Adjunctive Orthodontic Applications in Dental Implantology

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Implant placement is often necessitated for replacement of teeth with pathologically damaged alveolar bone due to periodontitis or traumatic injury. Surgical augmentation of resorbed bone has many limitations, including lower efficacy of vertical augmentation than horizontal augmentation, as well as morbidity associated with grafting procedure. Orthodontic therapy has been proposed as a useful method for augmenting the resorbed alveolar bone and reforming aesthetically appealing gingival margin, prior to implant placement. This narrative review summarizes the available evidence for the application of orthodontic strategies that can be used as adjunct in selected cases to augment bone volume for the future implant site and maintain space for the prosthetic parts of the implant. These are (1) orthodontic extrusion of compromised teeth to generate vertical bone volume and enhance gingival architecture, (2) tooth preservation and postponing orthodontic space opening to maintain bone volume in future implant site, (3) orthodontic implant site switching to eliminate the deficient bone volume or risky implant sites, and (4) the provision of a rigid fixed-bonded retainer to maintain the implant site. Although there are no randomized controlled clinical trials to evaluate the efficacy of orthodontic therapy for implant site development, clinical case reports and experience document the efficacy of orthodontic therapy for this application.

Key Words: orthodontic, implant site development, orthodontic extrusion, delayed orthodontic space opening, orthodontic implant site switching, orthodontic retention

INTRODUCTION

A prerequisite for the optimal esthetic and function of implants is placement of the implant in proper relationship to the planned restoration. This will require the presence of adequate volume and position of alveolar bone and mucosa.[1–8] In cases where the bone and soft tissues are defective due to pathologic diseases, varieties of reconstructive surgeries have been utilized. These procedures have generally been successful in augmenting bone and soft tissues. The most challenging condition is the vertical augmentation of alveolar bone and soft tissue. Another limitation is the potential morbidity of surgical augmentation procedures. Orthodontic therapy can often serve an adjunctive role in optimizing implant sites. The objective of the present paper is to review some of the orthodontic strategies that can be employed in preparation for implant therapy.

ORTHODONTIC EXTRUSION

Korayem and co-workers[9] have reviewed the available evidence on implant site development by orthodontic extrusion. The Table summarizes some of the clinical situations where orthodontic extrusion may be employed.[10–27] Orthodontic extrusion of nonrestorable or periodontally compromised teeth has been used in patients (age ranges of 19–62 years) to increase the hard and soft tissue (ie, increase the keratinized attached gingiva) volumes in the implant site,[10–27] reduce or eliminate vertical or buccolingual bone volume deficiencies, and obviate the need for hard and soft tissue augmentation procedures.[9]

Alveolar ridge augmentation techniques are more predictable in restoring the width of an alveolar ridge than its height.[28] The guided bone regeneration (GBR), distraction osteogenesis, and onlay bone grafts have been used for vertical bone augmentation,[29,30] technically demanding approaches with demonstrated varying degrees of success. The systemic review of Rocchietta and co-workers[30] reported that GBR and distraction osteogenesis were successful in 2–8 mm and 5–15 mm of vertical bone gain, respectively. The most commonly reported complication for GBR was the barrier membrane exposure with the reported incidence of 0%–45.5%. For distraction osteogenesis, a high percentage of complications (10%–75.7%) has been reported including the fracture of the distractor, infection of the distraction chamber, fractures of transported or basal bone, slight resorption of the transported fragment, soft tissue dehiscences, and premature or delayed consolidation as well as fibrous nonunion, to name a few.[30]

Orthodontic extrusion is one of the most reliable and noninvasive means of gaining vertical bone augmentation. This is particularly true in the maxillary anterior region where vertical bone augmentation is challenging. Review of the literature

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Table

Examples of clinical situations in which orthodontic extrusion can be used for implant site development

