

Prosthetic Considerations for Orthodontic Implant Site Development in the Adult Patient

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Proper site development is a key factor for long-term clinical success of dental implants. Whereas surgical and restorative techniques have been refined to ensure predictable functional and esthetic outcome, individual clinical prerequisites do not always allow proper placement of implants when prosthetic and material properties are considered. Orthodontic tooth movement may be a viable and nonsurgical site development treatment option. With the introduction and advancements of minimal invasive and less visible orthodontic appliances, a growing number of adult patients are willing to obtain orthodontic treatment. The spectrum of modern appliances is broad and ranges from clear aligners to lingual brackets. Skeletal anchorage devices such as orthodontic mini-implants often eliminate unpopular external anchorage devices (ie, headgear) in adult patients. This article discusses the selection of an appropriate pretreatment approach by taking patient-specific criteria into account.

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Although replacing missing single teeth with dental implants has become routine, in many cases the initial clinical situation does not provide for optimal implant positioning. Especially in adult patients with missing teeth, neighboring or opposing teeth may migrate,

tilt, or extrude over years, making correct placement of implants impossible, or jeopardizing the long-term clinical success of a restoration. This is especially true if material properties are not considered and minimum dimensions are ignored. In addition, the practitioner is challenged with increasing demands for esthetic outcomes, which require that multiple biological, functional, and biomechanical aspects be addressed and potential problems be identified preoperatively. The factors that have a direct influence on success or failure include the amount of available alveolar ridge, soft tissue type, correct positioning of the implant in all 3 dimensions, design and material of the selected restorative components, and adequate space for the definitive restoration.¹⁻³ Depending on the overall condition, an interdisciplinary team approach is indispensable for a predictable long-term success.

Recent advancements in new materials and manufacturing techniques integrating computer-aided design/computer aided manufacturing (CAD/CAM) technology into everyday laboratory routine allow industrial fabrication of prosthetic components for almost any clinical situation. Despite their many advantages such as biocompatibility, strength, and esthetic properties, several requirements apply when materials such as oxide ceramics are used. In situations where available space does not allow for minimum required thickness of components, material properties can result in catastrophic failure under clinical function. This is especially important when

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restoring posterior implants where functional occlusal loads are the highest. In many cases, long-term edentulism results in elongation of the opposing teeth, limiting the availability of vertical height for proper restorations.^{4,5} Meticulous treatment planning is also a necessity in the anterior maxilla, where the functional and esthetic outcome is significantly influenced by available hard and soft tissue morphology.

The increasing acceptance of orthodontics in adult patients enables the creation of more favorable clinical conditions before dental implants are being placed. The advantages are not only an improved esthetic outcome but more stable tissue architecture. Pre-prosthetic tooth alignment may also prevent the necessity for root canal treatment in cases in which elongated teeth have to be prepared for full-coverage crowns, providing sufficient space for all-ceramic restorations. Implant site development is typically limited to a defined region in most patients. Therefore, extensive full-arch bonding is not warranted in most cases. The 2 most easily applied orthodontic techniques for localized orthodontic pretreatment are forced orthodontic eruption and the application of orthodontic mini-implants. An alternative approach is the use of definitive osseointegrated dental implants as orthodontic anchors. Although various types of orthodontic appliances may be attached to an abutment in these situations, the technique requires adequate space for primary implant positioning and can be applied predominantly for uprighting tilted molars or mesiodistal movements of teeth.

The aim of this article is to present and discuss orthodontic options for implant site development and to discuss their limitations and potential risk factors in adult patients.

Orthodontic Miniscrews for Localized Site Development

The clinical use of orthodontic mini-implants or miniscrews is becoming increasingly popular. These tools are used as bone-retained anchorage devices to support orthodontic tooth movement and to resist reciprocal reaction to applied orthodontic forces.^{6,7} There are various screw systems available on the market, with differing designs, dimensions, and insertion techniques.⁸ Orthodontic mini-implants have greatly increased the treatment options for dental and skeletal malocclusions because of the simplicity of placement and removal, minimal invasiveness, and relatively low cost.⁹ In addition, the option of immediate loading and the elimination of shortcomings frequently associated with extraoral anchorage devices (eg, patients' noncompliance) result in increasing acceptance and clinical application in orthodontics.¹⁰ Currently, the greatest shortcoming

