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Research Paper
Imaging

Dental image replacement on cone beam computed tomography with three-dimensional optical scanning of a dental cast, occlusal bite, or bite tray impression

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Abstract. The goal of the present study was to compare the accuracy of dental image replacement on a cone beam computed tomography (CBCT) image using digital image data from three-dimensional (3D) optical scanning of a dental cast, occlusal bite, and bite tray impression. A Bracket Typodont dental model was used. CBCT of the dental model was performed and the data were converted to stereolithography (STL) format. Three experimental materials, a dental cast, occlusal bite, and bite tray impression, were optically scanned in 3D. STL files converted from the CBCT of the Typodont model and the 3D optical-scanned STL files of the study materials were image-registered. The error range of each methodology was measured and compared with a 3D optical scan of the Typodont. For the three materials, the smallest error observed was 0.099 ± 0.114 mm (mean error ± standard deviation) for registering the 3D optical scan image of the dental cast onto the CBCT dental image. Although producing a dental cast can be laborious, the study results indicate that it is the preferred method. In addition, an occlusal bite is recommended when bite impression materials are used.

Keywords: dental occlusion; computed tomography; registration.

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Introduction

Computed tomography (CT) has been used widely in recent years because it provides maxillofacial structure information in three dimensions (3D). However, CT imaging data may not reproduce an accurate 3D dentofacial model due to limited resolution and potential metallic artefacts caused by, for example, prosthodontic fillings, implants, and orthodontic brackets.[1] Therefore, various methods

have been investigated to create a more accurate reproduction of the dentition and occlusion on the CT Image.[2–5] One such method is to remove the image of the dental region on the CT and replace it with a more accurate digital dental image, thereby improving the CT dental Image.[4] The digital dental image is obtained with a dental cast model and impression materials using 3D optical scanning or CT scanning methods.[4–7] Methods used to register a 3D scanned dental image onto a CT image can be based on the regional surface, voxels, and paired points.[2,4,6–8] CT image registration by digital dental impression has been reported previously.[7] However, biting the impression material during the CT scan can cause a change in facial soft tissue; thus, the patient generally undergoes multiple CT scans with and without the impression material.

The current study assessed the use of an occlusal bite, which does not have an effect on soft tissue and thus does not require increased CT scans. However, there may be issues with the registration onto the CT image and the material stability with a small occlusal bite during the 3D optical scanning procedure. Another method requires making a dental stone cast model, which can be time-consuming. The current study compared 3D optical scanning using three methods: a dental cast, occlusal bite, and bite tray impression. Using surface-based registration, data from the 3D optical scans were overlaid onto the cone beam computed tomography (CBCT) images. The specific aim of the study was to verify the error ranges of the three experimental materials by comparing the reformatted occlusal image of experimental data with a 3D optical scan of the Typodont.

Materials and methods

CBCT scanning of the Typodont and conversion of DICOM to STL

The present study used a Clarity Self-Ligating Appliance System Bracket Typodont (3M Unitek, Monrovia, CA, USA) dental model with a bonded bracket (Fig. 1). CT images of the Typodont model were taken and data were saved in DICOM format. Implagraphy (VATECH Co., Ltd, Hwaseong, Gyeonggi-do, Korea), a CBCT device, was used with the following settings: field of view (FOV) 12.0 cm × 8.5 cm, 70 kVp, 7.0 mA, maximum scanning time 24 s, and voxel size 0.202 mm. When using an occlusal bite or bite tray impression, the experimental materials were fitted onto the Typodont dental models and fixed to ensure the vertical dimensions of the model did not increase. The CBCT data of the Typodont model in DICOM (digital imaging and communications in medicine) format were converted to STL (stereolithography) file format to fuse the 3D optical dental scan data using Mimics software version 14.0 (Materialise, Leuven, Belgium). The detailed parameter settings for the conversion to STL format were the following: threshold values were set to between 226 and 3071, the predefined quality settings were set as optimal during 3D modelling, the triangle reduction was 3, the edge angle of interaction was 10°, and the tolerance was 0.0547 mm.

Fig. 1. Clarity Bracket Typodont dental model.

3D optical scanning of three different materials for replacement in the dental area of the CBCT image

Method 1: 3D optical scanning of a dental cast

The dental impression of the maxilla was made with alginate (Alginoplast; Heraeus, Hanau, Germany). The maxillary dental cast models were created from the impression using dental stone (Mutsumi Chemical Industries Co. Ltd, Yokkaichi, Japan) (Fig. 2A). The above process was repeated 10 times to create 10 dental cast models for one Typodont model (3M Unitek). Each of the 10 dental cast models was scanned with a 3D optical scanner (Rexcan DS2; Solutionix, Seoul, Republic of Korea) and STL data were obtained (Fig. 2B). The STL data and the CBCT converted STL files (Fig. 2C) were registered using Rapidform XOV2 software (INUS Technology, Seoul, Korea) (Fig. 2D). The surface-based registration method was used and the dental occlusal surface was aligned using the software. Surface-based registration was performed with an iterative closest point (ICP) algorithm. CBCT dental images were removed and replaced with the 3D optical scanned dental casts (Fig. 2E).

Method 2: 3D optical scanning of an occlusal bite

The same Clarity Bracket Typodont dental model was also used for the occlusal bite, which was made in the model using Blu-Mousse Classic impression material (Parkell Inc., Farmingdale, NY, USA) (Fig. 3A). The bite impression of the occlusal surface was used, and the unregistered remaining parts of the bite impression material were removed. The above process was repeated 10 times for one Typodont to create 10 occlusal bites. Each of the 10 occlusal bites underwent 3D optimal-scanning using a Rexcan DS2 (Solutionix) and STL data were obtained (Fig. 3B). The occlusal bite impression splints were fitted onto the Typodont dental models and fixed to ensure the vertical dimensions of the model did not increase. CBCT images of the 3D Typodont model were obtained, as above, and saved in DICOM format to allow for registration of the occlusal bite scan data. Mimics software was used to convert the CT DICOM files into STL files (Fig. 3C). The CBCT converted STL files and 3D optical scan STL files of the occlusal bite were registered with the surface-based registration method of the Rapidform XOV2 software (Fig. 3D) using the outer surface of the occlusal bite splint. CT dental images were removed and replaced with the 3D optical scanned occlusal bites (Fig. 3E).

Method 3: 3D optical scanning of a bite tray impression

The Clarity Bracket Typodont dental model was also used with a bite tray impression. Disposable SW impression bite trays