

Biodental Engineering II

Editors

R.M. Natal Jorge, J.C. Reis Campos, João Manuel R.S. Tavares,
Mário A.P. Vaz & Sónia M. Santos

Universidade do Porto, Porto, Portugal



CRC Press

Taylor & Francis Group

Boca Raton London New York Leiden

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

A BALKEMA BOOK

CRC Press/Balkema is an imprint of the Taylor & Francis Group, an informa business

© 2014 Taylor & Francis Group, London, UK

Typeset by MPS Limited, Chennai, India

Printed and bound in Great Britain by CPI Group (UK) Ltd, Croydon, CR0 4YY.

All rights reserved. No part of this publication or the information contained herein may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, by photocopying, recording or otherwise, without written prior permission from the publishers.

Although all care is taken to ensure integrity and the quality of this publication and the information herein, no responsibility is assumed by the publishers nor the author for any damage to the property or persons as a result of operation or use of this publication and/or the information contained herein.

Published by: CRC Press/Balkema
P.O. Box 11320, 2301 EH, Leiden, The Netherlands
e-mail: Pub.NL@taylorandfrancis.com
www.crcpress.com – www.taylorandfrancis.com

ISBN: 978-1-138-00131-2 (Hardback)

ISBN: 978-1-315-79826-4 (eBook PDF)

Table of contents

Acknowledgements	VII
Preface	IX
Invited Lectures	XI
Scientific Committee	XIII
 How do dental students perceive profession demands? <i>M.E. Pinho, M.A. Vaz, J.R. Campos & P.M. Arezes</i>	 1
Designing dental implant surfaces by Laser microtexturing <i>M. Oliveira, J. Machado & A. Reis</i>	7
Three-dimensional visualization of teeth by magnetic resonance imaging during speech <i>S.R. Ventura, D.R. Freitas, I.M. Ramos & J.M.R.S. Tavares</i>	13
Backscattered electron imaging for the interface analysis of dental biomaterials <i>S.A. Bote, J.M. Osorio, J.M. Arroyo, P.C. Lobato & M.C.M. Céspedes</i>	19
Finite element analysis applied to a dental implant-supported structure <i>U. Garitaonaindia & J.L. Alcaraz</i>	25
Design of orthodontic mini-implants contributing to implantation torque <i>V. Katić, S. Špalj, M. Opalić & Z. Domitran</i>	29
Effectiveness of passive ultrasonic irrigation time in the smear layer removal <i>F. Tadeu, R. Madureira, O. Oliveira & L. Forner</i>	35
Impact of fluoride agents on mechanical properties of orthodontic wires <i>V. Katić, S. Špalj, J.L. Horina & D. Vikić-Topić</i>	39
Use of a clinical decision-support system in implant-supported rehabilitations <i>V. Correia, A. Correia & J. Rocha</i>	45
Composite-reinforced glass fiber morphology <i>S.A. Bote, J.M. Arroyo, J.M. Osorio, P.C. Lobato & M.C.M. Céspedes</i>	49
Biomaterials in critical-size bone defects: pointers for a standardized analysis <i>M.C. Manzanares, P. Carvalho, O. Torres, B. González, A. Fuertes, S. Arroyo & J.J. Echeverría</i>	55
Fluorescence <i>versus</i> confocal microscopy for the assessment of bone remodelling <i>P. Carvalho, B. Gallardo, M. Bosch, S. Arroyo & M.C. Manzanares</i>	59
Evaluation of the mechanical environment of the median palatine suture during rapid maxillary expansion <i>L.C.T. Serpe, L.A. González-Torres, R.L. Utsch, A.C.M. Melo & E.B. de Las Casas</i>	63
Numerical model of thermal necrosis due a dental drilling process <i>E.M.M. Fonseca, K. Magalhães, M.G. Fernandes, M.P. Barbosa & G. Sousa</i>	69
The occlusion in total prosthesis <i>P. Fonseca, M.H. Figueiral & M. Vaz</i>	75
Implant-abutment geometry and its role in bone level preservation <i>J. Ferreira, M. França, A. Correia & A. Reis</i>	79
Risk factors for implant treatment failure: a case-control study <i>C. Sedarat, S. de Chalvron, B. Ella, M. Mesnard & A. Ramos</i>	85