of mini-implants is an unpredictable clinical failure rate, ranging from less than 10% to greater than 30%.¹¹ Multiple scientific studies report that success is determined by a multitude of external factors, such as bone quality and quantity and surrounding anatomic structures,¹²⁻¹⁴ oral hygiene, insertion torque,¹⁵ insertion angle, root proximity,¹⁶ involvement of the periodontal ligament,¹⁷ applied loads, and screw design.¹⁸ This unpredictability is confirmed by several clinical studies. Chuang et al¹⁹ reported that placement of screws in nonkeratinized mucosa was associated with clinical failure. In a study by Moon et al,²⁰ significant differences in success rate in adult patients was related to placement site. The lowest success rate was seen between the second premolar and first molar in young patients in both jaws. Although Park et al²¹ found better success rates in the maxilla, Myawaki et al²² found no difference in the success rate for the maxilla and mandible. The underlying cause of the inconsistent results when comparing maxillary and mandibular implants remains unclear. Reports in the scientific literature agree that a predominant reason for failure of screws inserted into the alveolar bone is excessive micromovement upon load application. Although theoretical ratios exist for dental implants,²³ these values cannot be transferred to orthodontic mini-implants because of the significantly reduced size with resulting small surface area and the low horizontal forces being applied. The reason for the lack of relevant data in orthodontic applications is caused by the difficulty in measuring displacement occurring in the low-micrometer range. This lack of relevant data underlines the need for additional scientific research on this specific topic.

The time of load application is discussed controversially in the literature. Recent reports conclude that a healing time seems unnecessary for mini-implants. Concluding from a review, Chen et al²⁴ stated that failures also happened before loading and several experimental studies revealed that immediate loading of the threaded implant does not necessarily lead to fibrous tissue healing. The authors summarized that a bone-to-implant contact developed over time and is comparable to that of conventionally loaded implants. Load application within generally accepted ranges for orthodontics does not negatively affect the overall success. Costa et al²⁵ attributed failures to torsional stress and concluded that a force system generating a movement to the implant in the unscrewing direction caused an implant to fail. This statement is backed by findings of Wawrinek et al.²⁶ The authors demonstrated more microstructural damage in cortical bone caused by overtightening with deep insertion of orthodontic microscrews than with lower insertion depths. Extensive osseous micro-damage and subsequent

bone remodeling may detract from the stability of immediate-load microscrews and implants.²⁶

Nevertheless, because of the reduction of periodontal tissues in many adult patients, orthodontic mini-implants provide a valuable treatment option. The greatest benefit is the broad range of treatment options from mesial-distal tooth movements to intrusion, extrusion, and uprighting of tilted teeth (Figs 1-4).

Clinical Implication for Site Development With Orthodontic Mini-Implants

The current literature indicates an ongoing controversy over several aspects of orthodontic mini-implant treatment. However, because of its many advantages, this treatment alternative should be considered when localized retention is needed to counteract applied orthodontic forces or to provide additional retention. This is especially true when the periodontal anchorage potential, such as full-arch bonding, fails to ac-



FIGURE 2. Uprighting of a tilted mandibular molar with orthodontic mini-implants before implant placement.

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commodate the treatment goal. In adult patients, the reduced reactivity of the cells and the decrease in bone flexibility demand longer treatment times and reduced initial loading forces.^{13,27,28} Predominant aspects for success are selection of the appropriate location providing maximum cortical thickness and



FIGURE 1. Orthodontic mini-implants (Ortho Easy, Forestadent, Pforzheim, Germany) can provide additional anchorage. A, Transgingival insertion of mini-implant with insertion tool. B, Mini-implant immediately after placement.

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FIGURE 3. Factors for ideal mini-implant positioning are adequate distance to neighboring roots and positioning in attached mucosa. A and B, Simple orthodontic devices such as elastic bands can be used for intrusion of teeth.

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FIGURE 4. Intrusion of maxillary molars to provide adequate vertical space for restoring the posterior mandibular implant.

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attached gingival tissues. Self-drilling mini-implants should be used except for the posterior and inferior aspects of the mandible because of the high fracture rates.²⁴ Careful implant insertion and application of



FIGURE 6. Forced orthodontic eruption of left central incisor. Application of low forces (50gN) is ideal for subsequent coronal migration of hard and soft tissues.

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low initial forces are crucial to prevent micro damage to the surrounding bone.^{26,27} Immediate load application, however, does not seem to increase screw loosening.²⁴

Forced Orthodontic Extrusion—Basic Principles

Orthodontic eruption or forced orthodontic extrusion (FOE) is a noninvasive method to improve the three-dimensional topography of the periodontal complex and can be used to optimize the implant recipient site before extraction of nonrestorable teeth (Figs 5-7). FOE was first documented by Ingber and has been suggested for the management of an inadequate biologic width resulting from root fractures or extensive subgingival defects.²⁹⁻³¹ The underlying principle of any orthodontic tooth movement is the remodeling of periodontal ligament (PDL) and alveolar bone in



FIGURE 5. Preoperative situation: A, Intraoral view. B, Extraoral view. Initial leveled cervical crown margins and a high smile line with significant exposure of the maxillary alveolar process are esthetic risk factors. Extraction of the left central incisor was necessary.

