

CAD-CAM–fabricated mini-implant insertion guides for the delivery of a distalization appliance in a single appointment

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This article reports on the technical aspects of using a computer-aided design–computer-aided manufacturing (CAD-CAM) insertion guide for the placement of orthodontic mini-implants used for the purpose of providing anchorage support for maxillary molar distalization. A 10-year-old girl presented with a bilateral full-step Angle Class II molar relationship in the permanent dentition, with anterior arch-length insufficiency and blocked out maxillary canine teeth. The primary treatment objective was to provide an esthetic and functional occlusal outcome, and secondarily to avoid the removal of multiple premolar teeth. The patient was initially treated with an implant-supported distalization device, and the occlusion was subsequently detailed with preadjusted fixed orthodontic appliances. The CAD-CAM procedure facilitates the safe and precise insertion of mini-implants in the anterior palate, potentially broadening the scope of use of palatal mini-implants for less experienced clinicians. The illustrated protocol allows for the insertion of mini-implants and fitting of a prefabricated appliance in a single office appointment. (*Am J Orthod Dentofacial Orthop* 2019;156:148-56)

Class II malocclusions are frequently encountered in orthodontic practice. The distalization of the maxillary first permanent molar teeth may be considered as a treatment option for patients presenting with an Angle Class II malocclusion characterized with an increased overjet and anterior crowding. Molar distalization can be performed with the use of intraoral or extraoral appliances. Potential issues arising with patient compliance may be associated with the prolonged use of headgear.^{1,2} There has been an increasing trend in the clinical use of intraoral appliances that require minimal need for patient cooperation. However, most tooth-borne appliances for upper molar distalization produce an unwanted side-effect of anchorage loss resulting in maxillary incisor proclination, reported to be 24%-55% of observed tooth movement.³⁻⁵

To minimize anchorage loss, mini-implants have been incorporated into the design of maxillary distalization appliances.⁶⁻¹⁵ Mini-implants can be positioned intraorally with minimal degrees of surgical invasiveness, are readily integrated with concomitant biomechanical initiatives, and are relatively cost-effective.¹⁶⁻²⁰ The positioning of mini-implants into the anterior palate has been commonly used with maxillary molar distalization strategies.^{13,21-24} After successful distal molar tooth movement, the maxillary premolar teeth are observed to move distally owing to the recoil of the stretched interdental fibers. In contrast to treatment strategies involving the interradiation positioning of mini-implants, molars can be distalized and bicusps can drift distally without any interference because the palatally positioned mini-implants are not in the path of moving teeth.²³ Furthermore, good bone quality with thin attached mucosa implies minimal risk of tooth-root injuries and a very high success rate in the anterior palatal region.²⁵⁻²⁷ The failure rate of mini-implants in the anterior palate is reported to be 3.9%, which is significantly lower than in other regions.^{25,27} However, many practitioners are not immediately familiar with the placement of implants in the anterior palate and may be reluctant to use them. A mini-implant insertion guide can potentially assist clinicians to overcome their

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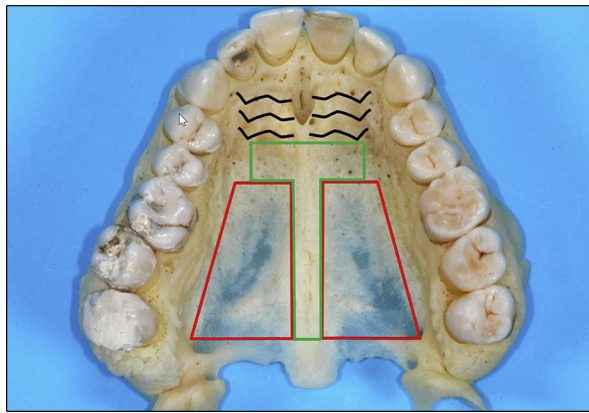


Fig 1. T-Zone (green): recommended insertion site posterior to the palatal rugae. The bone height is very low in posterior and lateral areas (red).