Biomodelling partial anodontia case for analysis and surgical implant rehabilitation <i>L. Queijo, J. Rocha & A. Ramos</i>	89
In vitro pilot study on bone heating during surgical implant bed preparation <i>S. Fangaia, M. Almeida, L. Carvalho & P. Nicolau</i>	93
<i>In vivo</i> dental implant micro-movements measuring with 3D digital image correlation method <i>T. Rodrigues, F. Moreira, F. Guerra, P. Nicolau & A. Neto</i>	97
Projection and construction of universal testing machine to simulate fatigue cycles during the insertion/detachment of implant attachments <i>C. Aroso, S. Silva, J.M. Mendes, R. Ustrell, M.C. Manzanares, J.M. Ustrell & T. Escuin</i>	101
3D evaluation of dental impaction using Computed Tomography <i>S.B. Goncalves, J.H. Correia & A.C. Costa</i>	107
Nasal bone in prenatal ultrasound and genetic changes with orofacial manifestations <i>P. Vaz, M.J. Catita, M.J. Ponces, A.C. Braga, O. Iskenderova & F. Valente</i>	111
Guided tissue regeneration and genetics <i>P. Vaz, B.M. Assunção, M. Henriques, C. Pintado, P. Mesquita & M.H. Figueiral</i>	115
Different methods for composite removal after bracket debonding <i>F.M. Lourenço, S. Castro, M.J. Ponces, J.D. Lopes, P. Vaz & L. Rocha</i>	123
Modified core design in an all-ceramic CAD-CAM crown – a numerical stress analysis <i>I. Lopes, A. Correia, J.C. Sampaio, Z. Kovacs, N.V. Ramos & M. Vaz</i>	127
New method and software prototype for automatized measurement of crestal bone levels around implants <i>A. Messias, R. Reis, S. Rocha, P. Nicolau, P. Cunha & M. Lopez</i>	131
X-ray fluorescence technique to evaluate in vitro the de/remineralization in bovine enamel <i>F.S. Calazans, R.F. Moreira, M.S. Miranda, R.S. Santos, M.J. Anjos & J.T. Assis</i>	135
Analysis of a bar-implant using a meshless method <i>H.M.S. Duarte, J. Belinha, L.M.J.S. Dinis & R.M. Natal Jorge</i>	139
Analysis of dental implant using a meshless method <i>J.R. Andrade, J. Belinha, L.M.J.S. Dinis & R.M. Natal Jorge</i>	145
Mandible bone tissue remodelling analysis using a new numerical approach <i>J. Belinha, L.M.J.S. Dinis & R.M. Natal Jorge</i>	151
A meshless method analysis of maxillary central incisor <i>S.F. Moreira, J. Belinha, L.M.J.S. Dinis & R.M. Natal Jorge</i>	159
Effects of Hydrogen Peroxide on the inorganic composition of bovine enamel <i>R.F. Moreira, F.S. Calazans, R.S. Santos, M.J. dos Anjos, J.T. de Assis & M.S. Miranda</i>	163
Analysis of failure cobalt-chromium alloy for partial removable dental prostheses <i>C.P.S. Porto, E.A. Monteiro, P.G.A. Borges, M.A.R. Nunes & S. Griza</i>	167
Stress distribution in a zirconia one-piece dental implant <i>A. Correia, J.C.R. Campos, P.C. Viana, Z. Kovacs, N.V. Ramos & M. Vaz</i>	173
Clinical records in removable prosthodontics: Paper vs computerized format <i>A. Cunha, A. Correia, J.C.R. Campos, M.H. Figueiral & J. Fonseca</i>	177
Development of a thematic learning object for removable partial denture teaching <i>S. Alves, M.H. Figueiral, A. Correia & A.V. de Castro</i>	181
Multimedia tools in the teaching of removable denture prosthesis <i>P. Rolino, A. Correia & A.V. de Castro</i>	187
Author index	193

Biomodelling partial anodontia case for analysis and surgical implant rehabilitation

Luís Queijo & João Rocha

Departamento de Tecnologia Mecânica – Escola Superior de Tecnologia e Gestão do Instituto Politécnico de Bragança, Bragança, Portugal

André Ramos

Clínica Avenida – Medicina Dentária, Bragança, Portugal

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 diagnosis 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

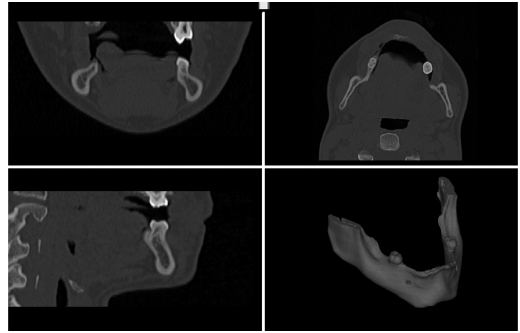


Figure 1. Image segmentation process – three planes view and rendered model.