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FIGURE 7. Immediate implant placement following a minimally invasive approach.

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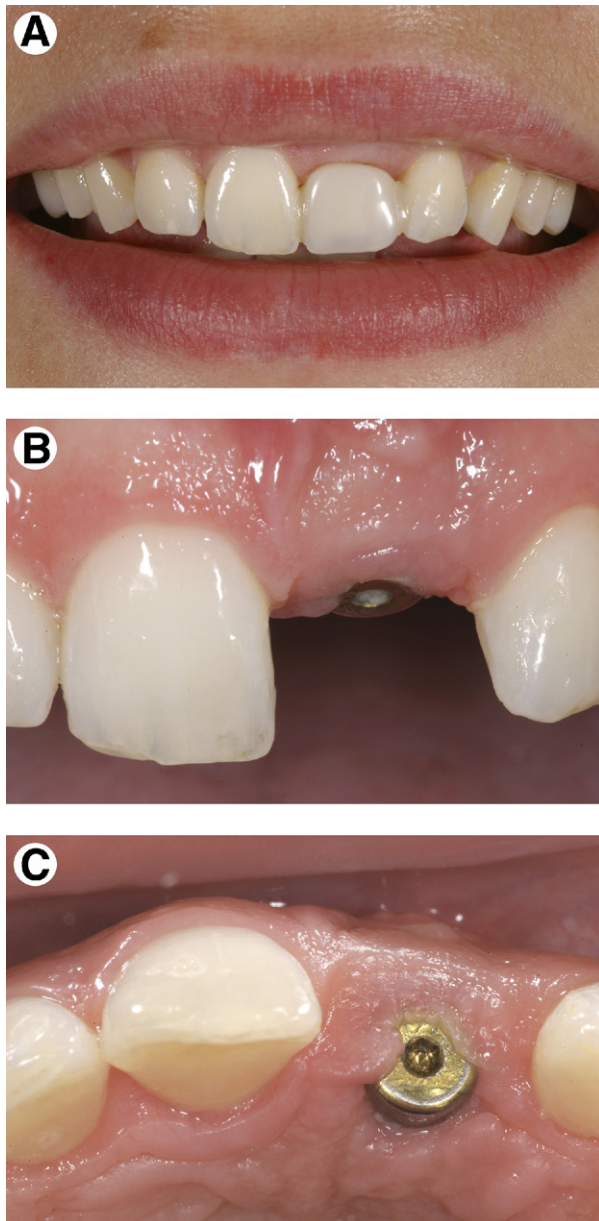


FIGURE 8. A-C, Extraoral, occlusal, and frontal views of soft tissue architecture after a 5-month healing period. Note the excess of soft tissue in the vertical dimension.

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response to mechanical loading.³² Eruptive tooth movement causes a stretching of the gingival and periodontal fibers, which leads to a coronal shift of bone and gingiva. The mechanical loading patterns are quite complex because of the intricate anatomy and tissue structure, as shown by finite element analysis investigations.³³ The transduction of mechanical forces to the cells triggers a biologic response, which has been described as an aseptic inflammation. It is mediated by a variety of inflammatory cytokines and does not represent a pathological condition.^{34,35} The

main difference to chronic inflammatory responses, in which stimuli sustain a long-lasting inflammatory response and result in tissue damage, is that the expression of inflammatory mediators after orthodontic force application is temporary and essential for orthodontic movement. Walker and Burin showed that anti-inflammatory drugs are capable of blocking tooth movement.³⁶ The tissue response initially involves vascular changes, followed by cell mediators (eg, prostaglandins, cytokines, growth factors). Finally, such mediators are believed to activate tissue remodeling, characterized by selective bone resorption or deposition in compression and tension regions of the PDL.^{32-34,37} An investigation by Kajiyama et al³⁸ demonstrated that upon FOE, the gingiva moved in the same direction in which the teeth were extruded. The free gingiva moved about 90% and the attached gingiva moved about 80% as far as the teeth were extruded. At the same time, the width of the attached gingiva on the labial surface increased (Figs 8, 9). No clinical or histologic problems were encountered in the gingival tissues if the teeth were extruded properly.³⁸

With these biologic reactions, both the hard and the soft tissue components of the anticipated implant

