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Chapter

Understanding Orthodontic Bone Screws

Agharsh Chandrasekaran, H.P. Naga Deepti and Harshavardhan Kidiyoor

“Progress is impossible without change, and those who cannot change their minds cannot change anything.”
—George Bernard Shaw

Abstract

The field of orthodontia has been witnessing numerous reforms in terms of treatment modalities through the years, under which the concept of absolute anchorage employing mini-implants can be well subsumed. The usage of orthodontic bone screws has witnessed growing popularity and has been deemed to revitalize the management of complex malocclusions. Orthodontic bone screws are larger in diameter (2 mm) in comparison with the average mini-implant and are placed in areas of high bone mineral density like the infrazygomatic crest in the maxilla and the buccal shelf area in the mandible. Owing to a difference in size, they are placed away from the roots and hence, the term extra-radicular implants seem a befitting one. With an expansion of the envelope of discrepancy to skeletal anchorage, the employment of these bone screws in practice will have to be appraised further in terms of biological limits. Orthodontic bone screws have been successfully utilized as an absolute anchorage system in well-chosen cases, pushing the realm of treatment possibilities further ahead in the sands of time. This chapter aims to provide you with a narrative insight into the salient features of orthodontic bone screws starting right from its inception to its contemporary usage in practice.

Keywords: anchorage, orthodontic bone screws, extra-alveolar implants, infrazygomatic crest, buccal shelf

1. Introduction

A universally accepted scientific perspective, the best current explanation of a natural phenomenon, has been termed a paradigm. A paradigm can be thought of as the foundation upon which a scientific structure is erected, similar to laying brick upon brick of new findings and insights. As each newer paradigm replaces an older one, today’s “truths” become tomorrow’s myths. In orthodontics, at present, we are on the threshold of a paradigm shift that changes the fundamental conceptual underpinnings of orthodontics, and with it, the traditional emphasis on diagnosis and treatment planning.
The goal of any orthodontic treatment is to achieve desired tooth movement with the minimum number of undesirable side effects [1]. Strategies for anchorage control have been a major factor in achieving successful orthodontic treatment since the specialty began. With conventional orthodontics, it is almost impossible to achieve absolute intraoral anchorage. Recently, the use of skeletal anchorage has grown in popularity, especially in challenging situations [2].

The field of orthodontics has had a lot of landmarks in its evolution, but very few can match the clinical impact made by micro-implants and the recently introduced extra-radicular bone screws. Temporary anchorage devices have revolutionized the orthodontic field with their concept of absolute anchorage and have proved to be an adjunct in the hands of a clinician to gain control in handling complex malocclusions and clinical challenges.

It aids in the conversion of borderline surgical cases to cases that can be handled with bone screws in an equally effective way. The purpose of this review chapter is to offer to the reader, an insight into the depths of orthodontic bone screws from cradle to what has been explored till date, while touching upon integral aspects that might prove to be of use in both an academic and a clinical sense [3].

2. History

Creekmore and Eklund (1983) used a small-sized vitallium bone screw to depress the entire anterior maxillary dentition. The screw was inserted just below the anterior nasal spine. Ten days after placement, a light elastic thread was tied from the head of the screw to the archwire. The maxillary central incisors were intruded by about 6 mm. The bone screw did not move during treatment and was not mobile at the time of removal [4].

Shapiro and Kokich (1988) described the possibility of using dental implants for anchorage during orthodontic treatment. Melsen and co-workers (1998) introduced the use of zygomatic ligatures as anchorage in partially edentulous patients. Under local anesthesia, two holes were made in the superior portion of infrrazygomatic crest. A double-twisted 0.012″ stainless steel wire was ligated between the two holes and inserted into the oral cavity. After surgery, nickel-titanium coil springs were attached from the zygomatic ligatures to the anterior fixed appliance for intrusion and retraction of maxillary incisors [5].

3. Structure of an orthodontic bone screw

Mindful of the fact that orthodontic bone screws have insertion points in areas with greater quantities of cortical bone, the regular mini-implant has been revamped with the following design features to form a bone screw (Figure 1) [2, 3]:

- A length of 10–14 mm that facilitates insertion in areas of high bone density with adequate primary stability. Also, the increased length is owed to its placement steered away from the roots at extra-alveolar sites.