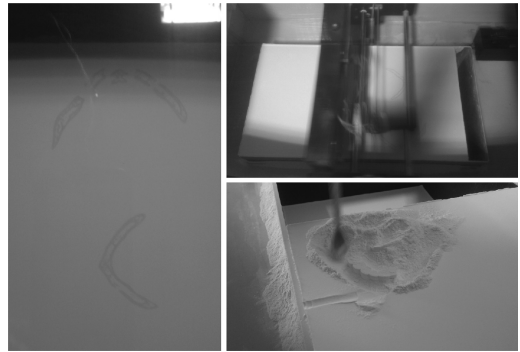


Figure 2. Model manufacturing process: sections printing, printing head working and model removal.

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.

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

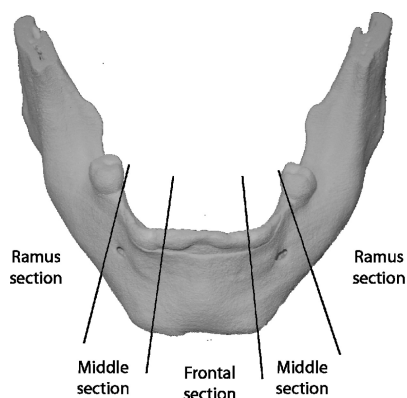


Figure 3. Complete mandible biomodel with sections definition.

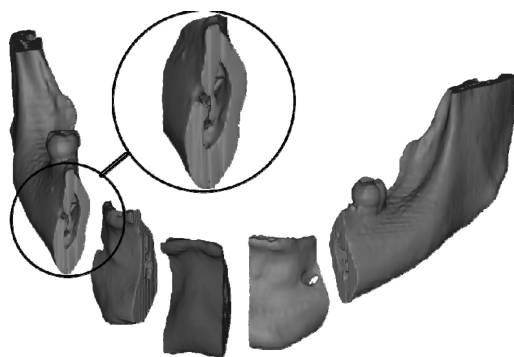


Figure 4. Sections in 3D digital model.

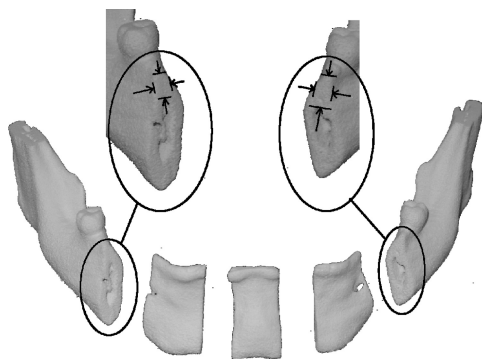


Figure 5. Sections in 3D biomodel with cortical bone evaluation.

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.

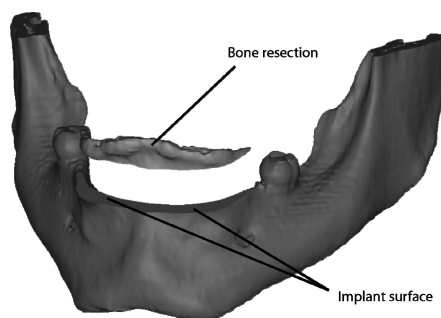


Figure 6. Mandible crest bone resection in 3D digital model.

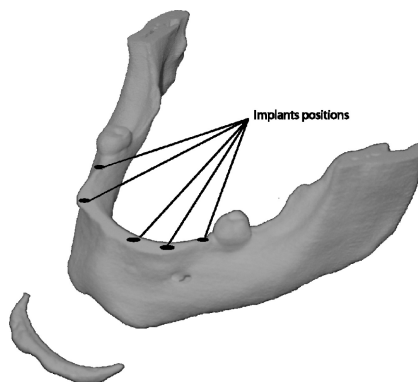


Figure 7. Mandible crest bone resection in 3D biomodel with implant positioning marks.

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 reiterated 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.

REFERENCES

- Nunn, J et al. 2003. The interdisciplinary management of hypodontia: background and role of paediatric dentistry. *British dental journal* 194(5): 245–251.
- Queijo, L et al. 2010. *Maxilla bone pre-surgical evaluation aided by 3D models obtained by Rapid Prototyping*. Boca Raton, Crc Press-Taylor & Francis Group.
- Queijo, L et al. 2009. A prototipagem rápida na modelação de patologias. *3º Congresso Nacional de Biomecânica, Bragança – Portugal*, Sociedade Portuguesa de Biomecânica.
- Queijo, L et al. 2012. Maxilla Bone Evaluation and Implant Surgical Planning in a Periodontal Disease Patient. *15th International Conference on Experimental Mechanics, Porto – Portugal*.
- Tarjan, I et al. 2005. Early prosthetic treatment of patients with ectodermal dysplasia: a clinical report. *The Journal of prosthetic dentistry* 93(5): 419–424.
- Vieira, K A et al. 2007. Prosthodontic treatment of hypohidrotic ectodermal dysplasia with complete anodontia. Case report. *Quintessence international* 38: 75–80.