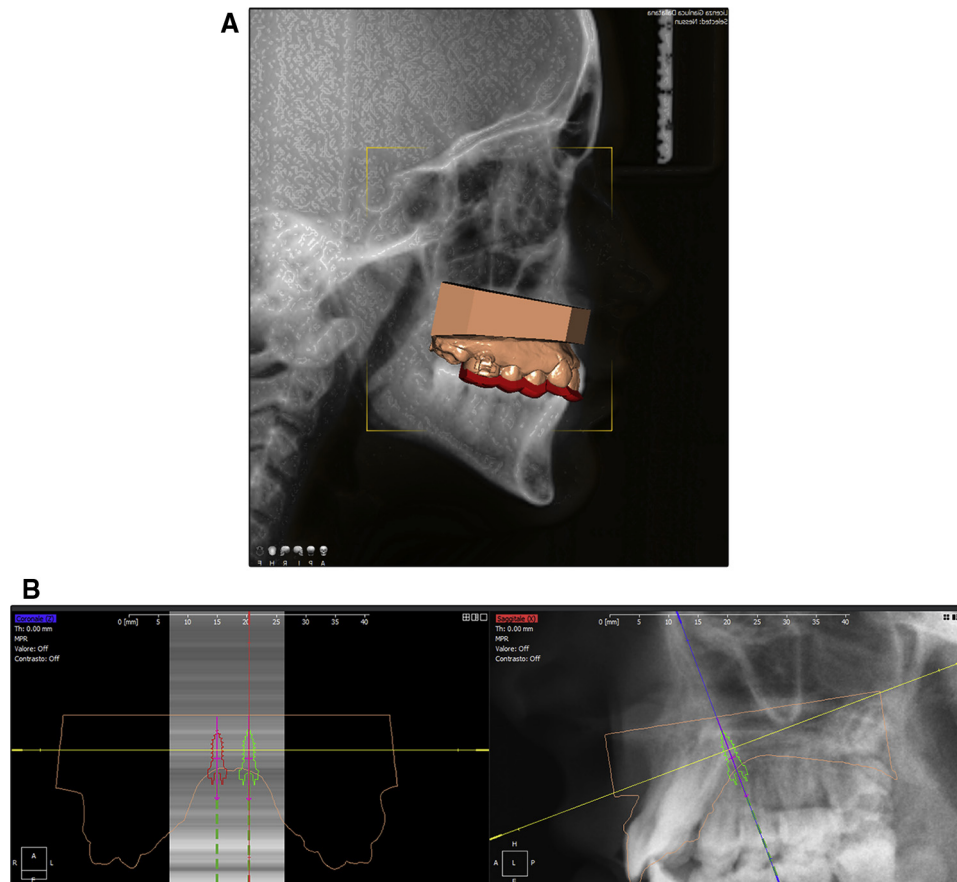


Fig 2. Virtual positioning of 2 mini-implants in the anterior palate: **A**, superimposition of the 3-dimensional model of the maxillary arch and the lateral cephalogram; **B**, transverse and sagittal virtual cut; **C**, virtual position of the 2 mini-implants from a horizontal view; and **D**, virtual position of the 2 mini-implants from an oblique view with the use of a semitransparent maxillary model.