- A diameter of 1.5–2 mm that ensures greater fracture resistance. The resistance to torsional fracture is directly proportional to greater diameter and length and hence, these are crucial design features that have been worked upon.
Commonly, a mushroom-shaped head is incorporated to allow greater comfort and better ease in the attachment of elastic chains.

- A four-way rectangular hole that offers a lever arm for disimpacting canines.
- A double neck feature that permits better maintenance of oral hygiene and additional attachments.
- A sharp cutting edge that allows for an insertion free of pre-drilling.

4. Material aspects of orthodontic bone screws

Bone screws inserted in extra-alveolar areas are made up of either stainless steel or titanium alloys (Ti-6 Al-4 V). There has been a serious bone of contention over the material of choice. Pure surgical stainless steel has gained more popularity in being the preferred material of choice.

4.1 Why stainless steel?

The reason for stainless steel being the popular material of choice is attributed to the high placement torque that occurs when these screws are placed in areas of high bone density. This demands the requisite of a high fracture resistance, and stainless steel seems to be a befitting choice due to its high modulus of elasticity in comparison with titanium alloy. However, both materials seem to be acceptable materials with a comparable success rate [6].

A popular titanium alternative is the Peclab screw kit that was developed by Almeida [7] that has shown promising results and is inclusive in terms of the armamentarium that is required.
5. Quantity and quality of bone at extra-alveolar sites

The extra-alveolar sites of insertion correspond to D1 site as described by Misch [8], which comprises dense cortical bone of greater than 1250 HU. According to Park [9], the cortical bone thickness and bone depth are as follows:

Infrazygomatic crest region:
- Cortical bone thickness: 2.2–3.6
- Bone depth: 3.0–6.2

Buccal shelf region:
- Cortical bone thickness: 2.0–4.0
- Bone depth: 12.7–13.9

5.1 Variability of bone thickness at different vertical facial heights

The bone thickness also seemed to vary with different divergence patterns. Infrazygomatic crest region did not show any change with regard to the patient’s vertical height. But the bone thickness at the buccal shelf region was found to be higher in short-faced individuals as compared to long-faced individuals [10]. Also, in comparison with the hyperdivergent counterparts, the buccal shelf has greater bone width and lesser bone height in hypodivergent individuals [11].

5.2 Is an initial perforation required in self-drilling screws?

In certain cases, an initial perforation with a clinical probe/spear tip is recommended even with a self-drilling bone screw to minimize the risk of fracture of the screw during placement, since it involves a considerable placement torque [9].

6. Envelope of discrepancy

The envelope of discrepancy is an expression of anteroposterior, vertical, and transverse in terms of the millimetric range of treatment possibilities. It gives us an estimate of tooth movement that can be deemed possible by purely orthodontics alone, orthodontic with dentofacial orthopedics, orthodontics with the employment of skeletal anchorage, and orthodontics with orthognathic surgery. Different colored zones connote the range of possibilities (Figures 2–4). The direction of movement in the diagrammatic illustration has been depicted by arrows. The different colors zones are as follows: 1) The pink zone denotes the envelope for orthodontics alone, 2) the yellow zone connotes orthodontics plus orthopedics, 3) the green zone shows skeletal anchorage, and 4) the blue zone any combination of the above with orthognathic surgery. The green zone has been depicted by a “fuzzy” area, as an indication of the paucity of reliable data available at this point to make any claims. The same drawback is why a figure depicting the mandibular transverse envelope does not exist at this juncture [12]. To sum up, the biological limits of the skeletal anchorage system in the management of severe malocclusions albeit proven useful in several case reports needs further research to arrive at a more definitive conclusion in the envelope.
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Figure 2.
Revised envelope of discrepancy.

Figure 3.
Revised envelope of discrepancy.

