Int. J. Oral Maxillofac. Surg. 2014; 43: 454–459
http://dx.doi.org/10.1016/j.ijom.2013.08.016, available online at http://www.sciencedirect.com

International Journal of Oral & Maxillofacial Surgery

Research Paper
Orthognathic Surgery

A novel approach for planning orthognathic surgery: The integration of dental casts into three-dimensional printed mandibular models

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A. F. Ayoub, M. Rehab, M. O'Neil, B. Khambay, X. Ju, J. Barbenel, K. Naudi: A novel approach for planning orthognathic surgery: The integration of dental casts into three-dimensional printed mandibular models. Int. J. Oral Maxillofac. Surg. 2014; 43: 454–459.

Abstract. A method of producing a composite model consisting of a three-dimensional printed mandible bearing plaster teeth is presented. Printed models were obtained from cone beam computed tomograms (CBCT) of dry human mandibles. The plaster casts of the teeth were obtained from impressions of the teeth of the dry mandibles. The distorted teeth of the printed models were removed and replaced by the plaster casts of the teeth using a simple transfer jig. The accuracy of the composite models obtained from six mandibles was assessed from laser scans. The scans of the dry mandibles and the composite models were superimposed and the magnitude of the discrepancies at six points on the dentition and six on the mandible were obtained. It was concluded that the errors of the method were small enough to be clinically significant. The use of the composite models is illustrated in two clinical cases.

Keywords: orthognathic surgery; 3D model; facial deformity.

Accepted for publication 28 August 2013
Available online 3 October 2013

Orthognathic surgery involves movement of the jaw bones and is usually planned using dental casts mounted on an articulator. An accurate recording and replication of the maxillomandibular position and correct orientation in relation to the skull is essential for accurate planning. Current methods of mounting dental casts on articulators using face-bows and wax bite are, however, inaccurate and unreliable,[1–4] with incorrect orientation of the maxilla being a major source of systematic error.[5–7] It has long been a desire of the oral and maxillofacial surgeon to carry out surgical prediction planning for orthognathic surgery on a physical model that accurately replicates the skull, jaw bones, and dentition.[8–13] The introduction of medical rapid prototyping and the ability to produce three-dimensionally accurate models of the cranial and facial structures using data from a computed tomography (CT) scanned image, may hold the key to future orthognathic surgery prediction.[9,10,14–16] However, the presently available physical models produced from CT scans of the jaw bones and their associated teeth do not reproduce the dentition with a satisfactory accuracy to predict the final occlusion and allow the construction of occlusal wafers to

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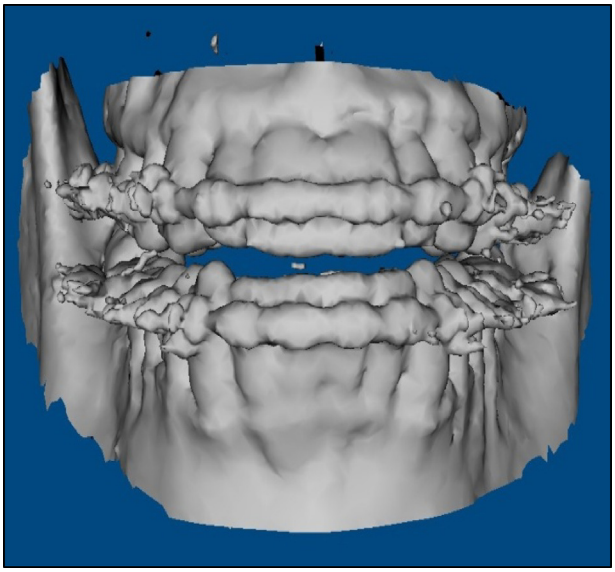

Fig. 1. 3D CBCT of the mandible showing the streak artefacts of the associated teeth.

guide the surgery. This is because teeth have a different composition from bone, which affects the deflection of X-rays during radiographic capture of the face. The dentition is also distorted due to the streak artefact produced from metallic restoration and orthodontic brackets (Fig. 1). The prevention of such artefacts, or more likely the replacement of the distorted dentition with accurate representations of the teeth, would facilitate orthognathic surgery planning and allow the surgeon to visualize the anatomy of the face, the jaw bones, the dentition, and occlusion. The surgeon would be able, for the first time, to simultaneously analyze the facial skeletal abnormalities associated with occlusal deformities that would influence treatment planning and the quality of surgical outcomes.

