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„Planning and Navigation Tools for Dental Implantology“

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Planning and Navigation Tools for Dental Implantology

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INTRODUCTION

Our goal is to develop an easy-to-use implant navigation system which is suitable to support both the template-based and free-hand navigation approaches in dental implantology. Both methodologies have their own field of applicability in clinical practice. Specific surgical template with **four metal markers** is fitted to the patient mouth at the time of CT scanning. In our case the surgical space is registered to the CT volume – which contains the treatment plan - through these markers. The surgical template can be supplied with guiding cylinders for the surgeon's drill. After registration the implant surgeon is able to prepare the template with high precision which guides the drill to the planned position. Alternatively, the template - with an attached sensor to detect the patient's movement -, can be placed into the mouth during surgery. In this case the template serves as console for the sensor and markers and supports direct navigated drilling with an appropriate moulding. The rigid, accurate fit of template can be fixed by three screws which are planned similarly to the implants.

The planning software has added features for virtual dentition planning based on tooth database [Pongrácz2006a][Pongrácz2006b]. The optimal dental occlusion is defined according to the condition of centric occlusion i.e. after bringing occlusal surfaces of mandibular and opposing maxillary arches into identical 3D position. This identical position of occlusal surfaces, which are approximated by triangles, represents the common reference frame for manipulation of tooth models. This way, the program simulates the diagnostic environment for ideal, centric occlusion and the user can estimate the change in the contact area on the opposite arch and decide on the necessary corrections.

Novel features are added to the navigation module which communicates with NDI Polaris camera. Both the template drilling and the free-hand navigation is controlled by the same optical system. Modular steps support clamp-free, accurate calibration of small dental drills to the sensor's space. The axis direction calibration can be performed by a new surface-scanning procedure to get reliable results for dental drills [Bárdosi2007].

MATERIALS AND METHODS

The patient data are read in from a CT sequence and stored on a 3D grid as a volumetric model (Xoran Technologies: i-CAT 3D Dental Imaging, GE Medical Systems: HiSpeed NX/i). If needed, the user starts with dentition planning by setting the occlusal triangles for the upper and lower jaws. The idealized dentition model from a database are stored separately and added during initialization. An implementation of the marching cubes algorithm is used in combination with component selection and decimation algorithms in order to generate the polygon models of teeth. A divided axial view is formed which displays the original and reflected volumetric models with the centric occlusal triangle positioned in the upper and lower jaws, respectively. The positioning of occlusal triangles is made in locked (registered) mode, i.e. with continuous update of the projection matrix between the upper and lower triangles (Fig.1).

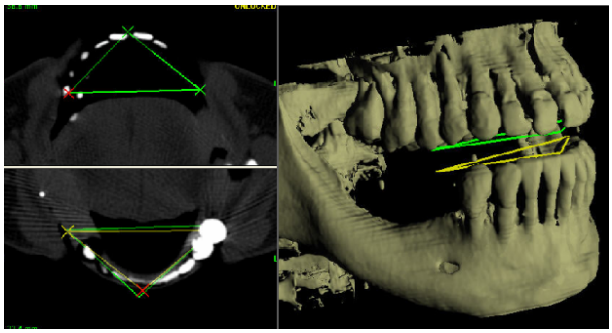

Fig. 1: Setting occlusal surfaces on the upper and lower jaws

Local alignment of each tooth model is possible within the ideal occlusal reference frame on separate panels for mesiodistal and faciolingual inclinations (Fig.2). These local views display the resampled image view together with tooth model to predict the small details for contact areas.

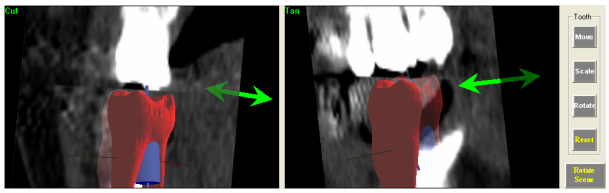

Fig. 2: Local alignment of tooth model under centric occlusion (left:mesiodistal, right:faciolingual)

The planning can be continued with virtual implant positioning in a standard way and the results can be visualized in a navigation panel. The registration to the CT volume can be performed with the help of surface markers of the template.

The drill calibration (both for template drilling and free-hand navigation) is based on the known pivoting procedure (tip offset vector calculation). The second phase of the calibration (tip direction) starts with data capture on that part of device which has a cylinder shape with an axis identical with the tip direction. An optimization algorithm (Levenberg-Marquardt method) was implemented which uses the output of data capture made by the random move of the pointer on the tool cylinder. This optimization procedure projects first the random surface points onto the plane centered by the tip offset vector which was determined during the pivoting phase. The 3D projection transform for the actual axis direction is calculated from two orientation angles. These angles are the parameters to be optimized. On output the axis calibration procedure gives back the orientation angles for the tip axis, the cost value at optimum and the estimated diameter of the fitted cylinder. The final orientation of the tool's space can be aligned to the tool's geometry (handle position) by an up-vector defined by the pointer (Fig. 3).

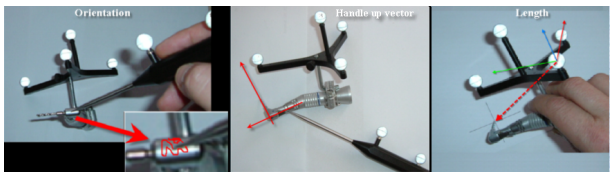

Fig. 3: Modular calibration of small dental drill

RESULTS

The proposed method of dentition/implant planning and navigated drilling has been tested with template-based implant surgery. The visualization of relative positioning of 3D model of individual tooth on the upper and lower arches helped the restorative dentist in estimating local occlusal contacts. Some of the results of the implant surgery are documented and will be presented. The real-time targeting with the navigation panel is illustrated in Fig. 4.

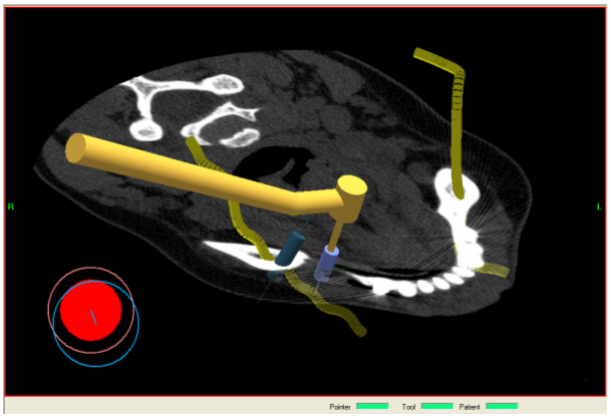

Fig. 4: Navigation panel

DISCUSSION

An implant navigation system is developed which has novel graphical feature of dentition planning. This feature can be initiated by volumetric resampling at estimated centric occlusion of maxilla and mandible. The system supports template-based navigated drilling but it is also suitable for free-hand navigation. In both cases, marker-based registration is used to transform drill movement. The calibration of the small, unique geometry of dental drills to the attached sensor's space is difficult and sometimes inaccurate, therefore statistical optimization is involved.

CONCLUSION

An implant planning and navigation system is developed which helps dental implantology by some new features added to the known methodology.

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