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Biomodelling partial anodontia case for analysis and surgical implant rehabilitation

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ABSTRACT: Partial Anodontia, also called Hypondontia or Oligodontia is a hereditary disorder occurring as a consequence of disturbances in the ectoderm of the developing embryo and manifests as a lack of development of all or most primary and/or permanent dentition, with or without a cleft lip and palate. In this case, patient is a young adult Caucasian male that suffer from Partial Anodontia and that, after clinical examination, presented the existence of 13th, 16th, 22th, 23th and 27th, with a 26th included tooth in maxilla and the presence of 36th and 46th teeth in mandible. Biomodelling – a technique that join medical imaging with additive manufacturing in order to obtain physical models will be used, and applied to mandible situation, with the manufacturing under 3DP® technique of the needed total or partial models, not only to better understand patient's case and bone condition but also to plan surgical procedures over mandible by defining implants placement and any bone reconfiguration.

1 INTRODUCTION

1.1 *Partial Anodontia disease*

Partial Anodontia, also called Hypondontia or Oligodontia is a sort of manifestation from Ectodermal dysplasia – a hereditary disorder occurring as a consequence of disturbances in the ectoderm of the developing embryo (Nunn et al. 2003; Tarjan et al. 2005).

Oral traits of ectodermal dysplasia (ED) may be expressed as Anodontia or Hypodontia – lack of development of all or most primary and/or permanent dentition, with or without a cleft lip and palate. Anodontia also manifests itself by a lack of alveolar ridge development, once there is an absence of bone production due to physical forces.

The most frequent prosthetic treatment for the dental management of ectodermal dysplasia is removable prosthodontics. Since alveolar bone development is dependent on the presence of teeth, patients with ectodermal dysplasia have little or no bone ridge upon which to construct dentures (Vieira et al. 2007).

1.2 *Biomodelling*

To face difficulty in evaluating bone quality, complementing CT (Computerized Tomography) scan diagnose method it was decided to recur to biomodeling techniques in order to produce both partial and complete physical biomodels from maxilla and mandible, once it has been proved as a valuable auxiliary technique (Queijo et al. 2010).

Biomodelling is a technique that combines image processing and additive manufacturing allowing medical image reconstruction in a 3D digital model and subsequent total or partial physical models construction.

Image processing techniques work with the image data from CT or MRI scanning devices in DICOM format, converting them in a series of sequenced images and are, essentially, based in image segmentation – an image processing technique that using the appropriated algorithms allowing user to define which anatomical structures are to maintain and which can be discarded. Once that operation is performed it is possible to perform a 3D reconstruction, using the processed image sequence, and obtaining a 3D digital model which surfaces can be translated in a triangular mesh and exported under a *.stl* type file.

This file is then transferred to proprietary software from additive manufacturing device that will translate it in a sequence of slices and allow defining additive manufacturing device setup.

Additive manufacturing is a fabrication method that builds physical models, layer by layer, over a wide range of techniques and materials available. These can go from the simplest methods of agglutinating powder composite materials with an aqua based binder, passing by plastic fused deposition or laser sintering and polymerization of resins until the high end of laser metal fusion (Queijo et al. 2009).

2 CASE

2.1 *Case description*

Patient is a young adult Caucasian male that suffer from partial Anodontia and that, after clinical examination, presented the existence of 13th 16th 22th 23th and 27th with a 26th included tooth in maxilla and the presence of 36th and 46th teeth in mandible. There were no variations in facial symmetry and no particular changes in palate or other anatomical structures with exception for light bone atrophy in the areas with dental absence. It was also reported that same situation had occurred in primary dentition and that there were not known similar cases in family.

2.2 *Case objectives*

It was intended the full rehabilitation of the total dentition by recurring to fixed implants. First phase in rehabilitation would be the mandible situation and is the case presented in this study.

3 PROCEDURE

3.1 *Image processing*

Image processing consisted in importing CT scanning images, in DICOM format, to appropriate image processing software, converting them in a sequence of editable images but maintaining CT scanning parameters. First phase of image processing is the segmentation phase. Over these images it is possible to apply a mask by defining a range, in Hounsfield scale (HU), that allow to "paint" each pixel which value lies in that range. The mask creation process is performed using an operation named *threshold*. After this process a first iteration in producing the digital rendered model, also known as 3D reconstruction, can be performed and will allow realizing which corrections in the initial mask need to be done.

Applying *erasing* tools it is possible to retouch the previously applied mask in order to maintain only the wanted anatomical structure – the mandible, without the existence of any noise or adjacent structures.

In figure 1 can be seen the overall look of segmentation process with applied mask visible in the three planes – sagittal, coronal and transverse, plus a view of the obtained 3D digital model.

