FEATURES SECTION

Current Products and Practice Section

The role of implants in orthodontics

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Introduction

In this article we will review the development of implants in orthodontic treatment and highlight their use in multi-disciplinary cases. The use of dental implants has greatly increased over the last three decades, largely as a consequence of their successful long-term osseo-integration. This has led to increased orthodontic use, with appropriate modifications in the design when required.

It is well established that implants can offer an option when replacing missing teeth, following orthodontic treatment. This article, however, will concentrate on the use of implants *during* orthodontics, to enhance the orthodontic treatment, with particular reference to the following:

- Implants as a source of absolute anchorage
- Implants used for anchorage and as abutments for restorations
- Implant site preparation improved by orthodontics
- Implants in osteogenic distraction.

Background to implants

Osseo-integration

The work of Branemark in the 1960s on osseo-integrated implants is well known.[1,2] His definition of 'a direct contact between living bone and an implant, on the light microscope level'[1] describes the objective of osseo-integration, but the essence of its clinical success is the reliability of long-term implant fixation, even in the presence of functional loading. This has been supported by many studies, including a meta-analysis,[3] which reported a 90 per cent success rate for osseo-integrated implants used for bridge abutments.

Types of implants

The rise in the use of dental implants has led to a great diversity in their design and manufacture. The classification of implants can be based on their position, material of construction, or design.

- The position of the implant can be subperiosteal, transosseous, or endosseous, the last of which is the most commonly used type of dental implant.
- Titanium is the accepted ideal material for implant fabrication, but other variants include gold alloys, vitallium, cobalt-chromium, vitreous carbon, aluminium oxide ceramics, or nickel-chromium-vanadium alloys.[4] Even with the favoured titanium metal, the implant surface maybe rough or smooth, and may have an additional hydroxyapatite or titanium-spray coating.[5]
- There appears to be a lack of consensus among researchers and clinicians regarding the best design for an implant. The main area of dispute focuses on how an implant gains its support from the surrounding bone. A screw thread around the implant surface aids loading of the surrounding bone in compression, whereas a smooth cylindrical design increases implant support when shear forces are exerted on the bone. Both these varieties show a more uniform stress distribution under loading when compared to other designs.[6]

Protocol of placement

The technique for successful osseo-integration of an implant, as historically described by Branemark,[2] involves a two-stage surgical procedure. First, the implant fixture is countersunk into position and a cover screw is located over it during the required 4–6-month healing period. The second stage involves the fitting of an abutment to the osseo-integrated implant after it has been uncovered. A 2-week period is allowed for resolution of the gingivae after this procedure and, subsequent to this, restorative work can begin. There is a trend towards earlier loading of implants and possible immediate loading, to minimize

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the delay that results from the extensive healing period required. However, there are no long-term follow up studies of this approach as it is still in its infancy.

Suitability for implants

Prior to commencing any implant treatment, factors that need to be considered include the quality and quantity of bone present, the age of the patient, and the reasoning behind their seeking implant treatment.

Bone quality and the extent of ridge resorption are important factors to assess, and radiographic classification of these has been previously described.[7]

The age of the patient is an important consideration, as implants are problematic if inserted in growing children for the following reasons.[8]

- The use of implants in the anterior maxilla is contraindicated due to the possibility of the mid-palatal suture being open
- Resorption in the posterior part of the maxilla, resulting from growth changes, could lead to the exposure of the implant into the sinus
- The posterior aspect of the mandible continues to undergo growth changes in all three planes of space and, as such, definitive implant placement in this area would be difficult to estimate

Even when growth is complete and the teeth appear fully erupted, infra-occlusion of implant-supported crowns may occur.[9] This is a result of minimal continued eruption of the adjacent teeth, post-adolescence, and is most frequently seen with upper lateral incisors.

Implants as a source of absolute anchorage

During active treatment, orthodontic anchorage aims to limit the extent of detrimental, unwanted tooth movement. There are methods available to reduce anchorage loss during treatment. However, these techniques are often only partially successful, for example, transpalatal arches or headgear. The ability of osseo-integrated implants to remain stable under occlusal loading has led orthodontists to use them as anchorage units without patient compliance.

