Three-dimensional metal printed orthodontic laboratory appliances

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The orthodontic world is facing a new paradigm shift: digitalization. Alginate impressions and plaster models have largely been replaced by intraoral scans and three-dimensional (3D) resin printing. Today, 3D metal printing of metallic orthodontic appliances is at the forefront of the digitalization movement. The purpose of this article is to provide a clinical overview of this new technology. (Semin Orthod 2021; 27:189–193) ***© 2021 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/)***

Introduction

Despite the breakthroughs of intraoral scanning and 3D resin printing, metallic orthodontic appliances such as expanders were still fabricated indirectly off base models using the conventional laboratory technique.[1-7] Recently, Graf et al.[8] and Graf et al.[9] introduced the first printed orthodontic expanders using a 3D metal printer and an almost completely digital process.

Following the intraoral digital scan, the framework was designed using CAD/CAM software, and then the stereolithographic (.STL) file was exported to the 3D metal printing machine for manufacturing. The printer built the metal framework layer by layer using a laser melting (sintering) process. The print medium was a powdered cobalt-chromium metal alloy.

The only non-digitized steps were the addition of the jackscrew, the electro-polishing, and the surface treatment of the saddle bands. Since the jackscrew currently cannot be printed, it must be laser-welded onto the printed framework afterward (Fig. 1). This often can be done without a base model. Lastly, the inner surfaces of the saddle bands were sandblasted to enhance their bond strength.

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1073-8746/12/1801-$30.00/0

https://doi.org/10.1053/j.sodo.2021.09.005

Saddle bands (islands, pads)

To obtain a digitalized process, conventional molars bands are replaced by printed saddle bands, otherwise referred to as islands or pads. These "bands" are essentially bondable pads that cover the occlusal, buccal, or lingual surfaces of the anchoring teeth, but do not extend interproximally. They are designed as large as possible and with close adaptation to the tooth's surface (0.05 mm gap).

The saddle bands are bonded using a standard metal bonding technique. For the primer, the authors advocate Scotchbond universal adhesive (3M Unitek) or Assure (Reliance). The primer should be applied to both the etched enamel and the sandblasted saddle bands. For the luting agent, the authors advocate Transbond XT (3M Unitek) for small bonding sites or Ultra Band-Lok (Reliance) for larger bonding sites.

The appliance is removed with a posterior bracket debanding plier or a band removing plier. To facilitate debanding, small ledges can be digitally designed and added on the buccal or lingual surfaces of the saddle bands, which is another advantage of metal printing.

Advantages of metal printing

The greatest advantage of direct metal printing is the customization. Other notable advantages include: improved communication with the laboratory technician;[10,11] reduced laboratory waste, as resin base models are unrecyclable; enhanced accuracy; better standardization; improved patient comfort during seating; and reduced orthodontic appointments by eliminating the need for separators.