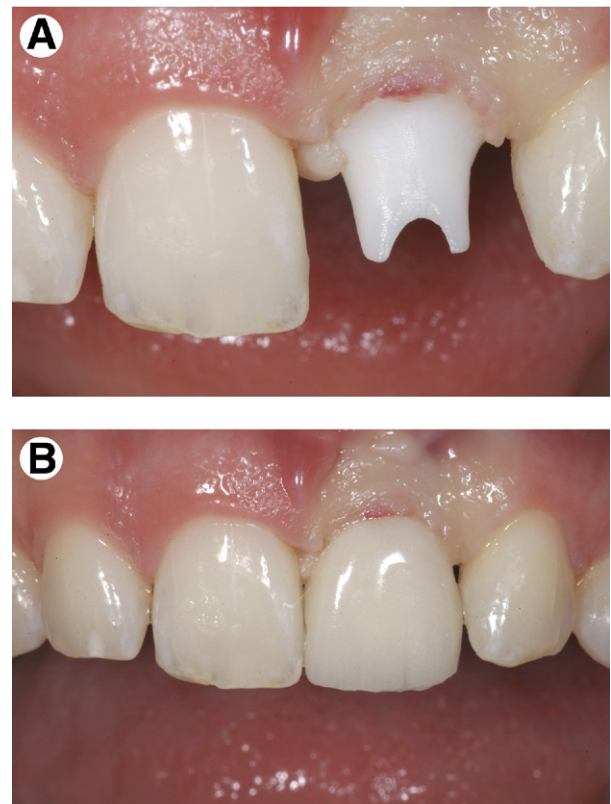


FIGURE 9. A and B, Frontal view of definitive custom-made zirconia abutment (NobelProcera Abutment Zirconia, Nobel Biocare, Zurich, Switzerland) and provisional restoration.

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site can be optimized to compensate for subsequent remodeling after implant insertion and abutment connection.³⁹

Clinical Implications of Forced Orthodontic Extrusion for Adult Patients

The application of FOE for implant site development is simple but requires consideration of other related aspects. The extra time and cost required for FOE is justified only when the clinical situation allows for minimally invasive extraction and implant placement without the necessity for extensive bone augmentation (eg, vertical root fracture, severe subgingival caries). One key factor for success of FOE when applied in adult patients is the application of appropriate orthodontic forces and an appropriate length of retention period after the extrusion to stabilize the tissues (Fig 10).⁴⁰ Another parameter is the potential for periodontal disease. Van Venrooy and Yukna⁴¹ showed that when assessing orthodontic extrusion of teeth with advanced periodontal disease in beagle dogs, extruded teeth had shallower pocket depths, less

gingival inflammation, and no bleeding on probing than control teeth. These findings, however, do not eliminate the risk of peri-implantitis around definitive implants without adequate pretreatment.

Orthodontic site development with orthodontic mini-implants or FOE can significantly improve a potential implant site to increase functional and esthetic success.

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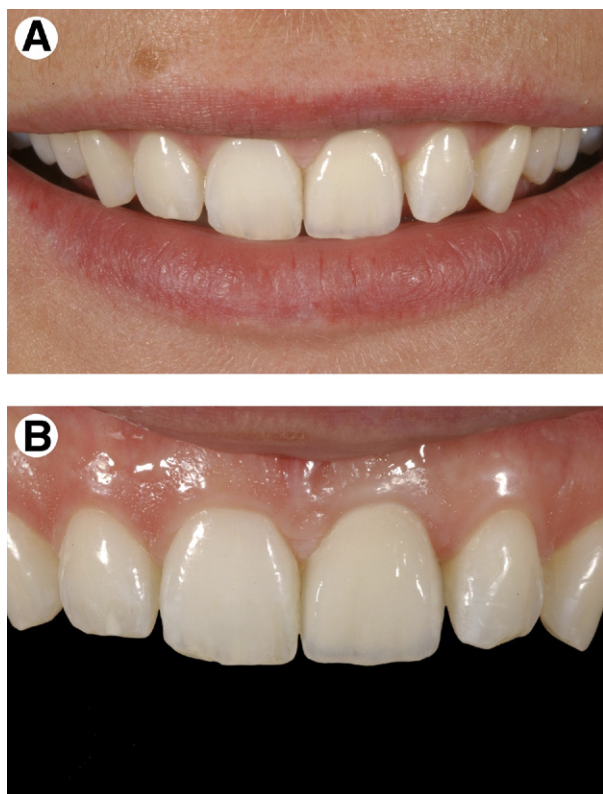


FIGURE 10. A and B, Extraoral and intraoral views of the definitive restoration and stable soft tissue at 36-month recall.

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