Historical background

The concept of metal components being screwed into the maxilla and mandible to enhance orthodontic anchorage was first published in 1945,[10] with the use of vitallium screws to effect tooth movement in dogs. Despite some success, the resultant tooth movement was limited due to the implants loosening within 1 month of commencing tooth movement. Two decades later, Linkow[11] described the endosseous blade implant for orthodontic anchorage, but did not report on the long-term stability. Vitreous carbon implants showed a failure rate of 67 per cent[12] when undergoing orthodontic loading, and attempts at using Bioglass-coated ceramic implants[13] for orthodontic anchorage were almost as disappointing. Although all the above materials were compatible with bone, none of them showed consistent long-term attachment of bone to the implant interface, which means they did not achieve true osseo-integration.

Osseo-integrated implants and orthodontics

In malocclusions requiring a high level of anchorage control, osseo-integrated implants can be used on a temporary basis to minimize loss of anchorage. For example, Roberts[14] used conventional, two-stage titanium implants in the retromolar region, to help reinforce anchorage whilst successfully closing first molar extraction sites in the mandible. After completion of the orthodontic treatment, the implants were removed using a trephine and histologically analysed. They found a high level of osseo-integration had been maintained, despite the orthodontic loading. In another study, Turley *et al.*[15] used tantalum markers and bone labelling dyes in dogs to illustrate the stability of two-stage implants in cases of orthodontic or orthopaedic traction. This work also showed that one-stage implants were less successful in this role.

Implant-based anchorage can be of particular benefit in treating certain aspects of malocclusions, for example:

- Retracting and realigning anterior teeth with no posterior support.
- Closing edentulous spaces in first molar extraction sites.
- Centre-line correction when missing posterior teeth.
- Re-establishing proper transverse and antero-posterior position of isolated molar abutments.
- Intruding/extruding teeth.
- Protraction or retraction of one arch.
- Stabilization of teeth with reduced bone support.
- Orthopaedic traction.

Design of orthodontic implants

One of the obvious disadvantages of two-stage implants for orthodontic anchorage is the need for a long healing period of 4–6 months, which adds significantly to the treatment time. The bone height required for traditional endosseous implants may also restrict the locations available for implant placement. As a result of these problems, implants have been designed specifically for orthodontic purposes. Ideally, an implant used to enhance orthodontic anchorage should be biocompatible, inexpensive, easily inserted and removed under local anaesthesia, and be small enough to locate in multiple sites in the mouth. It should also osseo-integrate in a few days, and would be stable to orthodontic loading in all planes of space.

Block and Hoffman[16] addressed the issue of bone height by developing a disc-like structure called an 'onplant' (Figure 1), which is designed to be placed under local anaesthetic. This hydroxyapatite-coated disc is 10 mm in diameter by 3 mm thick, and is placed subperiosteally on the posterior aspect of the hard palate, using a 'tunnelling' surgical procedure. The latter minimizes the potential for infection to occur around the onplant. After a 10-week healing period, the onplant is surgically exposed and a ball-shaped abutment (which replaces the cover screw) is attached. This is subsequently connected to orthodontic bands on the upper molar teeth by a transpalatal arch. This mechanism has been shown to resist greater than 300 g of continuous orthodontic force, which is comparable to the force required for conventional space closure of orthodontic extraction sites. After correction of the malocclusion, the onplant is removed using an osteotome, but the authors do not elaborate on any complications associated with this removal technique. Although the onplant requires less bone depth compared to conventional endosseous implants and the period of consolidation is approximately half as long, the surgical procedure is complex. The secondary surgical procedure to uncover the integrated onplant involves a large area of soft tissue being re-exposed, which is quite traumatic to the patient. In addition, the use of an osteotome to remove the onplant under local anaesthetic may be disconcerting for the patient.

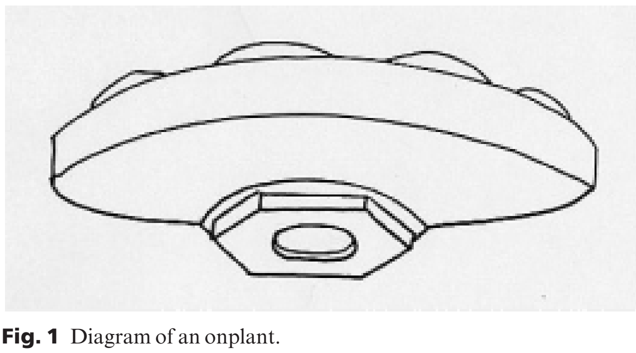

Fig. 1 Diagram of an onplant.

