Application of 3D printed drill guides in implant dentistry

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Abstract — **This paper describes usage of engineering procedures and techniques in dentistry and oral surgery. Numerous cases prove that using rapid prototyping technology in this field leads to improvement in control and accuracy. Duration of surgery and pain in some cases are significantly reduced which results in faster patient rehabilitation. Rapid prototyping models are very useful in the education of trainees, in surgical planning and give the possibility to manufacture customized implants, guides and fixtures at a reasonable cost. In our case report we describe surgery planning and dental guides manufacturing for teeth restoration. Due to the constant technology development it can be expected that some disadvantages like surface finish, limited choice of materials and nonstandard software procedures will probably be removed in the near future.**

Keywords — **rapid prototyping, dentistry, CAD, 3D visualization, computed tomography**

I. Introduction

Classical methods of production are quite limited when it comes to making products of complicated geometry, so the response to these requests is technology for rapid prototyping. For small production runs and complicated objects, rapid prototyping is often the best manufacturing process available [1]. Rapid prototyping (RP) is a manufacturing technology used in many industries to develop high fidelity 3D models from Computer Aided Design (CAD), 3D digitized or computed tomography data. The first systems for rapid prototyping were developed in the 1980's with the emergence of idea of Additive Manufacturing (AM) i.e. building objects layer by layer. One of the first processes used and developed for RP is stereolitography (SLA). It has been developed by the 3D Systems company from California in 1986., and introduced in the market by ZCorp in the year 1996. Today, there are many different RP technologies and processes but the most common are stereolitography (SLA), selective laser sintering (SLS), 3D printing (3DP), fused deposition modeling (FDM), laminated object manufacturing (LOM) [2,3]. After the wide application in the industry the RP technologies found their way to medicine and dentistry. Medical rapid prototyping (MRP) is defined as the manufacture of dimensionally accurate physical models of human anatomy derived from medical image data using a variety of rapid prototyping (RP) technology [4]. Application of RP in dentistry include education, visualization [5,6], preoperative planning [6-9], procedure rehearsal [6,7,9], simulation [6,7,10], customized medical implant design [8,11,12], tissue engineering [13] etc. In our case report we analyze and explain applications of RP for teeth restoration through surgery planning and dental guides manufacturing.

II. Preoperative planning and custom made implants

Rapid prototyping today does not necessarily mean finding new technical solutions and breakthroughs, but occurs through a departure from conventional approaches and traditional materials and designs. Building physical models from CT data was put forward by Alberti in 1979 [14]. Polystyrene model of a pelvis was constructed so that a custom – made metal implant could be designed for a patient with fibro sarcoma [15]. Using computed tomography data to build physical models today has a very wide application in oral and maxillofacial surgery and some of them are visualization and preoperative planning. Using RP models and techniques when planning a surgery results in possibility to exactly evaluate the position, size and anatomy of malformation. Using three dimensional imaging, stereolithographic models can be constructed, which is useful as they simulate the surgical procedure and allow the construction of custom-made implants, guides and fixtures that should fit the defect perfectly, shortening operating time [16]. One clinical report describes using CAD/CAM technology and CT imaging coupled with interactive planning software when planning and executing implant surgery [17]. RP models can be used to preshape implants that will be used in surgery. The dimensions of plates and screws can be determined during surgery planning [18]. Rapid Prototyping technology has been used to demonstrate the strange anatomy of three distal roots of a right mandibular first molar [19]. Physical models of dental anatomy can also be provided with the application of 3D scanner [20]. One study brings the focus on preserving the aesthetics (facial contour recovery) while doing a mandible reconstruction. In the selected case, implant placement was simulated [21].

RP can also be used for manufacturing removable orthodontic appliances. Removable fixtures are used for teeth straightening [22] and as templates for surgery assistance [17]. Research [22] describes process of teeth straightening using RP procedures.

In numerous cases rapid prototyping techniques improve control and accuracy, the patient's rehabilitation is faster, pain is reduced, and the hospital stay is shorter. Rapid prototyping models are very useful in the education of surgical trainees and patients.

III. Case report

Caucasian female, 56 years old, non smoker with good oral hygiene came to our dental practice wanting to replace her reduced removable denture in upper jaw on position of left second incisor and canine (teeth no. : 22, 23) with implants. Reduced removable denture did not satisfy her functional and aesthetic requests. Missing teeth were extracted few years ago in other dental practice due to chronicle periapical granuloma. For preliminary diagnostics a standard orthopantomogram was done to evaluate the possibility of placing implants. The results were satisfactory.

To achieve the best results we presented to a patient a possibility of placing implants guided with individual surgical drills that she willingly accepted. Patient insisted to have non metal implants, due to her believe that metal has negative side affects to her health. Further diagnostic methods included Cone-Beam Computed Tomography (CBCT) scan of upper left quadrant (slice thickness of 0.25 mm) and momomaxillar impression for the cast model. Using CBCT data the model of the maxilla was generated on the computer (Fig. 1).

Fig. 1 The 3D model of maxilla was generated from CBCT DICOM data using simple image segmentation procedures.

The .stl model of maxilla was converted to surface .iges file format and imported into CatiaV5 software. All surfaces were interconnected with *Join* function, sealed into a single unit (*Close surface*) and converted to a solid part. The 3D model was used to evaluate the best position, orientation and size of implants. Planning and all measurements were done in the CatiaV5 *Assembly Design* module (Fig. 2).

