Chapter 3

Orthodontic Implants

Gizem Yazdan Özen[1]

Abstract

Anchorage control in orthodontic treatments is one of the fundamental factors directly affecting treatment efficacy. Traditional anchorage methods, which mostly rely on dental structures and require patient cooperation, can result in undesired tooth movements and anchorage loss. In this context, temporary anchorage devices (TADs), especially mini-implants, offer alternative and reliable solutions in modern orthodontics. Mini-screws can serve as both direct and indirect anchorage elements in various orthodontic procedures—such as maxillary expansion, molar distalization, anterior tooth intrusion, and management of occlusal plane irregularities. Classified according to their surface characteristics and anatomical insertion sites, these implants provide stable anchorage, increase treatment predictability, and shorten treatment duration. A wealth of literature demonstrates that mini-implant–supported systems yield successful outcomes in balancing both skeletal and dental effects. This review comprehensively covers the classification, clinical applications, and advantages of orthodontic implants, emphasizing the role of mini-screws in contemporary orthodontic treatment protocols.

1. Orthodontic Implants

The term "orthodontics" is derived from the Greek words *ortho* (straight, correct) and *odontos* (tooth). Orthodontics refers to the discipline aimed at the proper alignment of teeth and the achievement of an ideal occlusion within the dental relationship.

During the process of aligning teeth and establishing proper occlusal relationships, various anchorage units are required. Anchorage can be obtained from teeth, jaws, and/or different points on the skull using various appliances.

1 Kafkas University, Faculty of Dentistry, Department of Orthodontics
dtgzmyazdan@gmail.com, ORCID ID: 0000-0002-8875-8267

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Conventional anchorage methods have certain limitations, and those dependent on patient compliance can negatively impact treatment progress. In response, minimally invasive orthodontic implants—known as temporary anchorage devices (TADs)—have been developed and are increasingly preferred in clinics. By using these implants, dependence on patient cooperation is eliminated, and tooth movements become more controlled.

Classification

By Placement in Jaw Bones (Albrektsson et al., 2008);

1. Endosseous (Intra-osseous) Implants: Placed in extraction sockets or on edentulous ridges after tooth extraction.
2. Subperiosteal Implants: Placed under the periosteum on top of the alveolar ridges.
3. Intramucosal Implants: Used to increase retention in prosthetic procedures.
4. Transmandibular Implants: Groups of mini-screws used in orthognathic surgery and mandibular fracture cases.
5. Endodontic Implants: Placed through the tooth canal, anchoring in the bone.

By Surface Characteristics (Albrektsson et al., 2008);

1. Machined (Unmodified) Surface Implants: Retain the natural surface texture post-manufacturing.
2. Surface-Treated Implants: Modified by physical or chemical methods to roughen or smooth the surface. Subtypes include:
    - Polished surfaces
    - Sandblasted surfaces
    - Acid-etched surfaces
    - Combined sandblasted + acid-etched surfaces
    - Laser-textured surfaces
    - Porous-surface implants
    - Sintered porous surfaces
3. Surface coated implants: Implants with coatings obtained by applying biocompatible materials to the implant surface. main types:
    - Plasma-sprayed coatings

- Ceramic-based coatings, including:

  -Tricalcium phosphate (TCP)

  -Hydroxyapatite (HA)

4. **Hybrid Surface Implants:** Combine multiple surface treatments to leverage varied mechanical and biological benefits.

2.Clinical Applications in Orthodontics

In orthodontic treatment, various intraoral and extra oral systems are used to achieve anchorage control. According to Newton's third law, some anchorage loss is inevitable. For cases requiring maximum anchorage, bone-borne anchorage units relying on mechanical (cortical stabilization) or biomechanical (osseointegration) principles can minimize this loss (Cope, 2005). Numerous studies have explored TAD-based orthodontic appliances (Gerlach & Zahl, 2003; Giancotti et al., 2004; Lee et al., 2014; Mommaerts, 1999; Prabhu & Cousley, 2006). Devices like mini-screws, micro-screws, and mini-plates are used for skeletal anchorage (Park et al., 2004; Prabhu & Cousley, 2006). To standardize terminology, such devices are often collectively termed "Orthodontic Bone Anchorage Devices" (BADs) (Prabhu & Cousley, 2006).

Orthodontic implants can function as either direct or indirect anchorage units. When the exposed portion of the implant provides anchorage, it's direct anchorage; when an implant stabilizes a tooth or group of teeth, which then serve as the anchorage unit, it's indirect anchorage (Celenza & Hochman, 2000).

Implants for orthodontic anchorage can be placed in various regions of the maxilla and mandible. In the maxilla, common sites include the anterior nasal spine region, mid-palatal suture, and infrazygomatic crest. In the mandible, they can be placed in the retro molar area, alveolar processes, or symphysis (Bae et al., 2002; Higuchi & Slack, 1991).

2.1.Orthodontic Implants in Maxillary Expansion

Although tooth- and tissue-borne expanders are widely used, they have reported drawbacks: limited skeletal expansion (Kanomi et al., 2013), buccal tipping of posterior teeth (Agarwal & Mathur, 2010; Weissheimer et al., 2011), predominantly dental effects with limited skeletal changes (Weissheimer et al., 2011), and molar extrusion (Agarwal & Mathur, 2010).

