CAD/CAM Metallic Printing of a Skeletally Anchored Upper Molar Distalizer

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N ew digital technologies, many involving three-dimensional printing, are regularly being incorporated into the practice of orthodontics. Highly accurate intraoral scanners now enable the creation of digital scans depicting planned implant locations.¹ Emerging enhancements include 3D metal printing of custom-made appliances that have traditionally been fabricated in the laboratory. Laser melting is an innovative method of 3D metal printing that can be used to produce rapid palatal expanders.²

Molar distalization is commonly used to treat a Class II molar relationship in an adolescent or adult patient with mild maxillary skeletal or dentoalveolar protrusion, especially when upper premolar extractions are contraindicated and mesialization of the lower molars is not possible because of the mandibular tooth-size/arch-length relationship. Traditional extraoral traction has largely been replaced by such intraoral devices as Wilson* distalizing arches, removable spring appliances, and intermaxillary elastics with sliding jigs,^{3,4} thus reducing the need for patient compliance.

Hilgers developed two hybrid appliances, the Pendulum** and Pendex,** that rely on the curvature of the underlying anterior hard palate and the upper premolars to provide anchorage support and



Fig. 1 Finished molar distalizer with semicircular rings for bonding to upper first molars and Slim Linet expansion screws mounted parallel to line of occlusion.



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resistance to anterior displacement of the appliance. This design has been associated with anchorage loss, however, resulting in anterior movement of the upper premolars.⁵⁻⁷ To minimize such anchorage loss, mini-implants—usually placed in the anterior palate—have been incorporated into the design of maxillary distalization appliances.⁸⁻²¹ Mini-implants can be inserted with minimal invasiveness, are readily integrated with concomitant treatments, and are relatively cost-effective.²²⁻²⁶ Wilmes and colleagues have introduced a method for distalizing the molars without adverse effects on the anterior dentition, coupling two implants in the anterior hard palate with a prefabricated framework that can be adapted for the individual patient.²⁷⁻²⁹

This article illustrates the application of a novel method for computer-aided design and manufacturing (CAD/CAM) and metal printing of a maxillary molar distalizer for use with mini-implant anchorage.

Procedure

After placement of two mini-implants in the anterior palate, the maxillary arch, including the mini-implants^{***} without transmission caps (scan bodies), is digitally scanned. The stereolithographic (STL) file is sent to a laboratory where the custom appliance is digitally designed. Our lab maintains previously scanned STL files of the mini-implants and expansion-screw mechanism on file.

The appliance is designed with .7mm-thick

semicircular rings (similar to the C-clasps used in removable prostheses), which in this example will be attached to the upper first permanent molars (Fig. 1). Each ring is positioned .05mm from the tooth surface to allow for the application of bonding adhesive. Small projection tips are incorporated on the palatal surfaces to aid in removal of the appliance, since the highly polished surfaces are too slippery for a debonding plier. The appliance is attached to the implants using round, flat rings of the same height and diameter as the miniscrew neck. The ring connections are designed from digitally matched implants (digital implant analogues, comparable to the physical implant analogues used by technicians for casts). Slim Line† expansion-screw mechanisms are digitally positioned to provide the largest possible area for welding to the wires.

The digital design is sent to a laser-melting machine‡ in which the main portion of the appliance is 3D-printed with Remanium Star†† metal alloy, commonly used in the fabrication of removable partial dental prostheses (Fig. 2). In the first phase of the metal printing process, a 25μ m layer of metal alloy powder is laid down by the coater

^{*}DynaFlex, St. Ann, MO; www.dynaflex.com.

^{**}Ormco Corporation, Orange, CA; www.ormco.com.

^{***}Benefit System, PSM Medical Solutions, Gunningen, Germany; www.psm.ms. Distributed in the U.S. by PSM North America, Indio, CA; www.psm-na.us.

[†]Forestadent GmbH, Pforzheim, Germany; www.forestadent.com. ‡Concept Laser, Hofmann Innovation Group, Lichtenfels, Germany; www.hofmann-impulsgeber.de/en.

^{††}Dentaurum, Ispringen, Germany; www.dentaurum.de/eng.



(the thickness of the layer depends on the grain size of the metal alloy powder). The powder is laser-melted and layered until the entire structure is completed. We use a 110W laser-melting machine with the smallest melting volume, $9 \text{ cm} \times 9 \text{ cm} \times 8 \text{ cm}$, which takes 11 hours to fabricate four

appliances, each with a build volume of $6 \text{ cm} \times 3 \text{ cm} \times 2 \text{ cm}$. The fabrication time could be reduced by using a larger machine with a larger build volume, two lasers, or a higher wattage.

We use CAMbridge^{‡‡} software to control the positions of the appliances in the build-up volume. Support sticks are required to keep an appliance from distorting under its own weight due to heat accumulation during the build process. The sticks should be designed as small crosses or as

[‡]Concept Laser, Hofmann Innovation Group, Lichtenfels, Germany; www.hofmann-impulsgeber.de/en.

^{‡‡}Registered trademark of 3Shape, Copenhagen, Denmark; www. 3shape.com.





Fig. 3 (cont.) 13-year-old male patient with rotated upper canines; diminutive upper lateral incisors; and Class II, division 1 malocclusion before treatment.

thin solid or hollow columns connected to the appliance at single points, so they can easily be removed after production. The bonding sites should not be covered with support sticks, because that would affect the precision of those areas.