Periodontally hopeless tooth with vertical bone loss presenting with Class II or III tooth mobility
Extensive coronal or recurrent subgingival caries
Traumatic vertical root fracture presenting with extensive vertical and horizontal bone loss
Severe gingival recession presenting with loss of interdental papilla and alveolar bone loss
History of failure of surgical periodontal treatment or unsuccessful endodontic treatment presenting with endodontic-periodontal lesions
Poor crown-to-root ratio
Severe external root resorption

reveals various orthodontic extrusion treatment protocols.[9] However, a good plaque control, elimination of periodontitis, the existence of at least one-third to one-fourth of the apical attachment, and sufficient stabilization period have been cited as requirements for a successful forced eruption.[13,16,31] Light and constant extrusive forces of 15 and 50 g for anterior and posterior teeth have been recommended, respectively.[9] Orthodontic extrusion is done at a rate of 1–2 mm per month, and a stabilization period of 1 month, for each millimeter extruded, has been recommended.[9,32,33] Immediate implant placement with or without additional bone grafting should be followed right after the extraction of the extruded tooth/teeth to avoid further bone resorption. When a periodontally compromised tooth is extruded, torquing[9,16] and tipping of the tooth toward the angular bone defect increase the alveolar bone volume in that region.[25] An animal study reported that 80% of the vertical tooth movement, in the direction of tooth extrusion, occurred in the attached gingival.[34] With this strategy, some improvement of the interproximal papillary height,[24] as well as the formation of peri-implant keratinized tissue, and coronal movement of gingival margin, can be expected.[9,25,35] Using orthodontic extrusion for implant site development often involves prior root canal treatment[35] and vertical crown height reduction of the tooth that is to be extruded, to eliminate creating a traumatic bite.[36]

Figure 1 shows a clinical case, where orthodontic extrusion was utilized to optimize the alveolar ridge in preparation for implant therapy. Preoperative clinical (Figure 1a and b) and radiographic (Figure 1c) examination revealed severe periodontitis, associated vertical alveolar bone loss, Miller class 3 recession defect, and supraeruption of the maxillary left central incisor. Orthodontic extrusion of tooth number 9 was performed, moving the tooth in a coronal (Figure 1d) and palatal (Figure 1e) direction. The tooth was extruded at a rate of 1 mm per month, followed by 6 months of maintenance to stabilize the newly formed alveolar bone. Periapical radiographs in Figure 1f and g provide evidence for correction of the angular defects of interproximal bone of tooth number 9. Cross-sectional reconstruction of the cone-beam computerized tomography (CBCT) image taken following 6 months of active orthodontic movement and 6 months of maintenance revealed significant vertical down-growth of alveolar bone. However, since the width of the alveolar bone was only 5.5 mm, it was decided to perform horizontal augmentation of the alveolar bone to optimize the implant site. To that end, the tooth was extracted (Figure 1i and j), and GBR was performed (Figure 1k). Access to the facial alveolar bone was accomplished by vestibular incision subperiosteal tunnel access (VISTA) technique.[37] This entailed making a 1-cm vertical incision in the vestibule over the midline frenum. Subperiosteal tunnel access was made to expose the facial plate. Two 1.5 $\times$ 8 mm tenting screws[38] (Salvin Dental Specialties, Charlotte, NC) were partially inserted into the facial plate in such manner that half of the screw was anchored into the bone and the remaining half was left above the bone (not shown). Deproteinated bovine bone mineral (Bio-Oss, Geistlich Pharma North America, Princeton, NJ) was placed over the facial plate of tooth number 9, as well as neighboring teeth. Six months later, CBCT was taken to evaluate the adequacy of augmented bone (Figure 1l). The alveolar ridge volume was determined to be optimal at this point. Prior to placement of the implant, a diagnostic wax-up was performed to design the proportion of the future restorations in the esthetic zone. A surgical guide was fabricated based on the wax-up (Figures 1n and o) to aid in positioning the implant based on available guidelines of 3 mm apical and 2 mm palatal of the cervical contour of the planned restoration.[39] Utilizing the guide, an implant (Astra Tech Osseospeed, 4.0 $\times$ 11 mm) was placed (Figure 1p). Figure 1q shows that in order to optimize the peri-implant soft tissue, the crestal incision was placed palatal of the crest. Before approximation of the flap, a palacci incision[40,41] was made on the facial and rotated mesially. A computer-aided design/computer-aided machining (CAD/CAM) abutment (ATLANTIS abutment, DENTSPLY Implants, Mölndal, Sweden) with full anatomic contour was designed virtually (Figure 1r) and milled (Figure 1s). A ceramometal restoration was fabricated and delivered (Figure 1t and u). As can be gathered from the description of this clinical case, the restoration of this patient with compromised periodontal and dental conditions involved an interdisciplinary team of periodontist, orthodontist, restorative dentist, laboratory technician, and CAD/CAM service. Orthodontic extrusion or "forced extraction" as Salama and Salama[13] called it, required careful planning, to ensure the outcome desired by the patient. It is important to note that although orthodontic extrusion was employed to improve osseous topography and optimize the implant site prior to implant placement, this was not the only reason for orthodontic therapy.