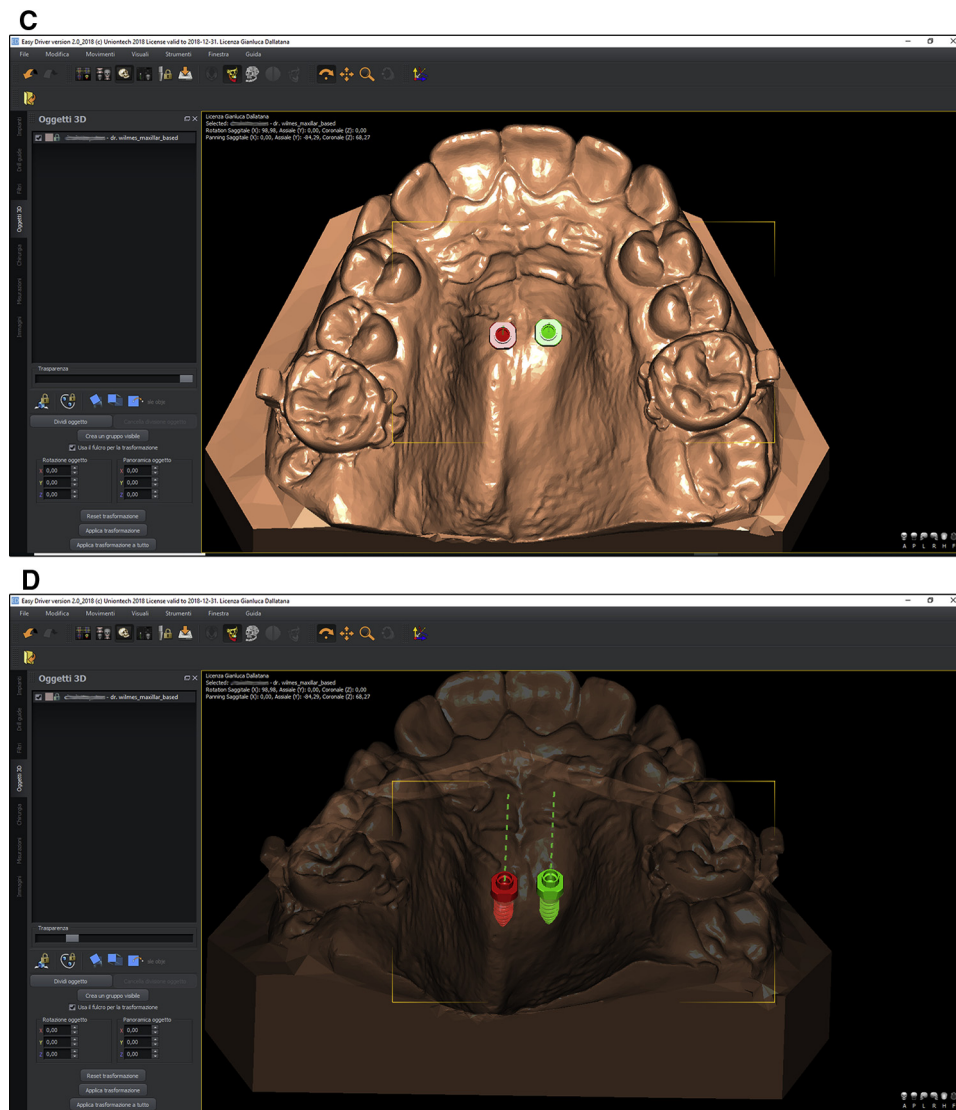


Fig 2. (continued).

uncertainty, providing assurance that the optimal position, length, and angulation for the mini-implant has been predetermined for an individual patient with the use of a computer-aided design-computer-aided manufacturing (CAD-CAM) platform.

CAD-CAM MANUFACTURING OF THE MINI-IMPLANT INSERTION GUIDE AND THE APPLIANCE

Following the adaptation of stainless-steel circumferential bands to the maxillary first permanent molar teeth, an STL (digital stereolithography) file of the maxilla is generated. This can be performed directly with the use of an intraoral scanner or indirectly by means of a laser scan of a plaster cast model. The

STL file is merged with either a cone-beam computed tomographic (CBCT) image or a lateral cephalometric radiograph (Fig 1; Easy Driver software; Uniontech Lab, Parma, Italy). The optimal sites for mini-implant placement with the anterior palate are identified (Fig 2), and the virtual planning software is used to confirm the precise anatomic positions, ideally located within the T-zone.²⁸ A rapid-prototyping process produces the insertion guide which locates the ideal position of the mini-implants within the anterior palate (Fig 3). The orthodontic appliance is fabricated in advance on a CAD-CAM 3-dimensional printed acrylic cast. Both the insertion guide and the acrylic cast for manufacturing of the appliance are made with the use of a Stratasys Orthodesk (Eden Prairie, Minn) using