Figure 4.
Revised envelope of discrepancy.
7. **Indications of orthodontic bone screws**

The indications of orthodontic bone screws [13]:

1. Borderline cases,
2. Camouflage treatment,
3. Molar uprighting by crown distalizing or by root mesializing,
4. Anterior open bite treatment with molar intrusion (with or without extractions),
5. Severe transverse discrepancies: severe scissors bite and severe crossbite,
6. Leveling of transverse tipping of occlusal plane,
7. Extraction cases,
8. Distalizing or anchorage after distal movement with other kinds of appliances, such as the pendulum, and

8. **Contraindications of orthodontic bone screws**

8.1 Absolute contraindications

1. Systemic diseases such as diabetes, osteoporosis, osteomyelitis, blood dyscrasias, metabolism disorders,
2. Patient undergoing the radiotherapy in arches,
3. Psychological disorders,
4. Presence of pathological formations in the zone, such as tumors or cysts,
5. Thin cortical bone and insufficient retention,
6. Deficient quality of the bone,
7. Soft tissue lesions, such as lichen planus, leukoplakia,
8. The patient who does not accept bone screw treatment.

8.2 Relative contraindications

1. Tobacco, alcohol, and drugs abuse,
2. Presence of active oral infections,
3. Uncontrolled periodontal disease, and
4. Absence of ability to maintain proper oral hygiene.
9. Concepts of placement of bone screws at different sites

9.1 Infrazygomatic crest (IZC) screws

9.1.1 Anatomy of the infrazygomatic crest (IZC)

The infrazygomatic crest is a crest of bone emanating from the buccal plate of the alveolar process, lateral to the roots of the first and second maxillary molars. It extends superiorly up to 2 cm to the zygomaticomaxillary suture and inferiorly into the areas of first and second maxillary permanent molars. The sites of placement at first or second molar have been much discussed and have been proposed by authors Liou and Lin respectively. Comparisons of both sites have been summarized in Table 1 [14]. Though both sites have been deemed fit, the IZC 7 site gains an upper hand in terms of having a greater bone thickness over the buccal surface of the second molar. Nevertheless, a CBCT evaluation of the area before placement is an important aspect of treatment planning with these screws.

9.1.2 Insertion technique and angulations

Liou [15] suggested orienting screws about 55–70° inferior to the horizontal plane to achieve maximal buccal bone engagement. During placement, the point of initial insertion is between the first and second molar, 2 mm above the mucogingival junction. The screw is directed first at the right angle to the occlusal plane and after a couple of turns when the initial notch has been made in the bone, the direction of the driver is altered by 55°–70° toward the tooth. This downward change aids in bypassing the roots of the teeth and helps direct the screw to the infra-zygomatic area of the maxilla (Figure 5). The bone screw is screwed until only the screw head is visible. The need for pre-drilling, flap raising, or a mucosal vertical slit has been deemed unnecessary.

9.1.3 Magnitude of the employed force

The recommended loading for orthodontic mechanics using miniscrews in the region of the IZC ranges from 220 to 340 g (8–12 oz). The force load can be employed by means of an elastomeric chain or closed coil springs [9].

<table>
<thead>
<tr>
<th>LIOU-IZC 6</th>
<th>LIN-IZC 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLACEMENT: Anterior to the anatomic ridge and buccal to the mesiobuccal root of the maxillary first permanent molar.</td>
<td>PLACEMENT: Distal to the anatomic ridge and buccal to the mesiobuccal root of the maxillary second permanent molar.</td>
</tr>
<tr>
<td>Small oral cavities are more convenient to place screws at this site.</td>
<td>Large oral cavities and lip reflection are needed for adequate access.</td>
</tr>
<tr>
<td>Less predictable as compared to seven sites due to lesser bone thickness over mesiobuccal and distobuccal roots of 6.</td>
<td>More predictable and greater retraction due to greater amount of bone thickness over mesiobuccal and distobuccal roots of 7.</td>
</tr>
</tbody>
</table>

Table 1. LIOU-LIN concept of IZC site: A comparison.
9.1.4 Anatomical considerations

An important consideration that one cannot overlook during the placement of infrazygomatic crest screws is the soft tissue irritation and this is a frequent occurrence if there is contact or close intimacy between the inferior platform of the screw head and the mucosa.

As a general guideline, 1.5-mm clearance is considered a necessity between the mucosa and the inferior aspect of the screw platform. This is important irrespective of whether the screw is placed in a region of attached gingiva or movable mucosa though the selection of the size of the screw would vary accordingly.