Orthodontic extrusion, as with any technique, has pros and cons. On the positive side, orthodontic extrusion can vertically translate the bone at the alveolar crest and provide native bone for implant placement. However, the drawbacks of this technique include the length of time required, as well as the fact that the vertically translated bone may not have sufficient buccolingual volume. This latter point was illustrated in the case in Figure 1. Therefore, the clinician is advised to consider these pros and cons in selecting an appropriate technique, which will be suited to the requirement of a give clinical situation.

Figure 1. Interdisciplinary management of a clinical case. Preoperative clinical (a,b) and radiographic (c) images at initial presentation. Note the palatal position of the crown of the tooth number 9 at the conclusion of orthodontic therapy (d,e). This helps the bone augmentation in the labial part of the socket that is frequently very thin.[72] Periapical radiographs during and after orthodontic therapy (f,g). Cross-sectional reconstruction of cone-beam computerized tomography (CBCT) at the end of active orthodontic therapy (h). Extraction socket (i) and extracted tooth number 9 (j).

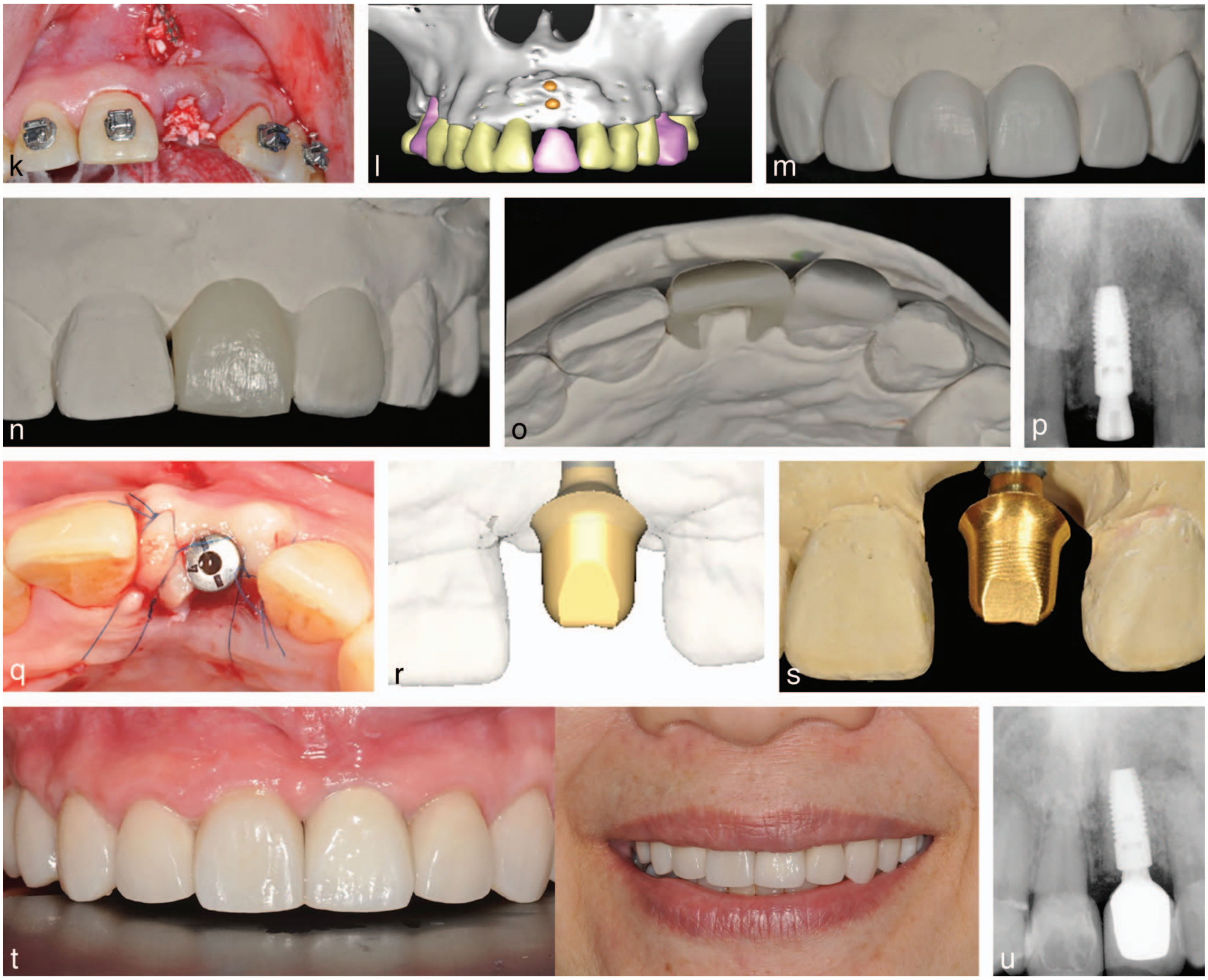

Figure 1 Continued. Vestibular incision subperiosteal tunnel access technique (k). CBCT following healing of bone augmentation (l). Diagnostic wax-up (m) and surgical guide fabricated based on the wax-up (n,o). Immediate postoperative radiograph (p) and clinical image (q) of the implant placed in central incisor position. Virtually designed CAD/CAM abutment (r,s). A ceramometal restoration (t,u).

Tooth Preservation and Delayed Orthodontic Space Opening

Some reduction in the buccolingual and vertical dimensions of the alveolar ridge occurs in the edentulous sites with congenitally absent teeth[33] or following tooth extractions.[42–47] Previous research showed that after extraction of primary mandibular second molars, the ridge narrowed by 25% during the first 4 years, and after 7 years, the buccolingual ridge width atrophy reached 30%.