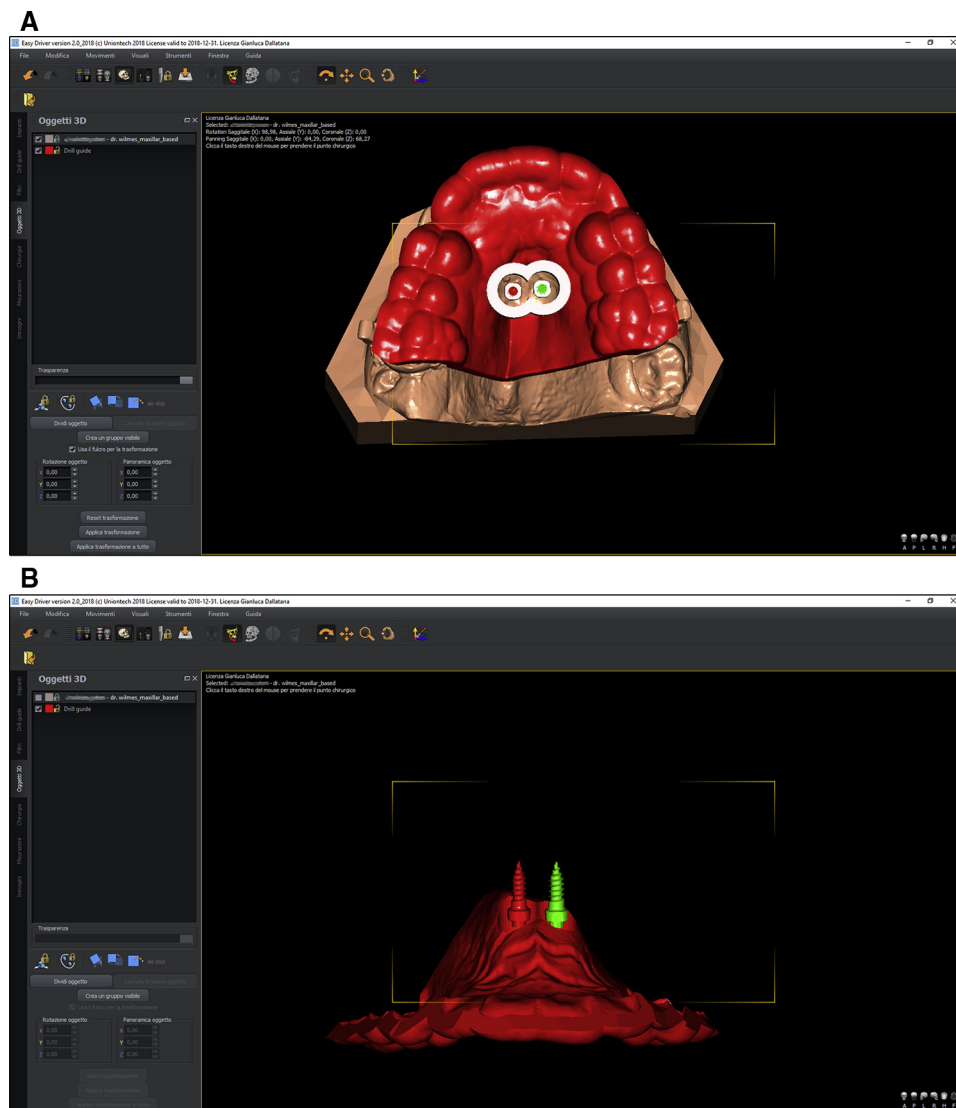


Fig 3. Design of the insertion guide according to the optimal mini-implant position (A, horizontal view; B, sagittal view).