Gerlach and Zahl performed rapid maxillary expansion using a palatal distractor with osteotomy support in a patient group consisting of growing

and developing individuals and adults. The researchers reported that this method is a suitable option for clinical applications due to its advantages such as short treatment time, ease of use and low relapse rates (Gerlach & Zahl, 2003).

In recent years, miniscrews have become more widely used in orthodontic treatments to obtain bone-supported anchorage (Liou et al., 2004). Mini screws are preferred because patients feel minimal pain during application, patient comfort is high after the procedure, and orthodontic treatment time is shortened (Kuroda et al., 2007). Furthermore, miniscrews have been reported to show a stability rate of over 80% (Kuroda et al., 2007); however, in some cases, these screws may be lost (Baumgaertel et al., 2008).

Bone-borne maxillary expanders include BAME (Bone-Anchored Maxillary Expander) (Lagravère et al., 2010), trans palatal distractors (Mommaerts, 1999), MARPE (Micro-Implant-Assisted Rapid Palatal Expansion), and mini-screw–supported expanders.

With the use of trans palatal distractors in rapid maxillary expansion procedures, implants used in the palatal region have entered the literature in this field (Mommaerts, 1999).

Dental-bone-assisted expansion appliances that provide anchorage from both dental and skeletal structures were first described in 2007 by Ludwig et al. as "hybrid hyrax". In this design, the researchers utilized two mini screws in the anterior region while receiving support from the maxillary first molars with the help of a band. They also stated that this arrangement can be used safely in cases where premolars have not yet erupted or deciduous teeth are mobile (Ludwig et al., 2007).

Wehrbein et al. clinically introduced an application in which intraosseous screws were placed in the anterior region for anchorage. In their study, screws with a diameter of 3.3 mm and a length of 4-6 mm were placed around the mid-palatal suture (Wehrbein et al., 1996).

Nienkemper et al. also applied the hybrid hyrax appliance in patients who required the use of a face mask and reported that more skeletal changes were achieved with this mechanism (Nienkemper et al., 2013). Similarly, Garib et al. demonstrated that the use of the hybrid hyrax appliance reduced the buccal tipping movement of the teeth (Garib et al., 2008).

2.2.Orthodontic Implants in Molar Distalization

In cases where there is not enough space in orthodontic treatments, distalization mechanics are one of the methods that can be considered.

Distalization, as the name suggests, aims to reduce and/or eliminate the insufficiency in the arch as a result of the distal movement of the teeth on the arch. Although many different techniques are used today, the most preferred methods are always mini screws (implants).

In patients with dental Class II molar relationships with sagittal and vertical directional anomalies, the preferred treatment method is either extraction of the premolars or distalization of the upper first molars (Moyers et al., 1980). It has been reported that the facial structures of patients with premolar extractions become flatter, the chin tips become more prominent and the lower lips have a retruded appearance (Bishara et al., 1997; Bowman & Johnston Jr, 2000; James, 1998).

In non-extraction treatments, distalization treatments with extra oral anchorage are difficult to use and require high patient cooperation, which prolongs the treatment time (Clement, 1984; El-Mangoury, 1981).

For these reasons, over time, orthodontists have developed distalization mechanics as an alternative to these treatment methods (Blechman & Smiley, 1978; Cetlin, 1983; Gianelly et al., 1991; Jeckel & Rakosi, 1991; Kalra, 1995; Keles & Sayinsu, 2000; Reiner, 1992; Wilson & Wilson, 1987).

Hilgers (Hilgers, 1991) reported in 1991 that Class II anomalies could not be solved without space gain and expansion of the maxilla. He developed an appliance called "Hilgers Palatal Expander" to move the upper molars distally, correct their rotation and increase the upper arch width. Then, he made some modifications on this appliance and introduced the "Pendulum" appliance in 1992. The Pendulum appliance consists of an anchorage system supported by a large Nance button and two springs made of TMA round wires with a diameter of 0.032 inch on each side, which provide a light, continuous force (Hilgers, 1992). Nowadays, mini-screw supports are added to this appliance to increase the bone anchorage of these appliances. The mini screws (implants) are placed under the acryl body, creating a more rigid anchorage unit.

In 1999, Keles and Isguden treated cases with unilateral Class II molar relationships with an appliance called "Molar Slider". This appliance consists of an acrylic bite plane in the anterior region and a distalization unit consisting of open Ni-Ti helical springs positioned on the palatinal side, passing through the resistance center of the first molars. With this system, which exerts a force of approximately 200 grams, distalization was achieved without loss of anchorage and without tipping of the molars. Researchers have reported that the "Molar Slider" appliance offers an effective and

reliable option in the treatment of Class II malocclusions because it requires minimal patient cooperation (Keles & Isguden, 1999).