[42] Human and animal studies confirm that this ridge defect is primarily in the buccal side,[42,48] and the reduction in the width of an alveolar ridge is greater than the loss of height.[44,47] This bone defect, which can be avoided by maintaining the retained primary teeth, often requires bone grafting or demands more lingual or palatal placement of implants. As can be seen in Figure 2a through g, preserving, extruding, and restoring a permanent tooth with crown fracture or severely damaged crown (due to decay or tooth wear) is another strategy during adolescence to maintain the alveolar bone volume prior to implant placement.

Finding implant sites with enough space is often rare; some orthodontic space opening may be needed to create space for implants. Orthodontic space opening has been associated with decreases in the width of bone in the newly created sites[49–51]; though, 2 years after finishing the space, opening changes were very minimal.[50] This bone defect can be seen in areas such as missing maxillary lateral incisors or mandibular premolars, common sites for congenitally absent teeth.[52] The limited available evidence suggests that to avoid the surgical ridge shrinkage and future augmentation at the site of congenitally absent maxillary lateral incisors, the distalization of canines should be postponed until after the age of 13 years[53] or near the end of skeletal growth.[54] However, this approach has been disputed.[50] Therefore, so far as possible, the time gap between the orthodontic space opening and implant placement should be reduced a practical minimum to avoid further ridge resorption.

Figure 2. Preserving, extruding, and restoring tooth number 8 with crown fracture (a,b) in a 14-year-old boy. Although the prognosis of the tooth was poor, implant therapy was not advised at an early age. Therefore, the crown was restored (c) and after root canal treatment, orthodontic extrusion was performed (d,e). The tooth was restored following orthodontic extrusion (f,g), and it has been maintained for almost 5 years after finishing orthodontic treatment.