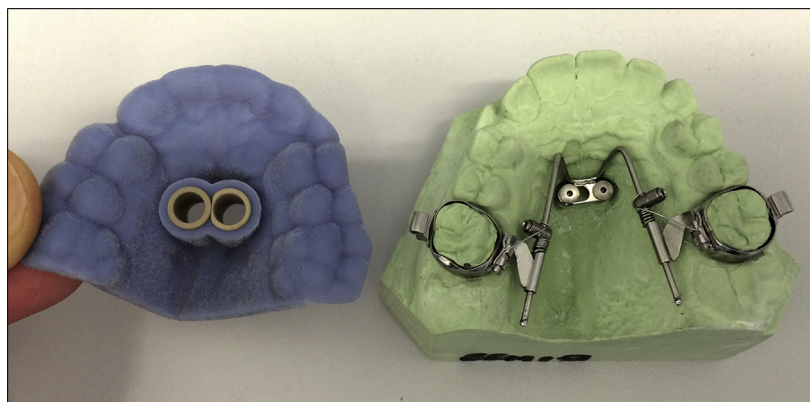


Fig 4. Insertion guide and Beneslider distalization appliance are sent together from the laboratory to the orthodontic office.

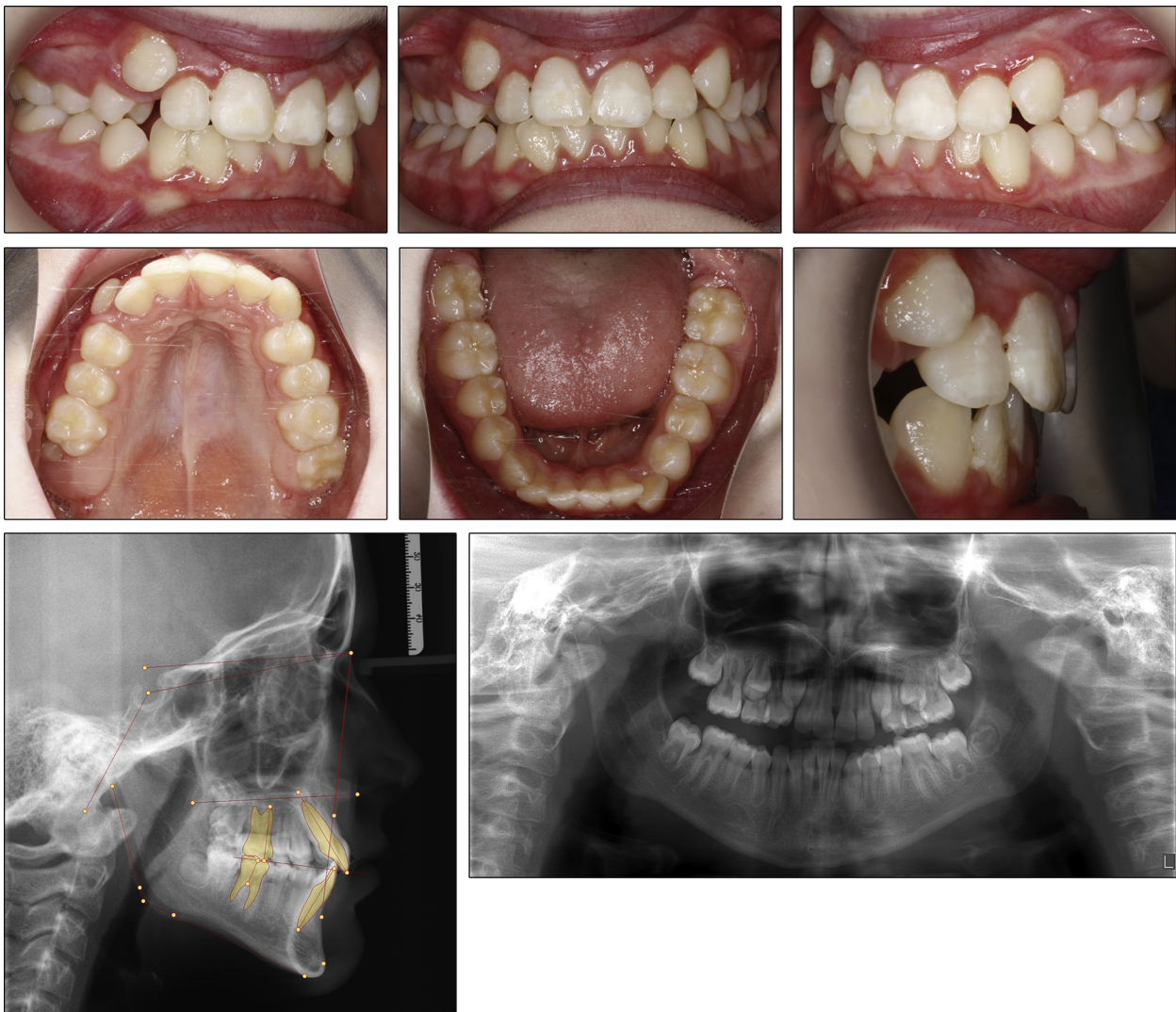


Fig 5. Ten-year-old patient with maxillary anterior crowding and Class II malocclusion: **A**, intraoral photographs; **B**, lateral cephalogram, and **C**, orthopantomogram.

Table. Cephalometric summary

Measure	Before treatment	After treatment
NSBa	129.3°	129.5°
NL-NSL	8.2°	9.9°
ML-NSL	36.2°	37.7°
L-NL	28.0°	27.9°
SNA	72.9°	73.4°
SNB	72.5°	72.8°
ANB	0.4°	0.6°
Wits	0.0 mm	0.9 mm
U1-NL	118.3°	112.6°
L1-ML	95.5°	96.1°
U1-L1	118.3°	123.4°
Overjet	4.7 mm	2.4 mm
Overbite	1.2 mm	1 mm

the Acrylic MED620 material (Stratasys). When circumferential bands are used, they are repositioned on the acrylic cast. As such, both the insertion guide and orthodontic appliance are prefabricated before the insertion of the mini-implants within the anterior palate (Fig 4). The described process allows for the insertion of both the mini-implants and the orthodontic appliance in a single office visit.

CLINICAL EXAMPLE

A 10-year-old fit and healthy girl presented seeking orthodontic treatment to address an Angle Class II Division 1 malocclusion with severe anterior arch crowding and



Fig 6. Insertion process with the use of the insertion guide. **A**, Mini-implant driver in the insertion guide. **B**, Test fitting of the insertion guide. **C**, Insertion of the left mini-implant with a contra-angle. Insertion site, depth, and angulation are predetermined by the virtual planning and transferred with the use of the CAD-CAM guide.



Fig 7. After **A**, mini-implant insertion and **B**, Beneslider fixation on top of the mini-implants.

