OPTIMIZATION OF IMPLANTODONTIC SURGERY BY BIOMODELS OBTAINED VIA RAPID PROTOTYPING (RP): CASE STUDY

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Abstract. *The use of advanced computational methods aiding manufacture of biomodels applied in diagnosis, design and treatment of complexes surgical cases, may be, most of times, decisive to success of clinical results. The application of Rapid Prototyping in medical area allows the acquisition of highly precise three-dimensional models that represent the accurate copy of the anatomic structure of the patient. The main systems of RP used in biomedical area are: Stereolithography Apparatus (SLA), Selective Laser Sintering (SLS) and Fused Deposition Modelling (FDM). With the physical model, the surgeon has, in a real scale of the anatomic region, better conditions to obtain the diagnosis, to design treatment and surgical intervention. Besides, the prototype reduces the surgical time, facilitates the communication between surgeon and patient and promotes an efficient integration between the multidisciplinary staff. The case reported here was developed in a patient with atrophy of superior maxilla needing prosthetic rehabilitation anchored on titanium implant. To obtain the biomodel, a computed tomography (CT) of the anatomical region, with axial slices of 1mm was required. The images were converted in format DICOM (Digital Imaging and Communications in Medicine) to posterior manufacture of the prototype that, than was used in the planning and production of the bone supported surgical guide. The aim of this work is to provide information necessary to the application of RP in surgical therapies, based on a case study.*

Keywords: *rapid prototyping, biomodel, implantodontic surgery*

1. Introduction

The technology for construction of prototypes in a short period of time is among the greatest advances of modern age provided by informatics. For this reason, this technology is known as Rapid Prototyping (RP), in contraposition to traditional methods which delays weeks or months (Artis, 2003).

Gorni (2001) defined Rapid Prototyping as a group of technologies used to manufacture physical objects just from data generated by project systems assisted by computer (CAD). Such methods are very peculiar, once they aggregate and bind material, layer by layer, to constitute the desired object. They offer several advantages in many applications when compared to classic processes of manufacture, based on the removal of material, such as milling and lathe.

Recently, this technique has being applied in medicine, mainly to create replicas of skeletal structures, by chattering with computed tomography (Mankovich, Cheeseman and Stoker, 1990), to help surgeries of the maxillofacial complex and orthopedic surgeries and help procedures to create osteosynthetic grafts with precise adaptation.

In Implantodonty, the Rapid Prototyping is indicated in the acquisition of precise surgical guides and in esthetic rehabilitation of anterior regions (Dinato, Ulzefer and Brum, 2004).

2. Rapid prototyping systems

The main systems of Rapid Prototyping used in manufacturing biomodels are:

2.1. Stereolithography Apparatus (SLA)

This is the oldest and most important technique of Rapid Prototyping (Artis, 2003). This pioneer process, deflagrate the revolution in Rapid Prototyping (Gorni, 2001).

According Pessa (2001), the Stereolithography uses the techniques of CAD and CAM. More recently, this technique has being used to construct replicas of human skulls during treatment design and in anthropology. The precision of SLA is due to advanced technology of Computed tomography (CT). Artis (2001) and Kermer *et al.* (1998) reported that SLA technique of Rapid Prototyping allows the creation of models in epoxy monomers, acrylic or vinyl resins.

In agreement with Artis (2003), this technique is based on polimerization of a photosensitive resin composed by monomers, photoiniciators and additives, by a laser UV bundle (ultraviolet). The machine SLA has a tub that is filled with resin, and inside this tub there is a platform that moves upside down. The computer sends the platform the first slice of the virtual model to be polimerized. The numerical control of the machine place this platform on the resin surface and the galvanometric mirrors direct the laser bundle to the portion of resin corresponding to this first layer. When this layer is reached by the laser, the photoiniciators trigger a localized reaction that promotes the formation of a polymeric chain between the monomers molecules scattered in the resin, and so, solidification occurs. After conclusion of this first step, the platform goes down and dives the first solid layer into the liquid resin, to get the polymerization of a new layer on the first. This continue until conclusion of the model.