After the unmelted powder is removed, the second phase of the metal printing process involves sintering and the elimination of accumulated stresses from melted spots (homogenization). The build platform is heated to 1,150°C and kept at this temperature for one hour. The entire sintering process, including heating up and cooling down, takes about five hours. The appliance and support sticks are then removed from the build platform, the support sticks are separated from the appliance, and the entire appliance is polished. Finally, the expansion-screw mechanisms are laser-welded in the digitally planned positions.

The principal advantage of laser melting over sintering alone is that there is no need to calculate a shrinkage percentage. In sintering, the green body must be removed from the supporting material within the structure. With laser melting, the basic structure is already the correct shape and size before sintering.

Case Report

A 13-year-old male in the permanent dentition presented with a Class II, division 1 malocclusion characterized by a half-unit molar relationship (Fig. 3). The upper posterior teeth had drifted mesially, and the upper canines were mesially rotated. The upper left and right lateral incisors were both diminutive, resulting in a Bolton toothsize discrepancy.

Treatment objectives were to level and align both arches, achieve a normal and stable overbite and overjet, and establish a bilateral Class I molar relationship by distalizing the upper first permanent molars. Restorative enhancement of the diminutive upper lateral incisors was also planned.

The first treatment alternative involved the prolonged application of extraoral traction with cervical headgear to distalize the upper first permanent molars, which would have required strict compliance with headgear wear. We also considered a Pendulum appliance for molar distalization, but that method would likely have resulted in loss of anchorage. The second option was to remove the upper first premolars, followed by full fixed appliances with moderate anchorage (group B) for closure of the extraction spaces and establishment of a therapeutic Class II molar relationship. The patient and family agreed to a treatment plan to distalize the upper first molars with skeletal anchorage, then maintain their positions during subsequent upper canine retraction with maximum anchorage (group A). This approach would

^{‡‡}Registered trademark of 3Shape, Copenhagen, Denmark; www. 3shape.com.

[§]Trademark of 3Shape, Copenhagen, Denmark; www.3shape.com. §§Trademark of 3M, St. Paul, MN; www.3M.com.



Fig. 4 Distalizing appliance designed from digital scan of upper arch with implants in place.

provide the necessary arch length for restorative enhancement of the diminutive upper lateral incisors with composite build-ups.

Two Benefit System mini-implants with interchangeable abutments ($2mm \times 9mm$ and $2mm \times 11mm$) were inserted in the midline of the anterior hard palate. The maxillary arch and miniimplants were recorded with a TRIOS‡‡ intraoral scanner, and the resulting STL file was sent to the dental laboratory for use with Appliance Designer§ software (Fig. 4). The appliance was constructed as described above, with two 12mm Slim Line expansion screws (.8mm per complete turn) positioned parallel to the line of occlusion of the maxillary arch.

About 10 days after the scanning appointment, the distalizer was securely attached to the two mini-implants with fixation screws and bonded to the palatal surfaces of the upper first permanent molars with Scotchbond Universal§§ and Transbond XT.§§ The patient was instructed to activate the appliance with one turn of each expansion screw per week, which would produce distal tooth movement of approximately .2mm per quarter-turn (Fig. 5). The patient demonstrated poor compliance with regular activation of the appliance, however, and it took seven months to move the upper first molars into a Class I relationship (Fig. 6).

Preadjusted orthodontic appliances were then bonded in both arches, and .014" nickel titanium round wires were placed from second molar to second molar. Because the semicircular bands were limited to the palatal surfaces of the upper first molars, we were able to apply multibracketed appliances as needed. To protect the lower anterior brackets, small bite turbos were bonded to the buccal cusps of the lower first molars. The implant-supported distalizer remained in place to



Fig. 5 A. After three months of treatment. B. After five months of treatment.

provide anchorage for retraction of the upper canines, which was started with light power chains^{††} on an .016" nickel titanium wire. Retraction was continued on an .016" \times .022" nickel titanium archwire, followed by an .019" \times .025" TMA§§§ archwire with closed-coil springs distal to the upper lateral incisors for space maintenance.

After nine months of fixed-appliance treatment, the arch length required for restorative enhancement of the diminutive lateral incisors had been obtained. The brackets were removed from the upper lateral incisors, the composite restorations were completed, and the brackets were reapplied for six months of finishing on $.019" \times .025"$ TMA archwires (Fig. 7). Upper and lower scans were taken, and upper and lower 3-3 lingual wires were bonded for retention (Fig. 8).

††Dentaurum, Ispringen, Germany; www.dentaurum.de/eng. §§§Trademark of Ormco Corporation, Orange, CA; www.ormco. com.



Fig. 6 After seven months of treatment.



Fig. 7 Patient after 23 months of treatment.



Discussion

CAD/CAM procedures now make it possible to fabricate orthodontic appliances using 3D metal printing. As this case demonstrates, the combination of digital intraoral scanning and direct metal printing of the framework for a molar distalizer can be used to successfully resolve a Class II molar relationship. The distalizing appliance is virtually invisible, and fixed orthodontic appliances are needed for only a short period to finish and detail the occlusion.

A learning curve should be expected with the adoption of a digital workflow that must be coordinated with a dental laboratory. A 3D-printed pretreatment study model may be helpful in verifying the fit and accuracy of the appliance, although we have not found that necessary in our experience with a number of cases.

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