blocked out maxillary and mandibular canine teeth (Fig 5; Table). At the initial appointment, circumferential stainless steel orthodontic bands were adapted on the maxillary first permanent molar teeth. A polyvinylsiloxane impression of the maxillary arch was recorded and remitted to the laboratory, along with the lateral cephalometric radiograph. A laser scan of the subsequent plaster model was recorded, and the STL file was superimposed with the lateral cephalogram with the use of a 3-point matching method (Fig 1; Easy Driver software). The ideal length (9 mm) and anatomic positions for the mini-implants were simulated by the technician and approved by the doctor. Then the insertion guide and the cast for the adaptation of the orthodontics appliance were manufactured by means of the rapid-prototyping method (Fig 3). Both the insertion guide and the implant-supported molar distalization appliance (Fig 4; Beneslider^{24,29}) were then remitted to the orthodontic office.

The clinical procedure commenced with the administration of local anesthesia in the anterior palate. Two paramedian mini-implants (2 × 9 mm, Benefit System; PSM North America, Indio, CA) were inserted without predrilling through the insertion guide (Fig 6). A contra-angle screwdriver was used for the placement of the mini-implants (Fig 6, C). After the insertion of the palatal mini-implants (Fig 7, A), the stainless-steel

circumferential bands were cemented to the maxillary first permanent molar teeth and the distalization appliance was fitted to the palatal mini-implants (Fig 7, B). A 240-g NiTi spring was applied to produce the distalization force. After 10 months of distalization, the maxillary first permanent molar teeth were moved into an Angle Class I occlusion (Fig 8) and preadjusted orthodontic brackets were bonded for the second phase of the treatment. After the initial orthodontic alignment and leveling, the residual maxillary interdental spacing was closed and treatment completed within a 12-month period (Fig 9). The total treatment time was 22 months, with 10 months required for molar distalization and 12 months of fixed orthodontic appliance wear (Fig 10).