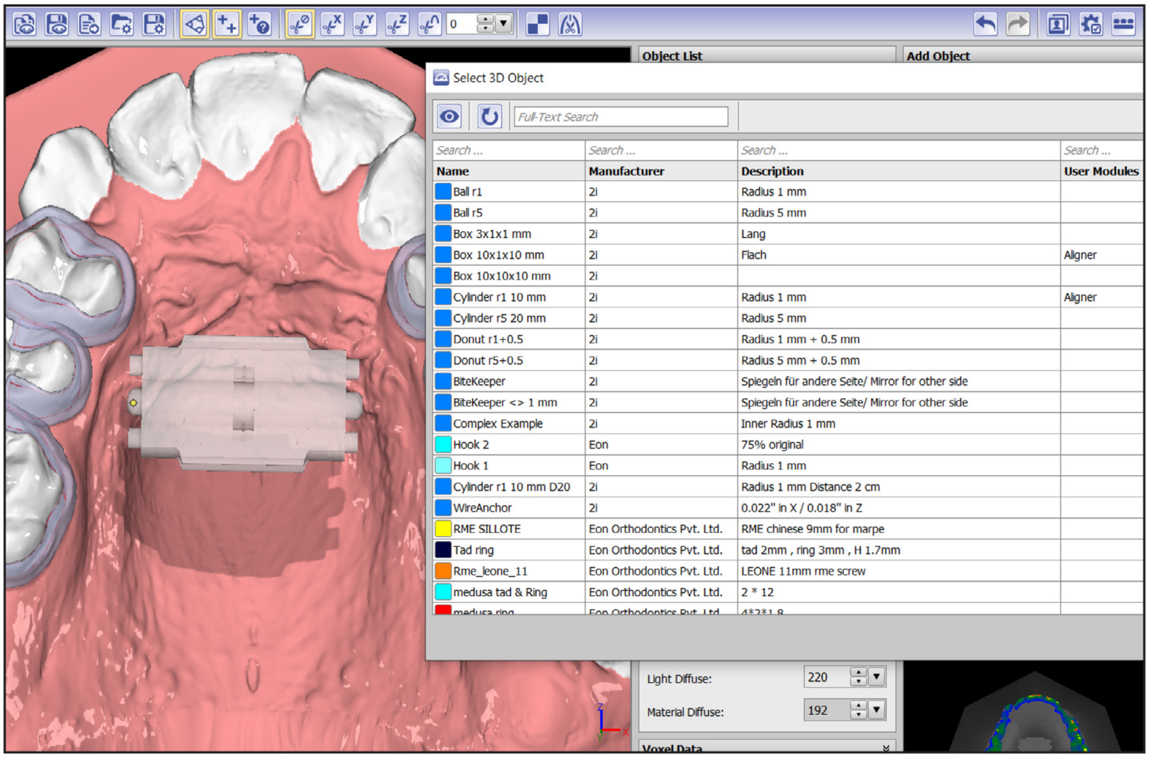

Fig. 1. Virtual placement of an expansion jackscrew.

As with most new technology, the greatest disadvantage is the equipment expense. Currently, the combined cost of a small-scale 3D metal printing machine and laser welder are approximately $150,000-$300,000. Clinically speaking, another disadvantage is the reliance on bonding. This may be more problematic for lower appliances, such as lingual arches, where isolation can be challenging.

Due to the high cost of equipment, nearly all orthodontists outsource their 3D metal printing to commercial laboratories. Dentaldigital Lab in Switzerland has been at the forefront of this technology. Most major US orthodontic laboratories (i.e. Motor City Lab Works, AOA, NEO, ODL, and Dynaflex) offer 3D metal printing with full capability. However, a word of caution is needed: some labs that claim to offer this service only print the saddle bands.

3D metal printed appliances

The following cases demonstrate the versatility of 3D metal printing. These examples were printed with the Mlab selective laser melting device (Concept Laser) using Remanium Star (Dentaurum) metal print medium.

Hyrax-hayrake-blue-grass combination

This appliance is a combination of three separate appliances: a hyrax, a split hayrake for habit-breaking, and a blue-grass for tongue-training (Fig. 2A-C). The movable metal bead for the blue-grass component was printed with the framework and connected with a sprue (a tiny rod that connects printed parts together). The sprue was removed during the electro-polishing which released the bead.

Hyrax - Halterman

This appliance is a combination of a hyrax and a Halterman to perform simultaneous maxillary expansion and distalization of the ectopic molars (Figs. 3A-C).[12] Buccal cantilever arms extended distally from the saddle bands on the deciduous second molars. Buttons were bonded on the occlusal surfaces of the first molars and elastic chains were connected from the buttons to the arms.

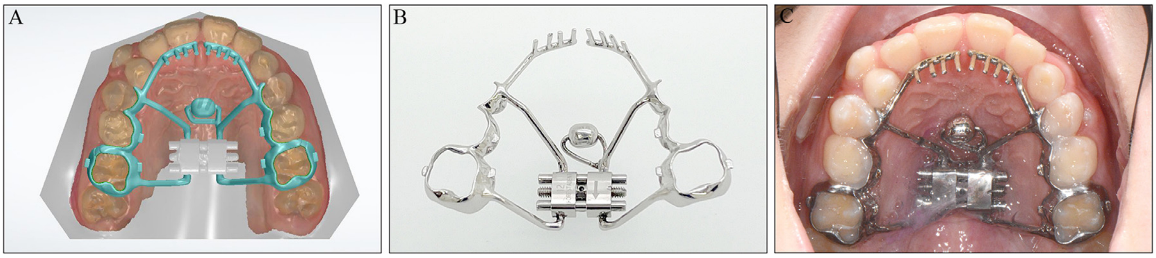

Fig. 2A-C. Hyrax-hayrake-blue-grass combination. A. CAD-CAM design. B. Printed appliance with jackscrew welded afterwards. C. Appliance inserted with movable blue-grass bead. (Courtesy of Simon Graf)

