CLINICAL ORAL IMPLANTS RESEARCH

Short Communication

The virtual patient in dental medicine

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Abstract

Objectives: The aim of this *Short Communication* was to present a workflow for the superimposition of intraoral scan (IOS), cone-beam computed tomography (CBCT), and extraoral face scan (EOS) creating a 3D virtual dental patient.

Material and Methods: As a proof-of-principle, full arch IOS, preoperative CBCT, and mimic EOS were taken and superimposed to a unique 3D data pool. The connecting link between the different files was to detect existing teeth as constant landmarks in all three data sets.

Results: This novel application technique successfully demonstrated the feasibility of building a craniofacial virtual model by image fusion of IOS, CBCT, and EOS under 3D static conditions.

Conclusions: The presented application is the first approach that realized the fusion of intraoral and facial surfaces combined with skeletal anatomy imaging. This novel 3D superimposition technique allowed the simulation of treatment planning, the exploration of the patients' expectations, and the implementation as an effective communication tool. The next step will be the development of a real-time 4D virtual patient in motion.

Digital technologies have recently received its way into dental medicine. Due to these developments, clinical practices and laboratory techniques are shifting to virtual-based processes (Eaton et al. 2008; Schoenbaum 2012). Routinely diagnostic methods include digital radiology and photography; treatment concepts benefit from modernized workflows with intraoral scanning, computer-assisted implant surgery, and streamlined manufacturing of dental prostheses (Patel 2010).

The fusion of these digital puzzle pieces to a whole seems to be the logical continuum of this trend: creating a 3D virtual patient. The entire treatment plan could be simulated noninvasively, shared via network-mediated communication tools, and adopted to the patient's expectation (Kau 2011; Katase et al. 2013). However, how far are we in virtual dentistry? Today, there are (still) more question marks than answers.

Therefore, the aim of this *Short Communication* was to update the current status of knowledge as well as the technical progress in the field of 3D virtual patients science, and presenting a workflow for the superimposition of 3D imaging as intraoral scan (IOS), cone-beam computed tomography (CBCT), and facial extraoral scan (EOS).

Material and methods

A clinical case, requiring an implant-supported reconstruction for the replacement of teeth 21 and 22, was chosen to demonstrate the stepwise procedure creating a 3D virtual patient prior to surgery:

Fig. 1. Pre- and post-extraction intraoral surface scans (IOS) as STL, cone-beam computed tomography (CBCT) as DICOM, and stereo-photogrammetric extraoral scan (EOS) as OBJ.

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Fig. 2. Pre- and post-extraction frontal as well as lateral 3D virtual patient data sets based on superimposition of IOS + CBCT + EOS.

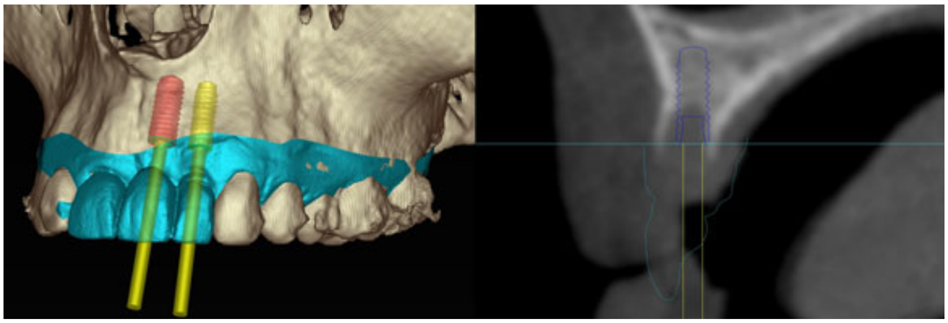

Fig. 3. Prosthetic-driven treatment planning based on CBCT and IOS with 3D implant software.

First, full arch IOS impressions were taken (iTero Align Technology, San Jose, CA, USA) and stored as STL files. The STL format describes triangulated surface geometries of 3D objects. Moreover, a CBCT was performed (i-CAT, Hatfield, PA, USA). The corresponding data format DICOM is a standard for handling, storing, printing, and transmitting information in medicine (ISO 12052:2006). Finally, stereo-photogrammetric EOS complemented the series of imaging techniques (3dMD, Atlanta, GA, USA). Three EOS were captured during different smile positions as OBJ files. OBJ is a universally accepted geometry definition file format that represents 3D color and texture information (Fig. 1).

Afterward, all media files were superimposed to a unique 3D data pool. This required reproducibly detectable landmarks in every part of the imaging files. Here, the connecting link between STL, DICOM, and OBJ was remaining teeth as constant objects in all three files (Fig. 2).

Moreover, computer-assisted implant guided-surgery in combination with 3D planning software offers an additional tool in a prosthetic-oriented digital treatment concept under consideration of the individual patient situation (coDiagnostiX Straumann, Basel, Switzerland) (Fig. 3).

Results

As a proof-of-principle, this application technique successfully demonstrated the feasibility of building a craniofacial virtual reality model by image fusion of IOS, CBCT, and EOS. The superimposition facilitated creating a 3D virtual patient data set under static conditions. Despite of these preliminary results, real-time actions of the jaws, lips, and mimic muscles could not be captured in a 4D prototype.

Discussion

Currently, no application system in the dental literature is known achieving a superimposition of STL, DICOM, and OBJ files to a 3D virtual patient. The presented application technique is the first approach that realizes the fusion of intra- and extraoral surfaces combined with skeletal anatomy imaging. Meanwhile, it has been only reported on two files-related fusions of either IOS + EOS (Rangel et al. 2008; Rosati et al. 2010) or CBCT + EOS (Naudi et al. 2013; Xin et al. 2013).

The presented 3D superimposition of IOS, CBCT, and EOS allows outstanding advantages in future dental medicine: (1) simulation of treatment planning and discovering patients' expectation; (2) facility for more effective patient and colleague communications as well as implementation in dental education; (3) noninvasive imaging technique for high-precision anatomical documentation; and (4) wide-range use in the fields of maxillofacial as well as plastic surgery.

The next step has to be the development of a real-time 4D virtual patient in motion. Even though, it is still feasible to extract a single frame of 3D data from a captured 4D video sequence and export this to an OBJ file that could then be superimposed with CBCT data. However, no commercially available system is (yet) able to fuse a 4D sequence of mimic facial movements onto DICOM, STL, and OBJ files.

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