RESULTS

The treatment result showed a stable Class I occlusion (Fig 10). The cephalometric superimposition displayed the full maxillary arch distalization (Fig 11; Table). The maxilla-mandibular plane (ML-NL) angle was essentially unchanged (from 28.0° to 27.9°), indicating that there was no change in the vertical relationship between the maxilla and the mandible during upper molar distalization. The maxillary incisors were uprighted from 118.3° to 112.6°, whereas the mandibular incisor inclination

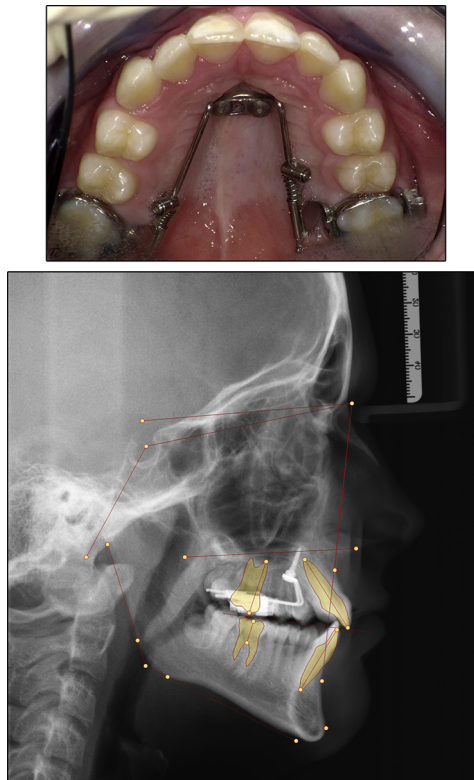


Fig 8. A, Intraoral photograph and B, cephalogram after 10 months of distalization.

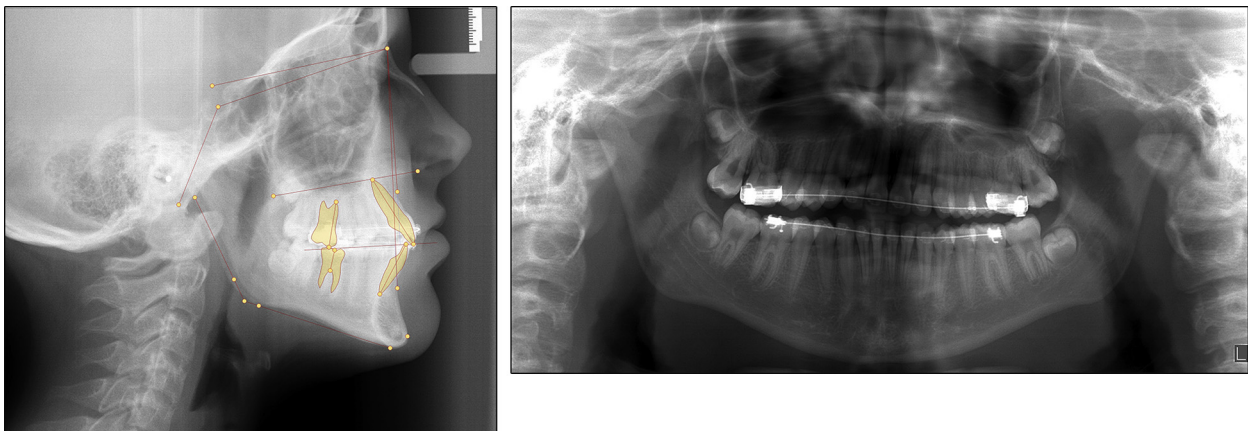


Fig 9. A, Cephalogram and B, orthopantomogram at the end of orthodontic treatment.

was marginally increased (L1-ML: pretreatment 95.5°, posttreatment 96.1°). The overjet was significantly improved from 4.7 mm to 2.4 mm.