The "Molar Slider" system, which has evolved over time, has come to be known as the "Keles Slider". This appliance was modified with mini screws placed in the anterior region, especially in the palatinal part of the incisors, and bone support was provided under the acrylic base, thus transforming it into a bone-supported anchorage unit. Thanks to this modification, the dependence on dental anchorage was reduced, the risk of anchorage loss was minimized, and more controlled and body distalization of the molars became possible. Furthermore, the use of the miniscrew-assisted system eliminated the need for patient cooperation, allowing the treatment process to be completed with more predictable and stable results.

Although intraoral molar distalization methods are more reliable than extra oral methods, this group has its own handicaps. There are studies reporting loss of anchorage in intraoral distalization mechanics (Carano, 1996; Chiu et al., 2005; Ghosh & Nanda, 1996; Hilgers, 1992; Keles & Sayinsu, 2000; Kinzinger et al., 2005). On the other hand, the idea of counteracting the reciprocal forces against distalization forces with mini screws and implants is becoming more and more common (Karaman et al., 2002; Keles et al., 2003).

In their 2002 study, Karaman et al. applied a modified Distal Jet appliance on a palatal implant placed 2-3 mm behind the incisive canal for molar distalization. This method has important advantages such as providing strong resistance against reciprocal forces, allowing immediate loading, allowing bilateral use, easy applicability and requiring minimal patient cooperation (Karaman et al., 2002).

Keles et al. applied the Keles-Slider appliance by placing a titanium implant with a diameter of 4.4 mm and a length of 8 mm in the palatal region for bilateral molar distalization in a patient with Class II, part 1 malocclusion. With the orthodontic force applied after the completion of the three-month osseointegration period, a 4 mm body distalization of the upper first molars was obtained at the end of a treatment period of approximately five months, without loss of anchorage, overjet increase or overturning of the upper incisors (Keles et al., 2003).

In a study involving 25 patients, Gelgör et al. used a trans palatal arch supported by an in-bone screw placed in the palatinal region to distalize the upper molars in a period of approximately 4.6 months without any loss of anchorage (Gelgör et al., 2004).

Sugawara et al. performed molar distalization with the Skeletal Anchorage System (SAS) method using mini-plates placed in the zygomatic region in adults aged 15 to 45 years. In the study, it was reported that a significant amount of distal movement was achieved with an average of 3.78 mm at the crown level and 3.2 mm at the root level (Sugawara et al., 2006).

Oberti et al. reported that a 5.6° distal bending and 5.9 mm distalization was achieved in the upper first molars during a treatment period of approximately five months in a study conducted with a bone-supported appliance called "Dual-force distalizer" (Oberti et al., 2009).

Yamada et al. reported that they obtained an average distal movement of 2.8 mm in the upper first molars by means of miniscrews placed in the interradicular region (Yamada et al., 2009).

Today, miniscrews have come to the forefront as an effective and reliable anchorage source in orthodontic molar distalization processes. The disadvantages of traditional tooth-supported distalization methods, such as loss of anchorage, unwanted tooth movement and the need for patient cooperation, have been significantly reduced with the use of miniscrew-supported systems. The miniscrews, which can be placed in short procedures and are minimally invasive, provide a stable bone anchorage, allowing the target teeth to be moved in a more controlled and predictable manner. In this way, unwanted dental changes in the anterior region during molar distalization are minimized, treatment time is shortened and clinical success rates are increased.

2.3.Use of Implants in Other Orthodontic Treatments

Although implants are preferred as skeletal anchorage units for maxillary expansion and distalization in orthodontics, they are also used outside these areas.

In the correction of 'Occlusal Kant' conditions, it can be used to embed the segment that has sagged into the occlusion or to support the driving of the opposing segment. In such cases, miniscrews can be placed in the prolapsed segment or in the opposing jaw of the incompetent segment. If they are to be placed in the maxilla, one screw can be placed in the vestibule between the roots of the teeth and the other in the palatine between the roots of the teeth and intrusion can be provided with fixed treatment. However, if the screws are to be placed on the mandible, only the buccal surface is preferred.

Kanomi used mini implants as anchorage elements to provide intrusion of mandibular incisors in a case with deep bite problem. The force was applied to the brackets through the implants placed in the alveolar bone between the root tips of the mandibular central incisors. At the end of four months of treatment, he achieved an effective intrusion of approximately 6 mm and did not observe any periodontal complications or root resorption (Kanomi, 1997).

Ohnishi and colleagues used mini-implants to correct aesthetic problems such as anterior crowding, increased overbite and 'gummy smile' in a 19-year-old patient. The implants were used as an anchorage unit to perform intrusion of the upper incisors and to achieve ideal alignment in the upper-lower arch without extraction. As a result, the overbite was reduced from 7.2 mm to 1.7 mm, the appearance of the 'gummy smile' was significantly improved and the treatment results remained stable after two years (Ohnishi et al., 2005).

Again, zygomatic screws can be preferred for distalization as well as intrusion and/or extrusion movements. De Clerck et al. reported that molar intrusions can be achieved with zygomatic screws (De Clerck et al., 2002). Erverdi et al. reported that zygomatic screws can be used to correct the anomaly by intrusion in patients with skeletal open bite (Erverdi et al., 2004).

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