It is vital to assess the anatomy of the IZC site to select an appropriate screw length. The average thickness of the attached gingiva in the maxillary first molar is about 1.0 mm, and the cortical bone thickness is about 1.1–1.3 mm. The screw threads must engage cortical bone to insure primary stability. Generalizing the widths, for soft tissue clearance, attached gingiva and cortical bone at 1.5 mm each, reveals that 8–12-mm IZC screws penetrate the medullary bone or sinus from 3.5 to 7.5 mm. Under most clinical conditions, an 8-mm screw is adequate to engage the cortical plate and secure primary stability [14].

9.1.5 Sinus considerations

Cases with the maxillary sinus extending low between the teeth are not ideal candidates for infrazygomatic crest screws. The thickness of the sinus floor is preferred to be over 6 mm to ensure safe insertion. Small uncomplicated penetrations into the sinus heal spontaneously [16]. The penetration into the maxillary sinus with IZC screws was found to be rather high and double cortical engagement with sinus penetration within 1 mm was recommended for adequate primary stability. Penetrations above 3 mm led to thickening of the Schneiderian membrane and sinusitis eventually leading to failure [17].
9.1.6 Guided infrasygomatic crest screws

To ensure greater precision, a number of guides [14] have been made available for easy installation of IZC screws. They are as follows:

- Chen double film radiographic method
- Pin Head soft tissue penetration method
- Double film method with a transparent adhesive patch like comfort brace strips.

9.2 Buccal shelf screws

9.2.1 Anatomy of the buccal shelf

Mandibular buccal shelf area is located in the posterior part of the mandibular body, buccal to the roots of the mandibular, and anterior to the oblique line of the mandibular ramus. The area buccal to the distal root of the mandibular second molar, between 4 and 8 mm from the cementoenamel junction, has been claimed to be the best anatomical location for fixation. However, the region shows significant anatomic variations and also possibly ethnic variations wherein some patients present with a well-defined bony plateau and some with a straight bony profile. This could be better evaluated with a CBCT and clinical examination [9].

9.2.2 Insertion technique and angulations

While placing bone screws in the mandibular buccal shelf, the point of initial insertion is between the first and the second molar, 2 mm below the mucogingival junction. The screw is first directed at the right angle to the occlusal plane at this point and then, the driving direction is altered by 60°–75° toward the tooth. This upward change in direction helps to bypass the teeth roots and directs the screw to the buccal shelf area of the mandible. Pre-drilling or vertical slit in the mucosa may be necessary if the bone density is too thick. However, raising a flap is never required during placement.

9.2.3 Magnitude of the employed force

The recommended loading for orthodontic mechanics using miniscrews in the region of the buccal shelf area ranges from 340 to 450-g. The force load can be employed by means of an elastomeric chain or closed coil springs [9].

9.2.4 Inflection point and limits of mandibular molar distalization

The intersection of the line of occlusion and the internal oblique ridgeline is the inflection point (Figure 6). The second molar cannot move on the internal oblique line, and the amount of possible movement depends on the distance of the original position of the second molar to the inflection point. This varies from patient to patient. A comprehensive evaluation of the buccal shelf area and the alveolar housing with the help of a cone-beam computed tomogram seems pivotal to treatment planning [18].
9.3 Ramus screws

Ramus screws were developed to overcome the difficulties that buccal shelf screws posed during the dis-impaction of horizontally impacted lower molars. From the standpoint of biomechanics, these screws are installed in the anterior ramus of the mandible to offer a traction force that is more superior and posterior in direction.
This coupled with simple yet efficient mechanics to upright the lower molars in tandem with ramus screws has offered a brilliant treatment option in such cases.

9.3.1 Anatomical location point

The insertion site for a ramus screw (red arrows) is between external and internal oblique ridges, about 5–8 mm superior to the occlusal plane (Figure 7).

A relatively long (14 mm) ramus screw is selected because of the need to penetrate thick non keratinized mucosa, with an underlying layer of masticatory muscle. For hygiene access, the ramus screws were screwed in until the head of the TAD was ~5 mm above the level of the soft tissue. The average bone engagement for a ramus screw is ~3 mm [19].

10. Biomechanics of orthodontic bone screws

10.1 Generations of biomechanical principles

According to Robert et al. [20]

- First-generation biomechanics: 2D/two-dimensional mechanics based on the third law of Newton and correspond to classical segmented mechanics.