The anterior region of the hard palate is an area that Triaca[17] first reported as having potential for orthodontic implant placement. The hard tissue in this area comprises the mid-palatal suture and a zone of compact bone adjacent to this. The degree of inter-digitation of this suture increases with age and the extent of this inter-digitation may affect the success of an implant placed in this region. A suture of narrow width, combined with a high degree of inter-digitation provides the best environment for one-stage surgery and, therefore, earlier orthodontic loading.

Wehrbein and Merz[18] have investigated the depth of bone in the mid-palatal area by measuring lateral cephalograms and have subsequently developed the Straumann Orthosystem implant (Institut Straumann AG, Waldenburg, Switzerland), which can be up to 6mm in height, based on the potential bone depth available. The Orthosystem implant (Figure 2) is a one-piece device with an 8-week healing period. It is composed of a screw-type endosseous section of between 4mm and 6mm in length (depending on palatal depth), a cylindrical transmucosal neck and an abutment, to which a transpalatal arch attaches. It is different from previously described mid-palatal implants[16,17] due to its dimensions: it has a smaller width and greater length that results in less soft tissue trauma at the time of surgery. To maximize stability, the implant uses a self-tapping screw with a sandblasted acid-etched surface. This results in a high level of direct bone contact when osseo-integrated, which helps to maintain anchorage control when supporting the length of the TPA, despite the minimal implant design.

The placement or removal of this implant takes about 15 minutes under local anaesthetic, and is more straightforward than the onplant procedure of Block and Hoffman.[16] However, the potential problem with depth and width of the mid-palatal suture, as well as proximity of the nasal floor in children, means that this location may not always be appropriate.

Bernhart,[19] using multi-planar CT reconstruction, has identified regions 3–6 mm lateral to the midline of the anterior hard palate, that consistently have an adequate depth of bone to accept insertion of these 6-mm implants.

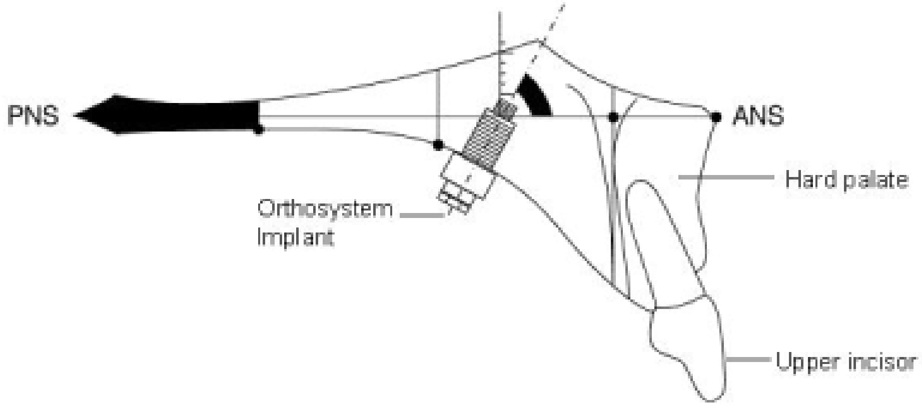

Fig. 2 Schematic representation of an Orthosystem implant.

The increasing desire for early loading of implants used for orthodontic anchorage led Melsen to develop the Aarhus implant[20] (Figure 3). Due to its small dimensions (6 mm length), this titanium anchorage screw can be located in multiple sites, including between the roots of teeth. It is said to allow osseo-integration to occur even in the presence of immediate orthodontic loading, providing the orthodontic forces (25–50 g from Sentalloy springs) pass through the screw. The strain that develops in the bone surrounding the loaded screw leads to a local environment in which increased bone formation results. Due to the size of the screw it can be used in a number of different locations and can be easily removed when no longer required.

In an attempt to produce an implant that is small and easy to place and remove, Kanomi[21] has described a mini-implant, which is 6 mm in length and 1.2 mm in diameter. This implant, which was developed from a mini-bone screw used for fixing bone plates, is screwed into the alveolus under local anaesthetic, to within 3 mm of the apices of the teeth. Subsequent to healing and osseo-integration, a titanium bone plate is fixed to the screw, and acts as a hook for the attachment of an orthodontic ligature wire to aid intrusion of the respective teeth (Figure 4). Due to potential oral hygiene problems, the ligature is not attached directly to the implant. The author did not clarify how long the healing period would be to allow osseo-integration, but did comment on the use of this implant for orthodontic space closure and molar distalization.

