Chapter 8.9
Visualization and Modelling in Dental Implantology

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ABSTRACT

Intraoperative transfer of the implant and prosthesis planning in dentistry is facilitated by drilling templates or active, image-guided navigation. Minimum invasion concept of surgical interaction means high clinical precision with immediate load of prosthesis. The need for high-quality, realistic visualization of anatomical environment is obvious. Moreover, new elements of functional modelling appear to gain ground. Accordingly, future trend in computerized dentistry predicts less use of CT (computer tomography) or DVT (digital volume tomography) imaging and more use of 3D visualization of anatomy (laser scanning of topography and various surface reconstruction techniques). Direct visualization of anatomy during surgery revives wider use of active navigation. This chapter summarizes latest results on developing software tools for improving imaging and graphical modelling techniques in computerized dental implantology.

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INTRODUCTION

In this chapter the author give his experiences gained developing visualization and graphical modelling tools in applications for computerized dental implantology. Intensive development efforts can be seen worldwide on the field of image-guided navigation systems applied in dental implantology. Several commercial products are available on European market (Simplant®, www.materialise.com; coDiagnostiX®, www.ivs-solutions.de; Denx®IGI, www.denx.com; ARTMA Virtual Implant®, www.landsteiner.org; Galileos Implant Guide, www.sirona.de, Dental Planner, Albadent Inc.). Drawbacks and advantages of technology in dentistry and oral surgery for the last decade are surveyed by several laboratories (Siessegger et al, 2001, Ewers et al, 2005). The computerized implantology evolves into two directions: 1/ surgery support with prefabricated templates; 2/ active, image guided navigated drilling. In case of surgical template preparation of both the registration and drill calibration can be made outside of operation room in a stress-free environment. This improves accuracy; however, other problems like template fixing to patient's jaw, complete absence of interactive control of drill's orientation in space make the future of this method uncertain. In case of active, intraoperative navigation, the lack of experience, poor software support for synchronization of real and virtual environments sometimes overburden the surgeon. Future trend in computerized dentistry predicts less use of direct diagnostic imaging and more use of 3D visualization of anatomy (laser scanning of topography and various surface reconstruction techniques). Functional modelling is now possible with tooth surface database and simulation of occlusal properties (Pongracz and Bardosi, 2006). Modern visualization methods like resampling the slice sequence in CT and MR diagnostic volumes, combined views of surface topography and mesh surfaces support the modelling. These new approaches help in direct visualization of anatomy during surgery that revives wider use of active navigation in the future.

The accuracy of dental hand piece tracking in active navigation highly depends on the alignment method between diagnostic and surgical spaces (REGISTRATION) and the alignment procedure between tool's own coordinate space and the coordinate space of attached sensor (CALIBRATION). Well designed computational approach is needed for calibration of dental hand piece with small and unique geometry (Bardosi and Pongracz, 2007, Pongracz et al, 2007).

GRAPHICAL MODELLING

Data Sources

Conventional (CT) and cone beam computer tomography (CBCT) are generally used for 3 dimensional dental imaging. Recent results have controversial results regarding optimization of image characteristics (artifacts reduction versus density resolution) by using CT and CBCT technologies (Humpries et al, 2006, Katsumata et al, 2007). In our studies the patient imaging data are read in from both CT and CBCT sequences and stored as volumetric model (Xoran Technologies: i-CAT 3D Dental Imaging, GE Medical Systems: HiSpeed NX/i). Reslicing algorithm is frequently included to generate slice view in arbitrary cutting plane orientation. Bone surface models are created by isosurface raytracing algorithm or marching cubes algorithm. Mesh surfaces can be imported for adding gips model topography and realistic model of implants. The surface models can be clipped to see interaction of surfaces with volumetric data and visualize the details of interocclusal relationships.

Tooth Database

This is a really difficult issue because the fine, realistic details of intercusp relations are important for dental planning and their presence in the program gives an impression of the real environment for the dentist. The realistic graphics helps in navigating within the virtual scene for medical personnel even if he doesn't like working with computers. The CT imaging was performed on teeth of undamaged surfaces taken from the same cadaver skull. The teeth had no metal filling. The surface reconstruction was made by marching cubes (Lorensen and Cline, 1987) and decimator algorithms to find polygons and set their number to a reasonable level (Figure 1). The ideal positions and the 3D surface models of each tooth are stored and added during initialization (read in from compressed file package). Their locations are rendered to the standard dentition curve (represented as cubic spline connecting the surface centers of teeth). The coordinates are based on detailed anatomical description of articulation of dental curves and classification of the permanent dentition which are available for a long time (Massler and Schour, 1958). Local alignment and scaling of each tooth is possible within the ideal occlusal reference frame on separate panels