The Orthodontic Implant Site Switching

Extraction of teeth, in particular in the absence of ridge preservation procedure, can lead to significant atrophy of the alveolar ridge.[55] An array of surgical techniques have been developed for augmentation of the alveolar bone. Orthodontic therapy has been proposed as an alternative to surgical augmentation in enhancing atrophic edentulous sites adjacent to natural teeth. Orthodontic movement of teeth toward an adjacent atrophic edentulous alveolar ridge is accompanied by movement of the alveolar bone associated with the tooth.[54,56–61] This leads to expansion of the alveolar bone, potentially obviating the need for surgical ridge augmentation. The application of orthodontic therapy in enhancement of adjacent atrophic alveolar bone has been termed orthodontic implant site switching (OISS).[62] In carefully selected cases, this can eliminate or minimize the need for surgical augmentation procedures (Figure 3). This procedure has been associated with minimal changes in the periodontal support of the transposed tooth[63]; and, by using adjacent teeth, as a stimulus for alveolar-site development, the need for bone graft may be eliminated.[59] OISS can be used in common sites for congenital tooth agenesis[52] to generate enough bone volume in the maxillary and mandibular lateral incisor or premolar regions. For instance, the mesialization of the second premolar into the narrowed and deficient site of a missing first premolar (or vice versa) leaves behind an alveolar ridge with adequate bone volume, eliminating bone grafting before implant placement.[54,59,61] Orthodontic tooth movement in edentulous ridge areas has been described in a case series by Lindskog-Stokland and co-workers,[61] reporting mean increases of 1.6 and 0.8 mm in the thickness of the buccolingual alveolar ridge width, at retention stage, at the 2- and 5-mm crestal level, respectively. These increases were associated with minimal changes at 1-year follow-up.[61]

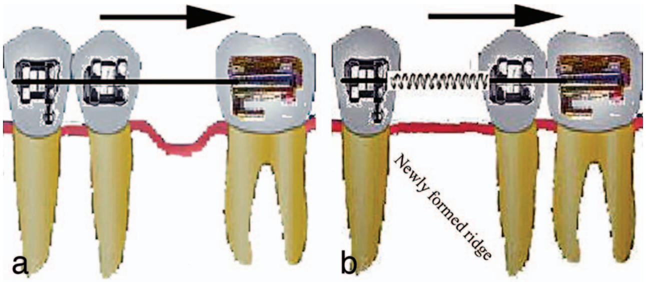

Figure 3. The orthodontic implant site switching[62] uses tooth movement to generate a new bone. (a) A first premolar is pushed distally into the second premolar position, where bone volume deficiency exists. (b) New bone is generated in the first premolar position and can be used for implant placement, obviating the need for bone grafting.

Orthodontic Retention

Provision of retention after orthodontic space opening or OISS is vital for maintaining the implant site. In children, several years can elapse between completion of orthodontic treatment and initiation of implant therapy. Consequently, a rigid bonded retainer or a resin-bonded bridge should be provided after the successful orthodontic implant site development because positional changes of teeth adjacent to implant sites are common.[64] The overeruption of the unopposed teeth into the edentulous space can also compromise the future prosthetic treatment.[65] With regard to the implant site, positional changes such as the root reapproximation of the adjacent teeth,[66,67] tilting of adjacent crowns into the implant site,[66,67] and overeruption of unopposed molars[65] should be prevented.

The study of postretention root position of maxillary central incisors and canines has revealed that 11% of patients experience relapse, significant enough to prevent implant placement in that area.[67] This relapse can potentially compromise or prevent future implant placement, requiring further orthodontic treatment to facilitate implant placement. Previous research has demonstrated that removable retainers are not efficient at maintaining the dimensions of edentulous space[67] and, therefore, placement of a rigid bonded wire or a resin-bonded bridge has been recommended. This prevents root approximation during the retention stage or overeruption of unopposed molars following tooth loss.[59,67]

Summary

Complications and morbidity of surgical alveolar ridge augmentation have been observed in association with both donor (ie, hematoma, altered sensation of teeth, mucosa and skin, postoperative pain) and recipient sites (ie, graft or membrane exposure, graft loss, graft displacement, infection).[68–71] Moreover, surgical ridge augmentation has biologic limitations, particularly with regard to vertical ridge augmentation.[30] It is advisable that clinicians recognize the potential of orthodontic treatment as an alternative/adjunct to overcome some of these limitations. Currently, no comparison has been made between the effectiveness of the surgical bone augmentation techniques and orthodontic alternatives. For instance, it seems that two methods of implant site development (orthodontic extrusion or bone grafting) are both effective and neither method is superior.[72] Future multicenter randomized clinical trials are required to address this question. However, setting up such a randomized clinical trial when comparing two treatment modalities with different levels of invasiveness would be challenging.[73]

Abbreviations

CAD/CAM: computer-aided design/computer-aided machining
CBCT: cone-beam computerized tomography
GBR: guided bone regeneration
OISS: orthodontic implant site switching

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