Custom Designed Orthodontic Attachment Manufactured Using a Biocompatible 3D Printing Material

RIHAM NAGIB[1], CAMELIA SZUHANEK[1]*, BOGDAN MOLDOVEANU[2], MEDA LAVINIA NEGRUTIU[1], COSMIN SINESCU[1], SILVIU BRAD[1]

[1] Victor Babes University of Medicine and Pharmacy Timisoara, 2 Eftimie Murgu Sq., 300041, Timisoara, Romania

[2] MdentalStudio Dental Laboratory, Doctor Gheorghe Marinescu Str., 300092, Timisoara, Romania

Treatment of impacted teeth often implies placing a bonded attachment and using orthodontic forces to move the tooth into occlusion. The aim of the paper is to describe a novel methodology of manufacturing orthodontic attachments for impacted teeth using the latest CAD software and 3D printing technology. A biocompatible acrylic based resin was used to print a custom made attachment designed based on the volumetric data aquired through cone bean computer tomography. Custom design of the attachment simplified clinical insertion and treatment planning and 3D printing made its manufacturing easier. Being a first trial, more reasearch is needed to improve the methodology and materials used.

Keywords: 3D printing, computer aided design, cone bean computer tomography, orthodontics

One of the most common methods used to bring impacted teeth into occlusion is placing a bonded attachment and using orthodontic forces to move the tooth [1]. Attachments used for impacted tooth orthodontic traction evolved through the years from now obsolete methods like wire lassos and threaded pins which required crown perforation [2] to lingual buttons, chain accessories, brackets and even individualised metal attachments [3,4].

The aim of the present study is to describe a novel methodology of manufacturing orthodontic attachments for impacted teeth using the latest CAD software and 3D printing technology.

Described as a technology that will change manufacturing, 3D printing is currently widely being used in orthodontics for splints, implant guides or models [5]. Very accurate and imediately accesible volumetric data aquired through CT and CBCT imaging technology [6] and the data on material and adhesion defects through optical coherence tomography [7] could make 3D printing even easier to be incorporated in orthodontic treatment plans.

In future years this combination is expected to help provide basis for more personalised orthodontic treatment [8]. Faber et al., found that 3D printed dental models can be included in the evaluation of impacted teeth [3]. Lee et al. concluded that 3D printed replica teeth can be used in orthodontic diagnosis and treatment planning [9]. His findings are in accordance to other similar studies on the subject of orthodontic models [10,11]. Although scanning plaster models for 3D printing provided good results regardless the printing method used, intra-oral scans have some limitations in providing 3D printed diagnostic models for orthodontics due to a deficiency in the transverse plane.[12] Krey et. al was able to prove the concept of implementing an orthodontic treatment plan with individual computer designed and 3D printed brackets in the dental clinic [13].

Experimental part

A cone beam computer tomography (CBCT) taken with CRANEX 3D (Soredex, Finland) equipment for diagnostic purposes was used to extract the impacted cuspid and obtain a 3D model of the palatal surface of the tooth. OnDemand3D (Cybermed Inc., USA) software was used to segment and manually clean the 3D volume. The resulting CBCT was converted into a STL file (fig. 1). The STL file was used to design an orthodontic attachment using computer aided design (CAD) software Exocad (exocad GMBH, Germany).

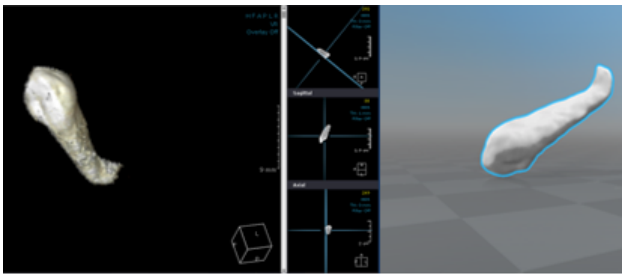

Fig. 1. Side by side views of the impacted canine : CBCT image and STL file after conversion

The attachment design took into consideration the position of the impacted tooth, bone coverage and direction of the long axis, thus permitting an easier surgical intervention. The base of the attachment was custom made to fit the palatal side of the impacted cuspid, in order to obtain good adhesion and minimise adhesion failure during orthodontic traction. Two holes were incorporated in the design for retention purposes. The attachment also presented a component for the orthodontic elastic similar to the ones used on standard metal lingual buttons (fig. 2).

