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. A biocompatible acrylic based resin was used to print a custom made attachment designed based on the volumetric data acquired through cone beam 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 research is needed to improve the methodology and materials used.

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

<table>
<thead>
<tr>
<th>Flexural strength</th>
<th>≥ 85 MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexural modulus</td>
<td>≥ 2.100 MPa</td>
</tr>
<tr>
<td>Water sorption</td>
<td>≤ 30 µg/mm²</td>
</tr>
<tr>
<td>Water solubility</td>
<td>≤ 5 µg/mm²</td>
</tr>
<tr>
<td>Hardness Shore</td>
<td>D 80 – 90</td>
</tr>
</tbody>
</table>

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

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 possibility 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 increased 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 subtractive 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 possibility of individualised orthodontic treatment planning and could be applicable beyond impaction cases. More research 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.

References
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