The obtained 3D model is then exported under a *.stl* file format that translates its surfaces into a triangular mesh and that allow the transfer to proper additive manufacturing device software.

3.2 *Model manufacturing*

Model manufacturing was performed using 3DP® technique in a ZPrinter® 310 from ZCorporation. In print manager – Zprint® are settled up manufacturing parameters like the printing layout, the base material and the binder to be used. This device builds models layer by layer by spreading, in a building platform, a thin layer of a composite material similar to plaster. Then, like a common printing head, a section from the wanted model is drawn with the binder in the powder surface. This process repeats spreading successive layers of base material as the building platform moves down and drawing each of the sections until the model is complete.

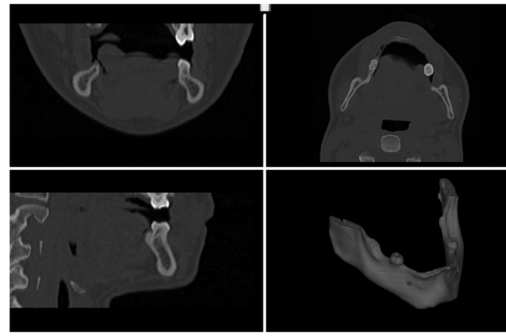

Figure 1. Image segmentation process – three planes view and rendered model.

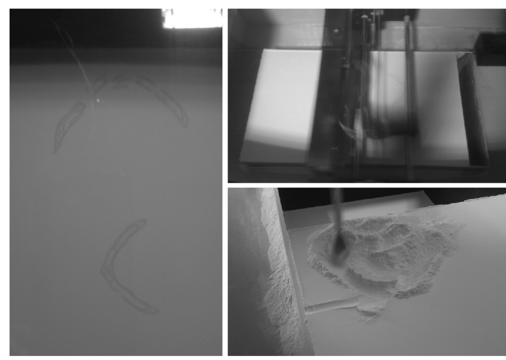

Figure 2. Model manufacturing process: sections printing, printing head working and model removal.

This model is obtained immersed in a bed of non-bonded material which leads to cleaning and surface stabilizing operations so it can be properly handled.

In figure 2 can be seen some of the manufacturing phase operations.

Cleaning and surface stabilization operations are related with models removal from the manufacturing platform, non-glued powder removal through a compressed air jet and subsequent recycling and, for last, impregnation with cyanoacrylate glue or epoxy resin, so the model gain resistance and could be perfectly handled.

4 SURGERY PLANNING

Surgery planning has been performed recurring to the models analysis, both digital and physical.

Considering complete mandible biomodel (figure 3) it was decided to divide mandible in five different

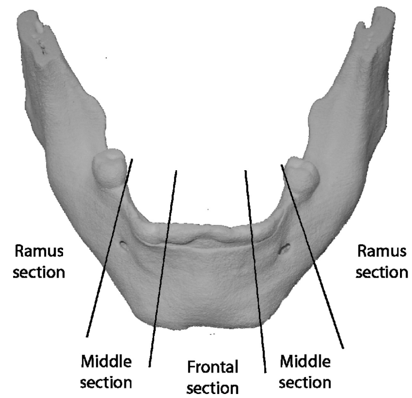

Figure 3. Complete mandible biomodel with sections definition.

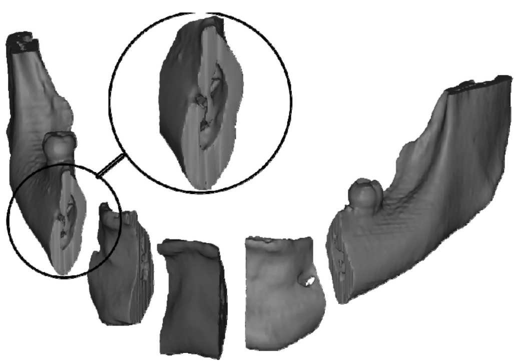

Figure 4. Sections in 3D digital model.

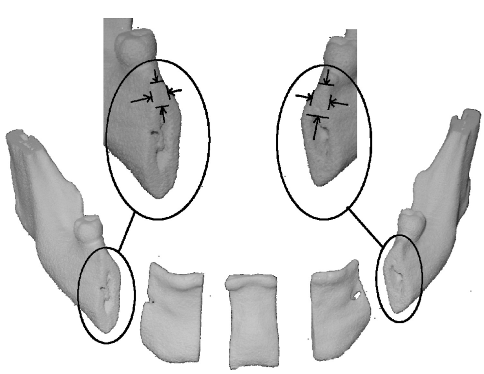

Figure 5. Sections in 3D biomodel with cortical bone evaluation.

sections so the cortical bone thickness in mandible frontal crest could be evaluated.