Orthopaedic traction

Implants have been suggested in treatment aimed at orthopaedic change. One study describes osseo-integrated implants inserted into the zygomatic buttress. These were used in combination with intra-oral extensions, to act as attachments for facemask therapy.[22] The orthopaedic changes observed in the maxilla over an 8-month treatment time occurred without any dental change. Implants may therefore be used to provide an alternative to conventional orthopaedic facemask therapy, while avoiding potentially unwanted dental movements.

Implants used for anchorage and as abutments for restorations

The previous section discussed implants used as a source of absolute anchorage. At the end of the orthodontic treatment they were then removed. However, implants can also be placed in a position that allows them to act initially as a source of anchorage, but then as an abutment for restorative work.

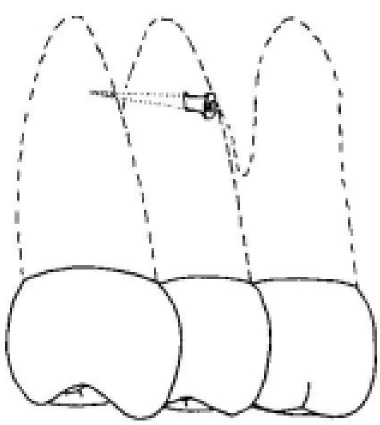

Fig.3 Diagram of an Aarhus implant.

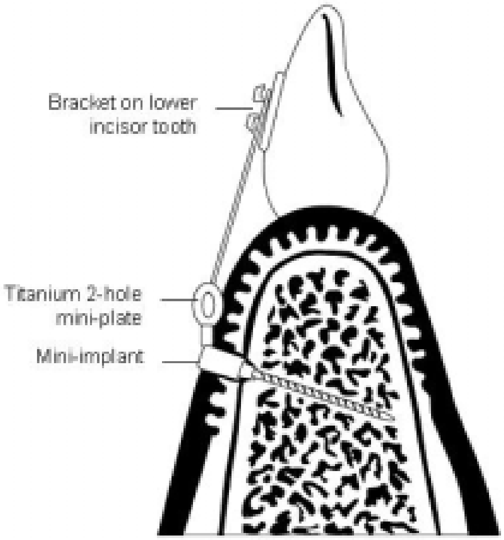

Fig. 4 A mini-implant, as described by Kanomi.

Cases requiring implants for both restorative management and orthodontic anchorage require extensive planning involving the orthodontist, restorative specialist, oral surgeon, and periodontist. There are cost and time implications, and the potential surgical difficulties of access and local anatomy that may prejudice against the ideal positioning of a conventional implant should be borne in mind. The restorative specialist decides on the exact location of the implants. A diagnostic wax-up of the final occlusion and a comparison of this with the original model are used to define the precise location of the implants. When this has been decided, a placement guide or stent is fabricated to ensure accuracy of placement of the implants.[23] This process may be aided by the recently developed Simplant software system (Columbia Scientific Inc., Columbia, Maryland, USA), which provides information on the optimal dimension, orientation, and inclination of the endosseous implant, through an interactive computer programme.[24]

The dimensions of the implant should conform closely to the desired emergence profile of the final restoration without compromising the inter-dental bone. For optimal aesthetics of the emergence profile, the implant head should be 2 mm below the cemento-enamel junction of the adjacent teeth.

If orthodontic treatment is necessary to create space prior to the implant being placed, then the roots of the adjacent teeth should be upright and parallel once this is complete. Adequate space is important, not only in the mesio-distal dimension, but also for the bucco-lingual width of the implant.

Orthodontic implant attachments

Once successfully implanted and after the bone has consolidated, the implant must be incorporated into the orthodontic appliance. It is possible to attach an orthodontic archwire directly to the implant cover screws, but movement of the teeth is faster and better controlled if single crowns or denture teeth are used as superstructures.[25] The type of attachment used depends on factors such as:

- The magnitude of force required.
- The need for aesthetics.
- The method of force application.