- Second-generation biomechanics/Stress sensor theory: 3D mechanics based on finite elements that determine the exact amount of stress in the periodontium with determinate mechanics. With the aid of determinate mechanics, extra-alveolar bone screws are employed in complex malocclusions in a multivector fashion, which simplifies and eliminates the need of numerous accessory devices that were used in segmented mechanics.

10.2 Employed force magnitude

The force magnitude employed is important in terms of anchorage stability. A force magnitude ranging from 220 to 340 g (8 to 12 oz) for mechanics with mini-implants in the IZC area, and from 340 to 450 g on the ones with mini-implants in the BS area, has been recommended. This is vital to achieve the en masse distalization that bone screws offer popularly in clinical settings. In cases that require partial retraction, force magnitude may be adjusted between 150 and 200 g.

10.3 Biomechanics of buccal shelf screws

Buccal shelf screws are employed for en masse retraction of the entire mandibular dentition since the screws are placed at extra-alveolar sites.

Three critical factors exist for this system to be deemed statically determinate when two screws are inserted into the buccal shelf areas for retraction:

1. Use of rectangular arch (full-size) with torque control during retraction,

2. Relative constant force stemming from superelastic NiTi springs,

3. Force applied directly to the arch.
Biomechanical effects of retraction with anchored buccal shelf screws:

- Molar intrusion and incisor extrusion with a counter-clockwise rotation of the mandibular occlusal plane.

- The axis of rotation was found close to the mandibular canine area.

- The counterclockwise rotation occurs since the line of force is occlusal to the center of resistance and thus causing molar intrusion and incisor extrusion. These movements offer favorable Class III correction presenting with open bite.

10.4 Biomechanics of infrrazygomatic crest screws

When two screws are installed in the IZC area for retraction, similar effects were found as in the buccal shelf region. With the retraction force from the coil spring to the screw, retraction occurs along with vertical side effects, that is, molar intrusion and incisor extrusion leading to rotation of the occlusal plane. The axis of rotation in the maxillary arch lies between the premolars and this change is beneficial in Class II cases with the open bite or where bite deepening is required.

10.5 How can the force system be varied to suit the needs of a particular case?

In order to overcome the side effects that are not suited for correction in all cases, the force system can be modified to obtain different kinds of dental movements:

- Height of hooks in the anterior area.

- Height modification in extra-alveolar mini-implants insertion (this often is not a viable option since insertion depends on numerous other factors).

10.6 Height of hooks/power arm

Depending on the force vector and direction required in each case, the height of the hook will help decide the type of tooth movement required along with torque and vertical control.

Short hook: Anterior teeth have a tendency to rotate clockwise when retraction/distalization force is applied by means of a force that passes below the Center of resistance, which leads to torque loss and a vertical extrusion force on the incisors.

Medium hook: The force action line is passing over the anterior teeth’s center of resistance, due to the middle positioning. When distalization force is applied to the entire maxilla, with force parallel to the occlusal plane, anterior teeth are likely to keep their initial inclination, minimizing vertical forces.

Long hook: The height of the hook is positioned mesial to the canine allows the force action line to pass above the incisors’ center of resistance. The positioning simply produces a counterclockwise anterior moment during retraction and simultaneous extrusion of the incisors. In the clinical scenario, it might be pointed out that this may offer a possibility of injuring the oral mucosa of the patient.
10.7 Simultaneous retraction and intrusion

In cases with vertical maxillary excess, in order to facilitate gingival smile correction while also balancing the clockwise rotation effect of the maxillary occlusal plane, it was suggested that two mini-implants were to be installed between central and lateral incisors apart from the IZC screws. This would help counter-effect the anterior extrusion, resulting in the intrusion of the entire maxillary dentition and favoring gingival smile correction (Table 2).

11. Conclusion

To encapsulate, orthodontic bone screws have recast the approach to complex malocclusions in a significant way. These have been designed without losing sight of the fact that they are installed in extra-alveolar sites away from the roots and in areas of high amounts of cortical bone to affect tooth movement. While they gain an upper hand in terms of safety to roots and effective tooth movements, it is pivotal that the clinician must focus on the appropriate case selection for the same. One cannot deny their role of marching into the orthodontic field and that too with a roaring success. Considering that there is still a great deal of research that needs to be done about them, they are interesting areas of study to further the understanding and applications of these screws in orthodontic practice.
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