The final attachment design was exported for printing to the Form2 (Formlabs Inc., USA) 3D printer. NextDent C&B (Vertex-Dental, Netherlands) was the 3D printing resin material chosen for the attachment. It is a biocompatible class IIa monomer based on acrylic esters with the following specifications, presented in table 1.

The printed result was rinsed twice in an alcohol solution (96%) to get rid of any excess material, making use of an ultrasonic bath. After cleaning, the parts were dried and

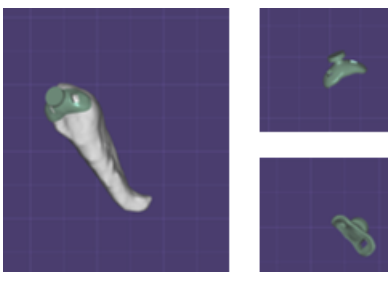

Fig. 2. Attachment design in Exocad (exocad GMBH, Germany) software

* *email: cameliaszuhanek@umft.ro*

Table 1
NEXTDENT C&B (VERTEX-DENTAL, NETHERLANDS) MATERIAL SPECIFICATIONS

Flexural strength	≥ 85 MPa
Flexural modulus	≥ 2.100 MPa
Water sorption	≤ 30 µg/mm³
Water solubility	≤ 5 µg/mm³
Hardness Shore	D 80 – 90

placed in a UV- light curing box for final polymerization. All support structures were removed and conventional dental instruments were used for final finishing and smoothening of sharp edges.

Clinically, the resulting attachment would be disinfected before its intended use with an ethanol solution and cemented with Resilience LC Orthodontic Adhesive (OrthoTechnology, USA),after surgical exposure of the impacted canine (fig. 3).

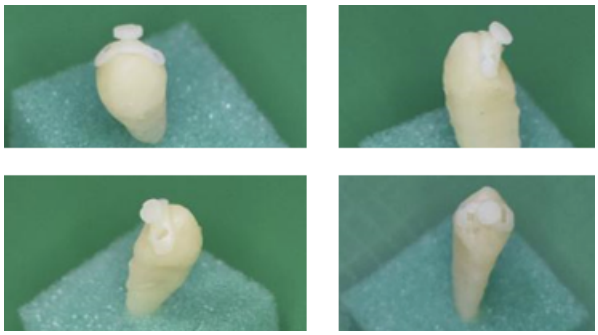

Fig. 3. 3D printed attachment on 3D printed model of the impacted canine

Results and discussions

The resulting attachment showed some advantages over the use of standard attachments. CBCT imaging provided the posibillity of creating a 3D printed model of the impacted tooth used as a guide to decrease surgery time and make it less invasive [14]. Positioning the attachment intra-operatory was fast and easy, given that the custom base only permitted a singular position on the palatal surface of the impacted tooth. This provided less time for field contamination and incresed the chance of good adhesion between the enamel and the attachment. Although similar attempts of manufacturing custom attachments were made [3,4], in the present paper, 3D printing technology made the process easier, more cost effective and the final design of the resulting piece smaller. It also has the advantage of minimal wastage over substractive methods [15].

Conclusions

The present paper presents a methodology that uses a combination of new technology that could easily be incorporated in the digital workflow trend of dentistry in general. Customisation of the attachment design provides the posibility of individualised orthodontic treatment planning and could be applicable beyond impaction cases. More reaserch is needed to improve the methodology and materials used, but after a first trial we conclude that 3D printing, a continuously developing technology, together with CAD software and CBCT imaging offers new possibilities in orthodontic component manufacturing.

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