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Clinical use of navigation based on cone-beam computer tomography in maxillofacial surgery

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This paper is dedicated to the memory of Professor Joachim Mühling.

Abstract

Image-guidance in maxillofacial surgery is based predominantly on computed tomographic (CT) images. Its main disadvantage is the considerable amount of radiation to which the patient is exposed, and dental metal artefacts. Recently, a new class of devices based on the concept of cone-beam computed tomography (CBCT) has been introduced for maxillofacial imaging, which we have investigated. In a clinical study, the first seven patients to be operated using a navigation system based on CBCT images, were evaluated. In all cases patient to image recording was uneventful and the surgical objective was reached. The guidance given by the navigation system was helpful. CBCT is an alternative to conventional CT, gives a lower dose of radiation, and costs less. Limitations in the quality of the images and the size of the field of view may restrict its use. It is suitable for image-guided surgery using a navigation system as long as the images show enough of the relevant anatomy and pathology.

Keywords: Cone-beam computed tomography; Surgery; Computer-aided; Foreign bodies

Introduction

Image-guided operations that use navigation systems have become more common in maxillofacial surgery.[1] A three-dimensional imaged data set is required. To use the imaged data in a navigation system, a registration procedure is necessary to align the image data with the body of the patient in the operating theatre. The gold standard is pair-point registration of artificial landmarks.[2] A reliable and accurate pair-point method in the face is the use of maxillary templates that are equipped with registration markers, such as titanium screws.[3]

The predominant method of imaging in maxillofacial surgery is computed tomography (CT),[4] the advantages of which are its availability, good geometric accuracy, and good imaging of bony structures. There are, however, disadvantages, particularly the amount of radiation to which the patient is exposed, and artefacts from metallic dental restoration. Cone-beam computed tomography (CBCT) has now become available, which allows for radiograph-based volume imaging of the maxillofacial area at reduced cost and a lower dose of radiation.[5] There are also fewer metal streak artefacts.[6] The main use of CBCT is image-guided placement of dental implants. For this application positive clinical experience was gathered in a previous study.[7]

Foreign bodies are a common finding in oral and maxillofacial surgery. For example, parts of broken instruments can intrude, and sometimes teeth are dislocated during extraction.[8–11] Various imaging techniques can be used to detect and locate these: plain radiographs, CT, magnetic resonance imaging (MRI), or ultrasound,[12,13] depending on the site and material.

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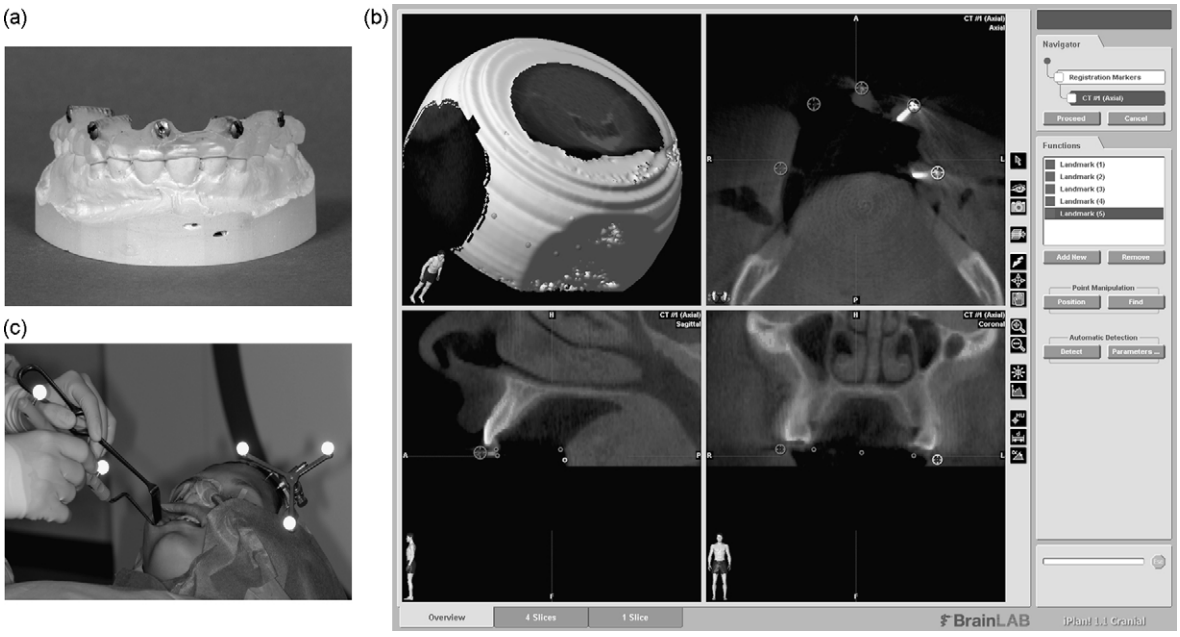

Fig. 1. (a) Individual maxillary registration template made from light curing resin: 5 titanium screws are used as fiducial markers for pair-point registration. (b) Screen shot from the navigation system's planning software: identification of the positions of the fiducial markers of the registration template in the imaging data. (c) Intraoperative identification of the fiducial marker during registration.

However, important anatomical structures can be damaged during removal of foreign bodies. The difficulty lies in the reproduction from the image data of where the foreign body is located in the patientĭs body if there is no adjacent definitive anatomical landmark. The search for a foreign body in a larger area rather than at a particular position then increases the risk of damage to adjacent structures. Today CT data are used successfully for navigated removal of foreign bodies.

We wanted to find out if CBCT would be suitable for image-guided maxillofacial surgery beyond the oral cavity. As it has shown that CBCT is suitable for imaging foreign bodies,[14] we evaluated its use for their removal.

Patients and methods

The inclusion criteria were: a clinical indication for the use of a surgical navigation system; no previous use of volume imaging; visibility of the relevant part of the body by CBCT; the foreign body and registration markers fitted into the volume of interest of the imaging device; and the patient's written informed consent before the procedure.

Registration template

The registration templates were made individually to be attached to the maxillary dentition. A plaster model was created from an alginate impression, and the template created using a light curing resin (Triad Gel, Dentsply, York, PA). Five titanium screws (Stryker Leibinger Micro Implants, Freiburg, Germany) were polymerised on to the template (Fig. 1a), and the ridges in the screw are heads were used as fiducial markers for pair-point registration later.

Imaging

All CBCT imaging was done with a NewTom DVT 9000 (QR s.r.l., Verona, Italy). The patients were equipped with the maxillary registration template and the images acquired with the patient supine. Axial slices were reconstructed with slices 1 mm thick and an in-plane resolution of 0.3 mm × 0.3 mm. Data were exported to compact disc (CD-ROM) using the standard DICOM (Digital Imaging and Communications in Medicine) format.

Registration/navigation

The images were imported into the navigation system (VectorVision Sky, BrainLab, Feldkirchen, Germany), and the positions of the fiducial markers were identified, as was the position of the foreign body sought (Fig. 1b).

A tracking body was attached to the patient's head during the operation for the infrared tracking camera of the navigation system. The registration template was re-attached to the maxilla. Finally, to complete patient to image registration, the positions of the fiducial markers on the patient were identified with an infrared-tracked pointing device (Fig. 1c) and the transformation to the previously determined positions of the markers in image data was calculated.