The replacement of the teeth and alveoli of the three-dimensional (3D) physical models of the skull with plaster casts and the use of the developed composite models for orthognathic surgery planning has been reported,[4,9] but the methods are complicated and there has been no report of the accuracy of replacing the dentition. A more recent study[17] has described a rather simpler method of producing composite models of the maxilla and teeth, reporting the accuracy as being acceptable for clinical use and giving an example of a clinical application. The aim of this study was to extend the method and to investigate the accuracy of replacing the distorted mandibular dental arch of a 3D printed model, from CT scan, with an accurate, correctly positioned plaster cast obtained from dental impressions of the dental arches, and to illustrate the clinical application and planning benefits of the method.

Materials and methods

Six dried human mandibles were scanned using a cone beam computed tomography (CBCT) I-CAT scanner. The mandibles were scanned using an extended height of view of 4 cm, 0.4 voxels resolution, and 20 s scanning time. The resulting DICOM (Digital Imaging and Communications in Medicine) data were processed and converted into standard tessellation language (STL) file format for rapid prototyping using Maxilim software (Medicim NV, Mechelen, Belgium). A rapid prototyping machine (ZPrinter 310 Plus; Z Corporation, Burlington, MA, USA) was used to build the 3D mandibles on a 1-mm thick layer-by-layer basis. To replace the dentition, dental models were produced from direct impressions of the dentition of the natural human mandible using alginate impression material (Xantalgin; Wright Cottrell, Dundee, the UK, Netherlands) and cast in a class IV dental stone (Shera Hard Rock; John Winter & Co Ltd, West Yorkshire, England, the UK).

The correct positioning of the plaster dentition relative to the model of the mandible is crucial for the production of an accurate composite model. This was achieved using a two-part denture relining jig (Dentsply, UK), which comprised a base with three parallel vertical columns of fixed vertical height and a top section that connected to the vertical columns with the aid of three locking nuts. The mandibular model was positioned in the lower section of the jig and held in place using silicone compound (Coltène/Whaledent AG, Altstätten, Switzerland). A dimensionally stable silicone impression material (AlgiNot; Kerr Corp., Romulus, MI, USA) was applied to the dentition of the 3D mandibular model, producing an impression of the dentition, and to the top section of the jig, which was then closed by tightening the locking nuts.

A 1-mm thick polyvinyl splint (Abacus, West Yorkshire, the UK) was fabricated covering all surfaces of the teeth of the plaster model using a pressure forming machine (Erkopress Es-200E; Erkodent, E.M. Natt Ltd, London, the UK). The 1-mm splint was used to compensate for the magnification of the dentition of the 3D models.[18]

The jig was opened once the impression material had set (Fig. 2). The inaccurate mandibular dentition was removed from the 3D mandibular model. The polyvinyl splint was placed into the impression of the dentition of the mandibular model and plaster poured inside the fitting surface of the splint to reproduce the accurate dentition. Cold cure acrylic resin (Ortho-Care

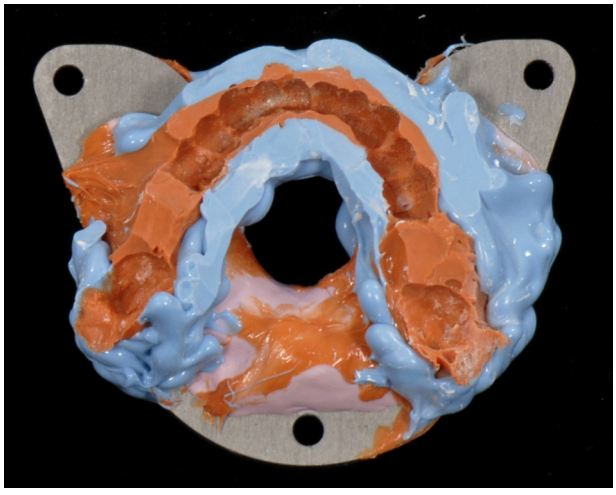

Fig. 2. Impression of the dentition of the mandibular model attached to the upper part of the jig.