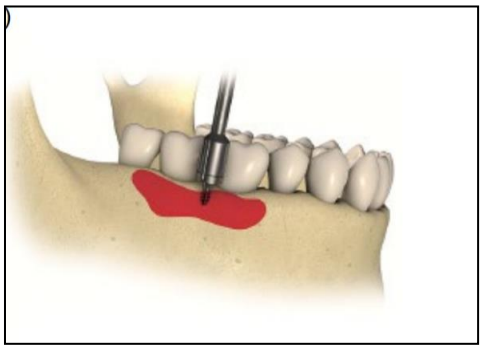

Fig: 11-Buccal shelf area (red) with the ideal site for the positioning of a mini-implant between the mandibular first and second molars.

Indication: [18] (Fig-12)

Indications for mini-implants placed in the mandibular BS area are quite similar to mini-implants in the IZC, in other words, they can be used in case of:

1. Class III treatment.
2. Retraction and/or canine distalization in cases of excessive mandibular crowding.
3. Mesial movement of molar.
4. Intrusion of posterior teeth.
5. Correction of occlusal plane asymmetries and midline deviation.
6. Anchorage for cantilever use in mandibular impacted canine traction.
7. Orthognathic surgery preparation in Class II cases.

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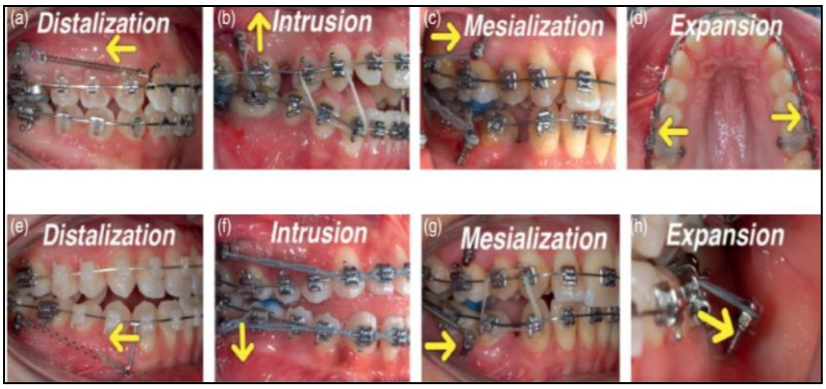

Fig : 12 (a,e)En-masse distalization. (b, f) Intrusion of the posterior teeth. (c, g) Mesialization of the posterior teeth. (d, h) Expansion or uprighting

The thread length of the screws may vary from 4 to 12 mm, and the diameter may vary from 1.2 to 2.0 mm. Interradicular miniscrews are usually smaller and of reduced caliber to reduce the risk of injuring the roots of adjacent teeth. Conversely, extra-alveolar miniscrews are larger, both in length (10,12,14,17 mm) and diameter 1.5–2.0 mm (Fig-13).According to Chang et al., 2.0×12 mm miniscrew dimension is recommended for the infrazygomatic crest.

Placement of Bone Screws in the Infra-Zygomatic Crest and Buccal Shelf Area[19,20,21]:

For placement of bone screws in the IZC (1st and 2nd molar region) –

1. Initial point of insertion is inter-dentally between the 1st and the 2nd molar and 2 mm above the muco-gingival junction in the alveolar mucosa. The self-drilling screw is directed at 90° to the occlusal plane at this point.
2. After the initial notch in the bone is created after couple of turns to the driver, the bone screw driver direction is changed by 55°–70° toward the tooth, downward, which aid in bypassing the roots of the teeth and directing the screw to the infra-zygomatic area of the maxilla.
3. The bone screw is screwed in till only the head of the screw is visible outside the alveolar mucosa. No pre-drilling, raising of flap or vertical slit in the mucosa is required for insertion of IZC screws. Immediate loading is possible and a force of up to 300–350 g can be taken up by a single bone screw.

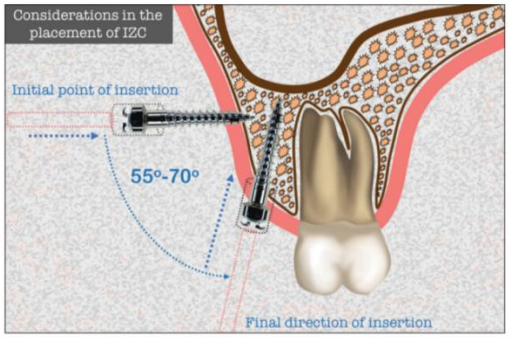

Fig-13: Consideration in placement of IZC

For placement of bone screws in the BS area of mandible (2nd molar region)-

1. Initial point of insertion is inter-dentally between the 1st and the 2nd molar and 2 mm below the mucogingival junction. The self-drilling screw is directed at 90° to the occlusal

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plane at this point. After the initial notch in the bone is created after couple of turns to the driver, the bone screw driver direction is changed by 60°– 75° toward the tooth, upward which aid in bypassing the roots of the teeth and directing the screw to the buccal shelf area of the mandible.