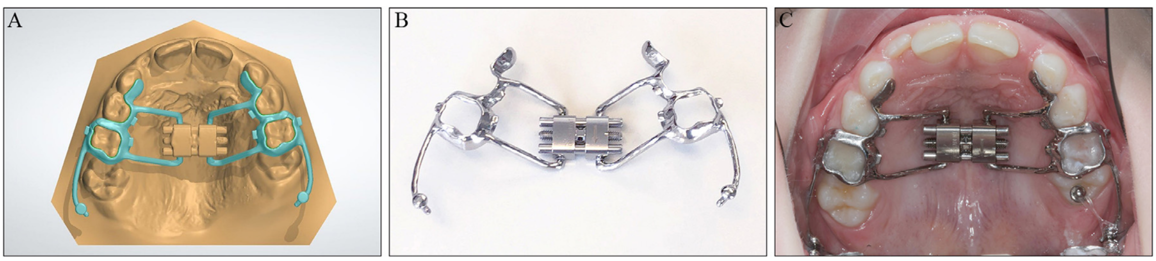

Fig. 3A-C. Hyrax-Halterman. A. CAD-CAM design. Saddle bands on the deciduous second molars are ideal in the presence of ectopic first molars. B. Printed appliance. C. After activation. (Courtesy of Simon Graf)

Herbst with brackets

This appliance has buccal brackets, rather than conventional tubes, added to the Herbst framework (Fig. 4A-F). The bracket slot better controls the torque and the wings aid in placement of an elastic chain or a steel-ligature. If a precise slot-wire engagement is required, for example, in the lower arch where incisor torque control is crucial, then the bracket slot should be printed slightly undersized.

Lingual arch with clasps

This appliance has clasps distal to the lateral incisors to prevent drift into the canine space (Fig. 5A-C). A fully-printed appliance will be rigid.

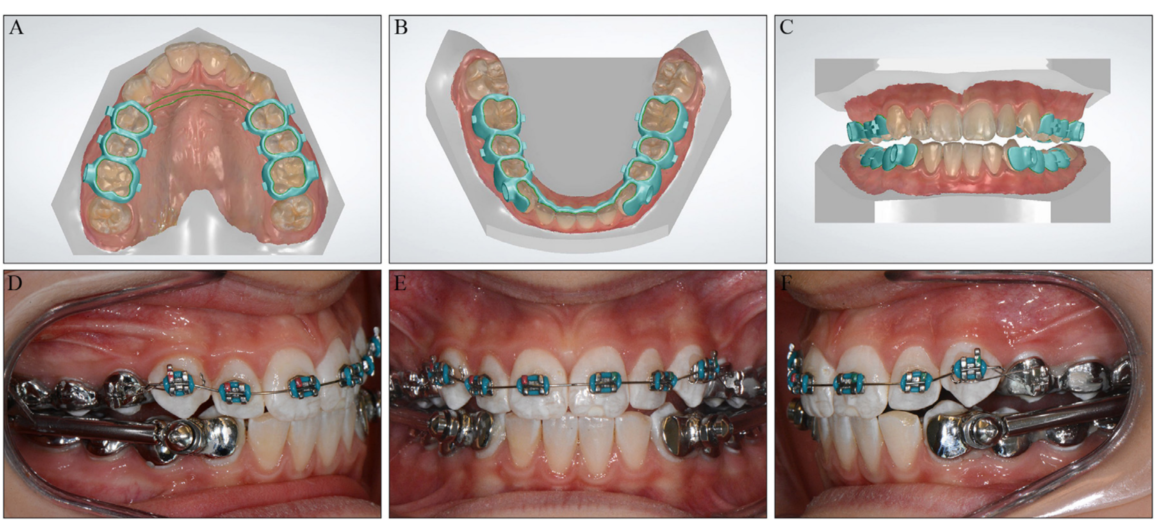

Fig. 4A-F. Herbst with brackets bonded with Assure primer and Ultra Band-Lok. A. Maxillary CAD-CAM. B. Mandibular CAD-CAM. C. Frontal CAD-CAM. D. Right-side view with appliance inserted. E. Frontal view. F. Left-side view. (Courtesy of Simon Graf)