The stereolithography outdoes the others in transparency, higher precision and better finishing of the model (Artis, 2003). Studies have being developed in Princeton University, using hydroxiapatite as a bone substitute in the SLA system (Wohlers, 1999).

2.2. Selective Laser Sintering (SLS)

As the name suggests, Selective Laser Sintering is a localized powder sintering by a CO_2 laser system confined in a specific machine. The system works with the laser passing over or scanning the surface of a powder layer deposited and regularized by the sub-system of nutrition; warming and agglutinating the particles to form a solid layer. Once the first layer is solidified, the mirrors point again the laser to a specific point, the platform moves down and the sub-system adds a new layer of powder and this continues until solidification of the last layer (Artis, 2003).

Various powders are used in construction of models and polyamide (plastic), polycarbonate (thermoplastic) and elastomers are among them.

According to Wohlers (1999), Biomedical Enterprises (San Antonio, TX) is investigating the use of an implant material the can be generated by SLS machines. The material would allow the production of structures that surgeons would implant to repair or replace the lack or damage in bone structures.

2.3. Fused Deposition Modeling (FDM)

Artis (2003) reports that Fused Deposition Modeling is based on the deposition on a platform, of layers resultant of the warming and softening of filaments (wire) from the plastic material used to build the model. Simultaneously, others soft filaments support free suspended model surfaces, in order to construct them. The wires destined to the model are ABS (acrylonitrile-butadiene-styrene), elastomers or wax, while those destined to the supports are a mixture of ABS+ lime. The FDM machine has a platform, clothed with dense foam.

According to Sratasys (2003), the process FDM allows to obtain prototypes with following material: wax, polyester, ABS, polycarbonate and sulfone.

3. Considerations and clinical applications

Wohlers (1999) affirmed that many medical specialties are using anatomic models when designing surgeries involving maxillaries, skulls, knees, hip, spinal column and so on, and most of them are used in bone reconstructions, although they also can be used in soft tissues and organs.

The acceptance of the new technology is always a long term process. Surgeons have being trained to plan their surgeries in a 3D vision and not 2D, standardizing some surgical procedures (Wohlers, 1999).

In the last decade, the emerging field of tissue engineering has developed a level of satisfaction that now offers alternatives to maxillofacial bone reconstruction (Alsberg, Hill and Mooney, 2001).

Today, CAD technologies, medical images, drawings and manufacturing have created new possibilities in the development of bone tissue engineering (Meyer *et al.*, 2003).

Among the various applications, its possible to visualize the anatomy of interest in a three-dimensional plan, design surgeries, simulate osteotomies or resections, make ATM prosthesis, osteogenic distraction, pre-surgical orientation to the patients, etc (Artis, 2003, Chilvarquer *et al*., 2004).

Mazzonetto *et al.* (2002) observed decrease in surgery time and better esthetic and functional result in reconstructions of the mandibles and autogenic grafts when biomodels were used during the planning.

4. Case report

Patient A.B, male, 37 years old, leucoderm and without systemic diseases, had as main complaint a esthetic and functional discomfort during use of a upper full prosthesis, and the instability of the prosthesis, due to atrophy of upper maxilla (Fig.1).

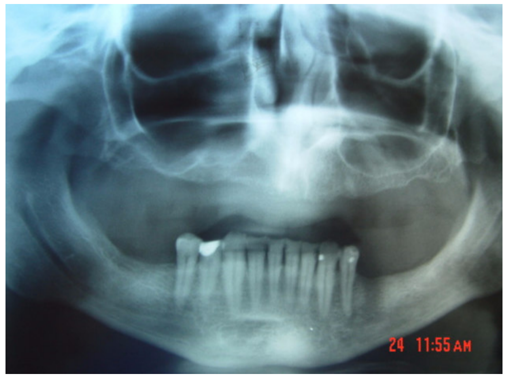

Figure 1. Panoramic X-ray showing atrophy of upper maxilla.

In the initial step of treatment, bone reconstructions onlay were performed in the anterior region, with autogenous bone of chin and inlay grafts in the posterior region with alogenic, cortico-cancellous particulate fresh and frozen bone, afterwards allowing viable bone bed to install the implants.