That way, an individual mask to each section has been created using *Boolean* operations tools in image processing software and individual models have been exported as *.stl* file. Those five individual models have, then, been manufactured following the previously described procedure. In figures 4 and 5 are shown both digital and physical 3D models.

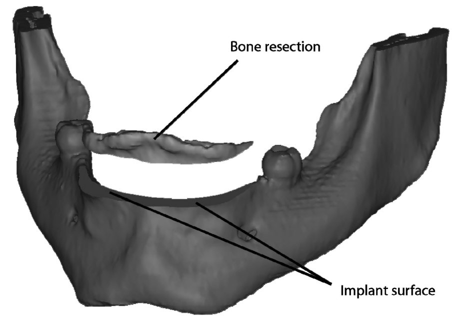

Figure 6. Mandible crest bone resection in 3D digital model.

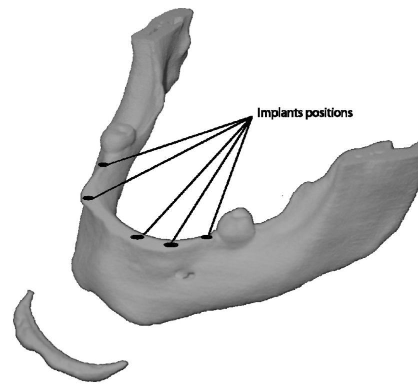

Figure 7. Mandible crest bone resection in 3D biomodel with implant positioning marks.

By measuring biomodels it was found that cortical bone at mandible crest level varied between 3 and 5 mm at a 5 mm depth from the crest top. That resulted in a medium thickness of 4 mm what totally unadvised implant placement.

Once it was considered that the available cortical bone thickness, allied to its irregularity, was unable to allow implants placement, it was decided to lower mandible central crest by performing a bone resection and creating a smother surface with incremented thickness (figures 6 and 7).

That resection should be performed at 7–8 mm from crest top in frontal view, creating a plane that should face the 36th and 46th teeth base, approximately.

The surface should be obtained with a medium thickness of about 6 mm what doesn't fulfill totally the requirements for implant placement.

As said before, after bone resection, the obtained surface still not allowing implant placement due to the bone thickness, so it was planned to perform a bone distraction in implant drilling to gain some more space that could be traduced in 1 to 3 mm what would allow placing the implants without major risks.

5 SURGERY

Surgery procedures start with gingival flap and its detachment with a periosteal elevator that allowed the

Figure 8. Implant drilling osteotomes.

Figure 9. Implant placement.

confirming mandible crest status. Following the previously planned procedures in the physical model, has been made a bone resection of mandible frontal crest, with hand tools and appropriated drills, in order to obtain the needed bone thickness.

In the cut bone surface has been used an initial drill followed by 1.8 mm drill to enlarge the holes. After parallelism confirmation, 1 mm mesial and distal drillings have been performed to turn easier osteotome bone distraction and avoid fractures.

In implants drilling have been used MIS® osteotomes until size 3.5 mm after which have been placed five 3.7 mm diameter TSV (Tapered Screw-Vent®) Zimmer® implants. In figures 8 and 9 can be seen these two last phases.

6 CONCLUSIONS

As conclusion it can be reinterred the suitability of biomodeling techniques as a valuable complementary diagnose tool in bone condition evaluation and surgical planning when applied in dental disease situations (Queijo et al. 2012).

The conventional diagnose means like CT or MRI scanning, allied to biomodelling techniques prove themselves as an outstanding way to gain full perception over a patient bone condition, especially in complex cases. The possibility of having a full scale anatomical structure replica and over it study the procedures that would be executed in surgery reduces not only surgery time but also the possibility of occurring complications due to tissues exposure and also patient's discomfort.

3DP® technique, by having a low cost operation, even that the biomodels don't have, particularly, special mechanical characteristics, presents the needed qualities to perform the wanted studies.

Through the manufactured models was possible to realize patient's bone condition and to preview the type of needed techniques to be used in his rehabilitation, either in surgical procedures as in implant locations and bone reconstruction, if needed.

By combining digital and physical 3D models analysis it was possible to define implant locations and to, clearly, define surgical procedures by realizing that it was not needed to perform bone growth in frontal mandible body, as was expected, and that with the resection to be made at that level would be enough for implant screwing after osteotome drilling.

Implants were placed successfully converting mandible rehabilitation a reality, despite the time that would be needed to allow implant osteointegration and final teeth placement.

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