DISCUSSION

Distalization of the maxillary first molars can be performed with the use of intraoral or extraoral appliances.

Because of potential issues with patient compliance using the headgear, there has been an increasing trend in the clinical use of purely intraoral appliances. However, all intra-arch tooth-borne appliances for upper molar distalization produce an unwanted side effect of anchorage loss resulting in maxillary incisor proclination. Interarch anchorage modalities for upper molar distalization include Class II elastics, Jasper Jumper,



Fig 10. Intraoral photographs after finishing of the treatment.

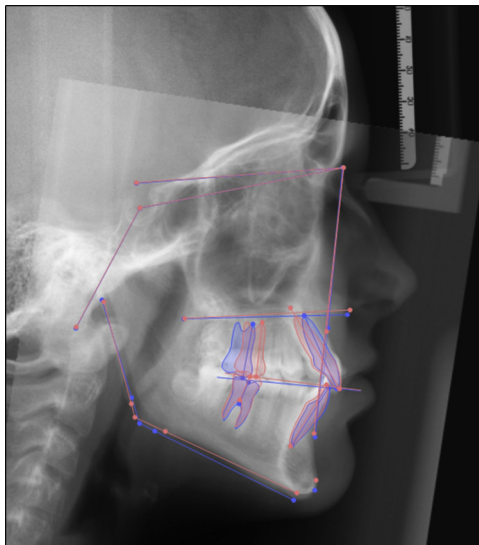


Fig 11. Superimposition of the tracings of the cephalograms from before and after treatment.

Herbst appliance, and modifications thereof.³⁰ However, these modalities are regularly associated with excessive proclination of the mandibular incisors and anterior displacement of the dentition.³¹ To mitigate the potential loss of anchorage, various iterations of implant-supported distalization appliances have been published in recent times. The retromolar region seems to be unsuitable for mini-implant insertion owing to the unfavorable anatomic conditions (poor bone quality and thick soft tissue).²⁶ The alveolar process also has been shown to be inappropriate in cases of a desired molar

distalization because the mini-implants are in the path of the moving teeth, resulting in a failure rate that is much higher compared with the anterior palate.^{25,27}

As such, the anterior palate seems to be the preferred insertion site for mini-implants where the treatment objective is distal movement of a maxillary first permanent molar without associated anchorage loss and maxillary incisor displacement. The advantage of skeletal anchorage is that maxillary and mandibular incisor proclination can be avoided. In the clinical example cited, the maxillary incisors were uprighted, with minor and insignificant changes to the lower incisor angulation only.

Traditional maxillary molar distalization appliances have demonstrated a tendency to increase the vertical dimension, with a risk of bite opening.^{32,33} With the use of skeletal anchorage, however, unwanted molar extrusion can be avoided during distalization. Moreover, the angulation of the guide wires can be modified to provide a force vector to achieve concomitant molar intrusion during distalization.³⁴

A CAD-CAM insertion guide system facilitates safe and precise insertion of mini-implants in the anterior palate, availing the opportunity for use of palatal implants to the less experienced clinician. Potential applications for the computer-guided placement of mini-implants in the anterior hard palate would be for the patient presenting with a cleft palate, where bone availability in the anterior palate is unpredictable. In addition, this approach may be prudent for those patients presenting with palatally impacted maxillary canine teeth. The system allows for the insertion of mini-implants and installation of the appliance in a

single office visit. There is an associated cost for the manufacturing of the insertion guide.

CONCLUSION

The presented CAD-CAM procedure facilitates the safe and precise insertion of mini-implants in the anterior palate. The protocol may prove to be efficient and useful for clinicians who want to establish mini-implant-borne anchorage as a novel procedure in their office as well as for experienced doctors. The insertion of the mini-implants and fitting of a prefabricated appliance can now be performed in a single appointment.

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