Full 3-dimensional digital workflow for multicomponent dental appliances

A proof of concept

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ABSTRACT

Background. The authors used a 3-dimensional (3D) printer and a bending robot to produce a multicomponent dental appliance to assess whether 3D digital models of the dentition are applicable for a full digital workflow.

Methods. The authors scanned a volunteer's dentition with an intraoral scanner (Lava Chairside Oral Scanner C.O.S., 3M). A digital impression was used to design 2 multicomponent orthodontic appliances. Biocompatible acrylic baseplates were produced with the aid of a 3D printer. The metal springs and clasps were produced by a bending robot. The fit of the 2 appliances was assessed by 2 experienced orthodontists.

Results. The authors assessed both orthodontic appliances with the volunteer's dentition and found the fit to be excellent.

Conclusions. Clinicians can fully produce a multicomponent dental appliance consisting of both an acrylic baseplate and other parts, such as clasps, springs, or screws, using a digital workflow process without the need for a physical model of the patient's dentition.

Practical Implications. Plaster models can be superfluous for orthodontic treatment as digital models can be used in all phases of a full digital workflow in orthodontics. The arduous task of making a multicomponent dental appliance that involves bending wires can possibly be replaced by a computer, design software, a 3D printer, and a bending robot.

Key Words. Orthodontic appliances; technology; robotics.

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For creating the treatment plan and for producing appliances, a plaster model of the dentition has traditionally been the criterion standard in clinical dentistry. A plaster model is, however, associated with difficulties and problems related to storage and retrieval, damage of the model, reproduction, and communication.[1] Therefore, efforts have been made over the years to replace these models with digital equivalents.

Even though many steps in the production of a removable appliance are already digitized,[2] a physical model of the dentition was still needed for the production of the end product as there were, until recently, no printable resins that, once set, could remain in contact with the oral mucosa for a prolonged time. Furthermore, most removable appliances consist of both metal parts and plastic parts that need to fit together seamlessly to ensure a proper fit in the mouth that avoids interfering with the occlusion or articulation. These complex interactions of removable appliances are not only challenges in traditional orthodontics and prosthodontics, they have long interfered with adaptation to full digital workflow.

Innovative technology is available to address the impression and casting challenges of traditional techniques. A full digital workflow and robotics makes treatment planning, design, and virtual model making that produces an orthodontic appliance ready for patient

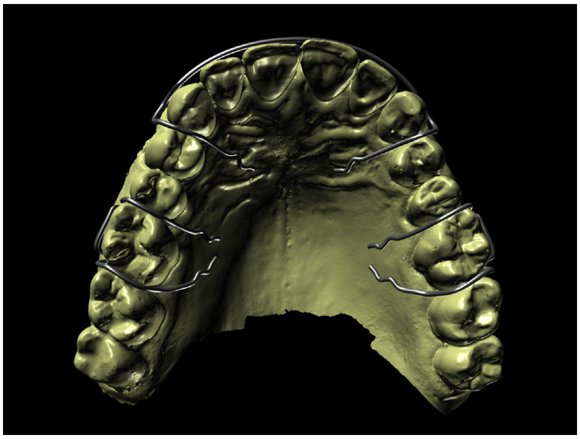

Figure 1. The digital design of the wire parts of the orthodontic appliance.

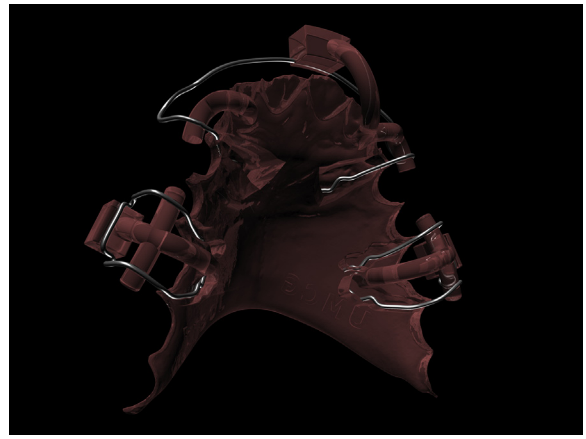

Figure 2. The design for the 3-dimensional printed part with support arms to position the wire parts correctly.

try-in within reach. The aim of this proof-of-concept study was to assess whether a digital model can be used in a full digital workflow to produce a multicomponent orthodontic appliance.

METHODS

Participant. A staff member from the Department of Orthodontics, University Medical Center Groningen, The Netherlands, volunteered to participate in this proof-of-concept study. Informed consent was obtained before the study. The Medical Ethics Review Board of the University Medical Center Groningen ascertained that the study was not clinical research with human test participants as described in the Medical Research Involving Human Subjects Act[3] and that formal ethics committee approval was not necessary (METc 2014/147).

The impression. We lightly dusted the dentition of the participant with titanium dioxide powder to enable the scanner to register the 3-dimensional (3D) images. We scanned the dentition with an intraoral scanner, sometimes referred to as a *digitizer* (Lava Chairside Oral Scanner C.O.S. (3M), according to the manufacturer's instructions and automatically uploaded to digital cloud storage. We downloaded the digital file of the scanned dentition as a .PLY file from the central server of the manufacturer.

Production of the multicomponent dental appliance. We used the digital model obtained from intraoral scanning to produce a multicomponent removable appliance. We constructed 2 appliance designs for the maxillary model:

- a removable appliance with an expansion screw, labial bows, protrusion springs, and Adams clasps;
- a retainer plate consisting of a labial bow and Adams clasps.

To construct the maxillary model, we imported the 3D file of the model in a modelling and animation software program (3ds Max, Autodesk) and designed the necessary springs, clasps, and acrylic baseplate (Figure 1). We modeled a fitting space for the expansion screw and for the extensions of each of the springs and clasps. We modeled small support arms and attached them to the baseplate. We fitted the supports with grooves, thus ensuring that the different wire parts would be positioned correctly in respect to the baseplate (Figure 2). We exported the baseplate design as a stereolithography format (known as an *STL file*) and sent it to a 3D printing company (NextDent). The company converted the 3D file to a physical model in a 3D printable biocompatible material (NextDent Ortho Rigid, NextDent) with the aid of a 3D printer (Rapidshape D30, Rapid Shape).

We exported each of the wire designs as an .ASE file, which consists of an American Standard Code for Information Interchange (that is, ASCII) description of wire part. One of the authors (W.J.v.d.M) wrote a software routine in C++ computer language to convert the ASE files to one that could be used by a wire-bending robotic machine (FMU 2.7, Wafios). The files were read by the bending machine and the labial bows, springs, and clasps were bent from .07 and .08 millimeter orthodontic spring wire (Dentaurum) (Figure 3). A dental technician positioned the constructed wires on the support arms of the 3D printed baseplate and filled the holes with the biocompatible light-curing resin of which the baseplate was constructed and light cured. He removed the support arms from the baseplate and polished the palatal side, rendering a smooth palatal surface (Figure 4).

Two experienced orthodontists fitted the removable appliances in the mouth of the participant and independently assessed the appliances for proper fit. Two

ABBREVIATION KEY. 3D: 3-dimensional.