The most durable options are all metal or bonded metal crowns. The incorporation of a Class V cavity in the fabrication of these prior to casting, allows a mechanism for orthodontic bracket retention with composite resin. Other options include soldering the orthodontic bracket to a second-stage, non-rotating implant abutment[26] or bending a loop in the orthodontic archwire to secure it to part of the implant.

It is important that endosseous implants required for restorative management are not compromised during their use for orthodontic anchorage. To ensure maintenance of osseo-integration during and beyond treatment, orthodontic loading of a single two-stage endosseous implant should not commence for 6 months in the mandibular arch. However, if multiple implants are placed, occlusal loading of the implants can start sooner. This is because the cross-arch splinting that results from loading the prosthesis allows integration to occur around the functioning implants.

Stability of implants

Concern regarding the stability of osseo-integrated implants undergoing orthodontic loading has been addressed by Hurzeler *et al.*[27] This team looked at the bone implant interface of implants used for orthodontic anchorage in healthy mouths. Their histological findings indicated that repetitive mechanical trauma did not result in increased peri-implant bone loss. In addition, the application of any lateral load did not cause marginal bone loss, but in fact led to a compensatory increase in density of the peri-implant bone through structural adaptation.

Histologically, there is no statistically significant difference in the response of peri-implant bone to orthodontic loading, (as measured by the bone to implant contact length) for either pressure or tension forces when compared to control sites.[28] Even in implants used for orthopaedic traction, with non-axial loading of 500 g, perfect osseo-integration has been demonstrated.[29]

From a clinical standpoint, up to 400 g of orthodontic force (which is greater than the normal range required for conventional orthodontic tooth movement), has been successfully anchored against an osseo-integrated dental implant in several malocclusions.[30] The only reported problem in these cases was repeated loosening of the abutment screw, with no significant loss of anchorage.

Implant site preparation improved by orthodontics

Orthodontics can be used before implant placement to improve the quality of the implant site. For example, where there has been bone loss associated with periodontal disease, which can significantly affect the aesthetic outcome and prognosis of implant treatment. The depth of bone available in such a diseased region may be insufficient for placement of an implant when the compromised tooth is eventually lost. Even if this is not the case, the difficulty with managing the poor gingival aesthetics that result, may caution against implant treatment.

Teeth that are compromised beyond the scope of periodontal treatment can be used to develop the alveolar bone in that region, through orthodontic traction, to allow the subsequent use of implants. This 'forced orthodontic eruption' of such a hopeless tooth causes an alteration in the soft tissue architecture of the periodontium as well as improving the amount and quality of bone available for implant placement.[31] The increased bone level allows better implant angulation, which will maximize the final aesthetics of the restoration. The emergence profile of the final prosthesis will also be improved by this technique due to the increased gingival depth. Once acute periodontal disease has been stabilized, the tooth is extruded. The tooth should then be allowed to stabilize for 4–6 weeks after orthodontic extrusion, and once consolidated the tooth should be extracted and immediately replaced with the implant.[31] To prevent any collapse of the gingivae around the implant, healing abutments should be placed at this stage and consideration given to replacing these with cover screws 3 months later.

Implants in osteogenic distraction

Osteogenic distraction may provide a stable method of addressing facial skeletal deformities through bone generation, which allows adaptation of the surrounding soft tissues, due to its gradual process. It has, however, been suggested that distraction devices that are fixed using conventional bone screws, may not transmit forces evenly across the distraction site. Pilot studies on the maxilla and mandible, undertaken by Ueda *et al*.[32] have illustrated the use of osseo-integrated implants to transfer continuous distraction forces through the full width of the distraction site. This has been successfully completed in mandibular lengthening, maxillary advancement, and alveolar ridge augmentation but requires further research prior to becoming an established technique.

Conclusion

Osseo-integrated implants may now be used to enhance more traditional orthodontic techniques. In particular, they may have the potential to provide a useful method of anchorage reinforcement, particularly in cases otherwise dependent on patient compliance. The continuing development of orthodontic implants has led to the production of smaller designs which are easy to insert and remove, and do not require a long healing period prior to loading.

With astute planning in hypodontia cases, osseo-integrated implants can be used for orthodontic anchorage to correct a malocclusion, prior to acting as the coping for the definitive restorative prosthesis.

In the future, as developments occur in implant technology, they may have a significant role as anchorage reinforcement aids and make headgear obsolete. However, there is a need for high quality research in this area.

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