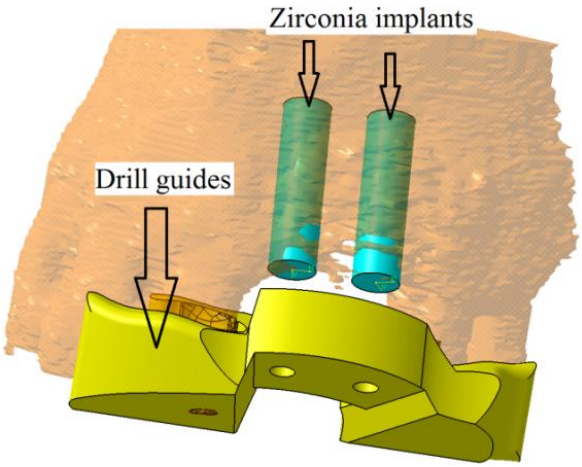

Fig. 2 Implants position planning on the computer. The implants were positioned perfectly parallel and the distance between axes was 6.8 mm (> 3mm of bone between implants).

Drill guides for implants positioning were designed using free form surface modeling paired with simple Boolean operation (*Remove*) in the *Part Design* CatiaV5 module. The guides were manufactured on the powder based ZCorp 450 3D printer and infiltrated with thin epoxy resin. When designing drill guides we dropped one link in the chain so no data from 3D scanner was used. Higher resolution CT images did a fine job so there was no need for scanning a cast. Prior the surgery the guides were sterilized in 70% ethyl alcohol.

Due to patient request for non metal implants we decided to use one piece zirconia implants (SDS Swiss Dental Solution AG, Zollstrasse 8, CH-8280 Kreuzlingen). Flapless implant surgery aided with individual drill guides for implant placement was performed and two implants (Ø 3.7 x 14 mm) were placed on positions 22 and 23. Non immediate loading temporary acrylic crowns were placed for osseo integration period that will last next 4-6 months. On regular controls third and seventh day after surgery healing process was uneventful (Fig. 3).

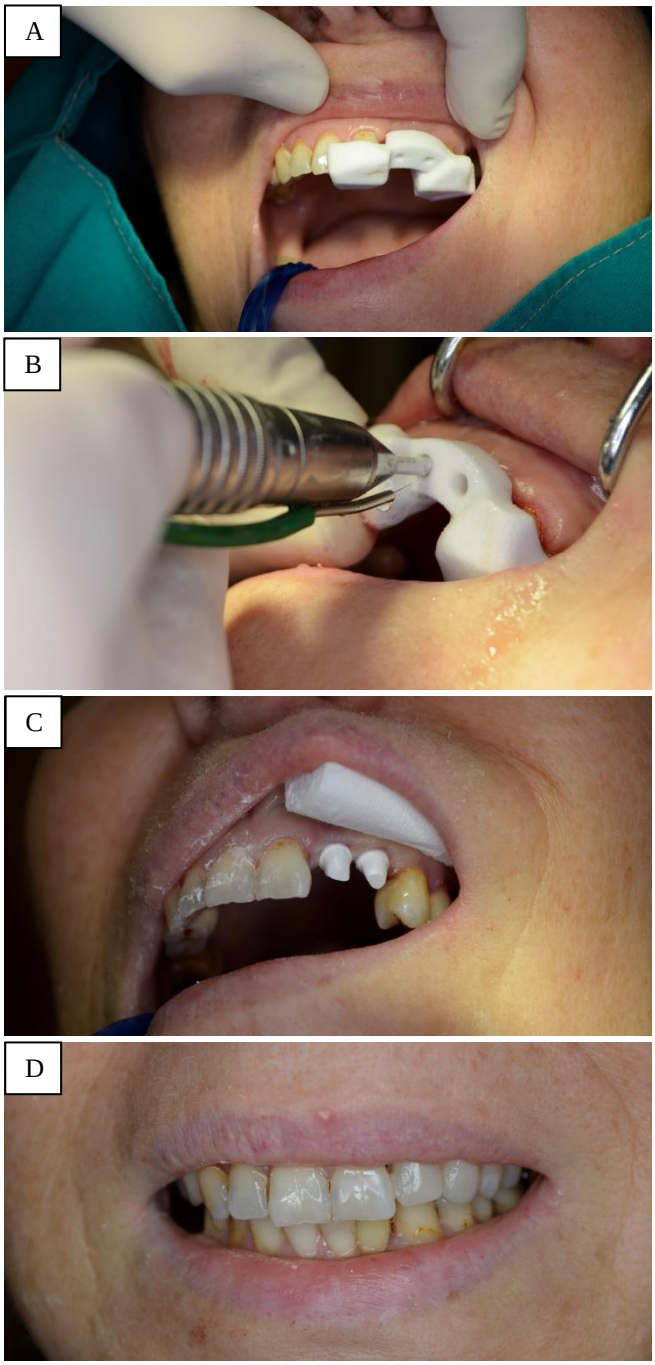

Fig. 3 Placing zirconia implants using drill guides; A) patient trying out the guides; B) drilling pilot holes using guides; C) implants prepared for placing crowns; D) excellent preliminary functional and aesthetic results

IV. Conclusion

Individual surgical drill guides for implant placement allow minimally invasive oral surgery. They reduce operation time; facilitate the work of the surgeon making the whole procedure minimally invasive. Healing process due to flapless technique proceeds uneventfully, giving the patient maximum postoperative comfort in function and aesthetics. In our case patient was very satisfied with multidisciplinary approach, postoperative course, functional and aesthetic outcome of the procedure. Due to the small CBCT image layer thickness the guides were a perfect fit and there was no need for using a 3D scanner. The implants were positioned perfectly parallel to each other surrounded with optimal bone thickness which could not be done without drill guides and 3D planning on the computer.

In our case, to achieve maximum outcome and excellent results in this multidisciplinary approach a good cooperation and communication between clinicians and CAD engineers was essential.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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