After 9 months, an upper maxilla computed tomography was requested, with slices of 1mm thickness in the axial plan (Fig. 2). The images were recorded in electronic midia (format DICOM) and directed to the enterprise of Biomedical Prototyping to manufacture of the prototype using SLS technique (Fig. 3).

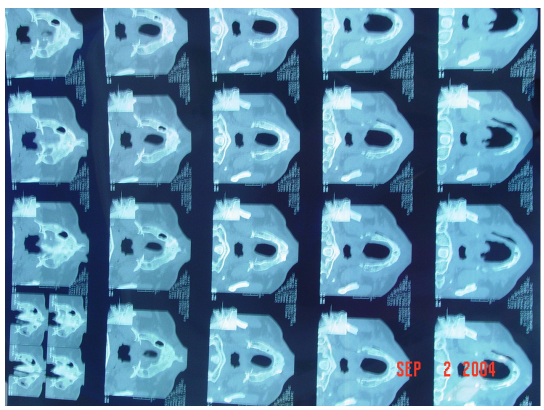

Figure 2. CT: Axial slices with 1 mm

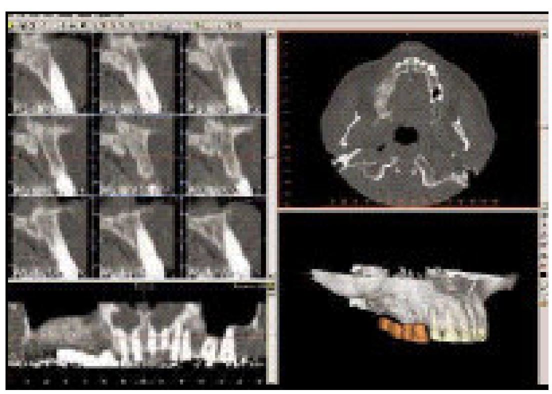

Figure 3. Virtual Process

With the prototype (biomodel) ended up, the design begins, making all measurements need in an adequate surgical-prosthetic rehabilitation (Fig. 4 and 7).

Figure 4. Prototype ended up in nylon

Figure 5. Transference of the guide

Figure 6. Surgical simulation and verification of the mesurements

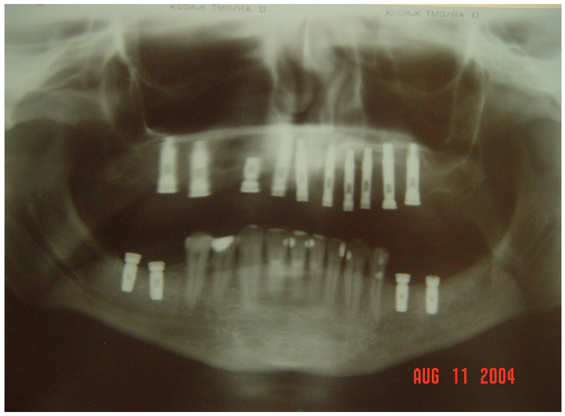

Figure 7. Final Radiographic Aspect

Cylindrical implants of external hexagons, with treated surfaces, DSP (Dental Special Products®), were used. The anterior region received implants of 3.3 mm diameter and the posterior regions implants with 4 mm diameter.

5. Conclusions

The main conclusions generated by this review of the literature and a clinical case reported, of the use of Rapid Prototyping in Implantodonty are:

- The solid replica of the patient's anatomy greatly simplifies the surgical practice and precise analysis of osseous topography;
- Provides spatial information in 3D to surgery staff;
- Evaluation of optimal implant size and position relative to anatomic limitations, existing deficients and variations;
- The models aid diagnosis, design, surgical simulation and preservation;
- Promote integration of multidisciplinar staff to obtain results closer to the proposed therapy;
- Minimization of the need for decision making at the time of implantation;
- Shortened chairside time, reduced length of surgical osseous exposure, and potentially reduced overall implant mortality and postoperative complications;
- Reduces discomfort of the patient, improve rate of success, velocity of recuperation and lower costs.

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