2. In the mandible, however, sometimes pre-drilling or vertical slit in the mucosa is necessary if the bone density is too thick, however, raising of flap is never required. Immediate loading is possible and a force of up to 300–350 g can be taken up by a single bone screw.

RAMUS BONE SCREW: [22,23]

1. From a biomechanics perspective, the anterior border of the mandibular ramus (MR) is an ideal location for an anchorage screw. Lin reviewed six different methods of molar uprighting, and concluded that surgical exposure of the deeply impacted molars, followed by traction with elastic chains anchored by ramus screws, was the most efficient method.
2. A 12 mm screw length was adequate to leave 5 mm of clearance between soft tissue and the head of the screw after installation. On the other hand, a ramus screw must penetrate much thicker soft tissue before engaging the dense cortical bone of the mandible. A 14 mm screw was necessary to provide at least 5 mm of soft tissue clearance, after the bone has been penetrated 3 mm or more.(Fig -14)

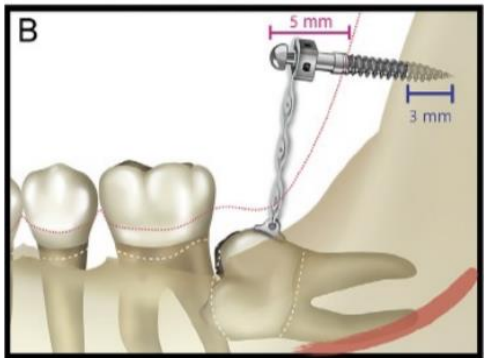

Fig-14: Specification of ramus screw bone screw

BENEFITS OF EXTRA ALVEOLAR TADS: [19.20]

Extra-alveolar miniscrews, located in areas far from the roots of the teeth to extend the limits of conventional orthodontic treatment. There are several benefits of this approach, such as:

1. Reduced risk of traumatizing roots;
2. More cortical bone at the placement sites, which allows the use of a more rigid miniscrews (2.0 mm) and greater length (12/14mm).
3. They do not interfere with mesiodistal movement of teeth or groups of teeth.
4. The achieved anchorage is appropriate for the retraction or mesial movement of the entire dental arch, allowing simultaneous movement of the entire dentition.
5. Low failure rate, if compared to the conventional mini-implants.
6. Smaller number of mini-implants used to solve complex cases.
7. Recent studies have shown that the success rate of long miniscrews placed in the IZC is from 93.7% to 96.7%, with 78.3% of them penetrating the maxillary sinus. With the assistance of extra-alveolar screws, displaced teeth and entire dental arches can be moved effectively and efficiently to restore optimal esthetics and function.

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CONCLUSION : Achieving absolute anchorage has been one of the dreams of practicing orthodontists and Temporary anchorage device are an effective and powerful tools for achieving absolute anchorage In fact these devices allow an absolute anchorage - independent and methodological cooperation of patient ,also give the opportunity to make quick treatment ,aesthetic and economic. The success of implants being used as anchors has widened the horizons of the orthodontists which should be explored to the best possible advantage for treating cases Temporary anchorage devices have provided answers to questions deemed unanswerable a couple of decades ago. Its incorporation into orthodontic mechanotherapy has probably been the boldest brush stroke on the orthodontic canvas. The ability to have bone anchored growth modulation devices has expanded the envelope of growth modulation. The ability to treat even adult patients conventially indicated for surgery by TAD supported appliance assemblies has introduced the term "Orthognathic like Orthodontics" into the orthodontic glossary. While long-term effects of therapy and data that can quantify these effects are still around the corner, there is no looking back on the fact that TADs are orthodontic mainstay today. The widespread application of TADs has stimulated newer thinking in orthodontic biomechanics to simplify mechanics and minimize untoward reciprocal effects. The application of TAD supported protocols in lingual and aligner mechanics integrates well with the perceived tomorrow of orthodontic appliances. As we crystal gaze into the future—TADs and customized orthodontic appliances will further integrate to improve the predictability of mechanotherapy; and a well-defined new "**envelope of orthodontic discrepancy**" would have proven indicators and protocols on the evidence terrain!

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