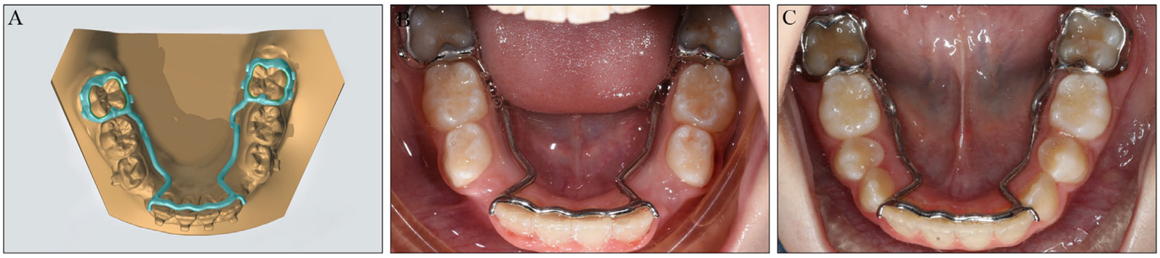

Fig. 5A-C. Lingual arch with clasps. A. CAM-CAM design. The left activation loop was unnecessary as the printed metal framework cannot be adjusted. B. Appliance inserted. C. Lower canines erupted. (Courtesy of Nour Tarraf)

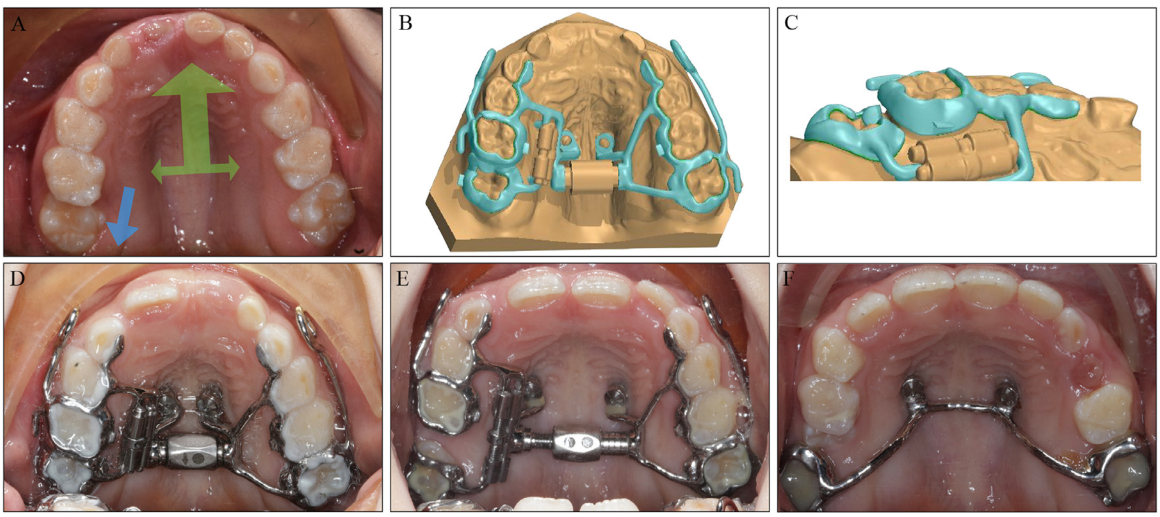

Fig. 6A-F. Miniscrew-supported Hyrax-distalizer with facemask hooks. A. Pre-treatment occlusal-view. B. CAM-CAD design. C. Close-up view of the saddle band on the ectopic molar. D. Appliance inserted. E. Following expansion and distalization. F. Hyrax removed and a printed TPA inserted. (Courtesy of Nour Tarraf)

Therefore, if the orthodontist prefers nonrigid adjustment loops, then a conventional wire will need to be welded onto the printed saddle bands.

Miniscrew-supported Hyrax-distalizer with facemask hooks

This complex appliance epitomizes the advantages of 3D metal printing. The objectives were to design a miniscrew-supported hyrax with facemask hooks that also distalized an ectopic molar (Fig. 6A-F).[13] A saddle band was ideal for bonding the partially erupted molar. Both jackscrews, which were different in type and size, were precisely measured virtually and then welded onto the printed metal framework.

Conclusion

The 3D metal printing process uses a laser melting device and a powdered cobalt-chromium metal alloy. Its greatest advantage in the manufacturing of metallic orthodontic laboratory appliances is the flexibility of the digital design; however, the dependence on bonding may be problematic in the lower arch. In the future, as the metal printing process becomes further digitalized, the base model will become a laboratory relic.

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