The assessment of the thermal necrosis due a drilling dental process with or without irrigation

Elza Fonseca[1*], Kelly Magalhães[1], Maria Fernandes[1**], Gerdal Sousa[2], Marcos Barbosa[2]**

[1]Instituto Politécnico de Bragança, Bragança, Portugal (Departamento Mecânica Aplicada*, Tecnologia Biomédica**)

[2]Universidade Federal de Minas Gerais, Belo Horizonte, Brasil

TOPICS

- Objectives.
- Materials and methods.
- Numerical model: heat propagation from drilling process.
- Experimental model: Infrared thermal images (without and with irrigation).
- Conclusions.

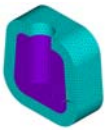
1- OBJECTIVES

- Main goal of this work is to present a numerical model to study the thermal necrosis due a dental drilling process, with and without water irrigation.
- Also an experimental methodology is used to measure the thermal occurrence in a pig mandible.
- Motivation, the assessment of bone damage, using the temperature criterion (above 55ºC) [1].

2- MATERIALS AND METHODS

- For numerical analysis the Ansys program is used.
- The heat flux produced during the drilling process is in transient heat conduction.
- The initial temperature is equal to 37ºC.
- The mesh has a hole, 2 different materials, cortical (2mm) and trabecular bone.

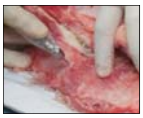




Surgical drill from 3i - Brasil. An idealized mandible: Solid90 with 20nodes, element length equal to 0.5mm.

- For experimental process a pig mandible submitted to a drilling is considered.
- The drill bit has a rotational speed equal to 750 rpm.
- The initial temperature is equal to 20ºC.
- The experimental results are obtained with a infrared thermography camera.






Experimental setup: Pig mandible.

3- NUMERICAL MODEL: HEAT PROPAGATION

- The heat propagation from drilling process was described by a heat flux density *q* received in the bone surface, according the drilling parameters, [2, 3].
- The total cutting power *Pc* is a combination between the power obtained from the feed component (*Pf*) and the power obtained from the cutting torque (*PM*).

$$q = P_c / S \quad (W/m^2)$$

$$P_c = P_f + P_M \quad (W)$$

$$P_f = V_f \times F_{fw}$$

$$P_M = M_W \times n \times 2\pi / 60$$

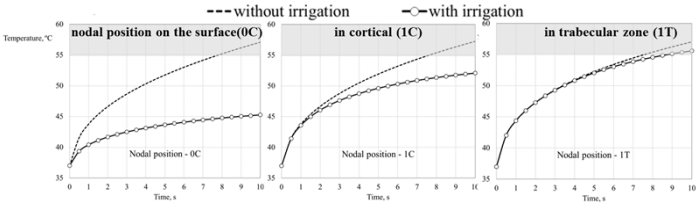
Final conic Drill bit		
d	4.1mm (in surgical process, ***3i – Brasil***)	
l	10mm (in surgical process, ***3i – Brasil***)	
V_f	50mm/min [2, 3]	
n	750rpm (in ***3i – Brasil***)	$q = 7.14\ kW/m^2$
M_W	12.5×10^{-3}Nm [2, 3]	
F_{fw}	37.5N [2, 3]	

- The thermal properties for cortical and trabecular bone are presented in table:

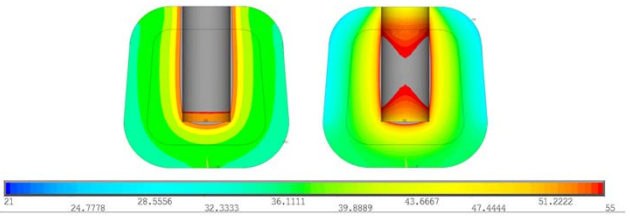
Properties	Bone	Model C2
Density, kg/m³	Cortical	2100
	Trabecular	1100
Conductivity, W/mK	Cortical	0.4
	Trabecular	0.5
Specific heat, J/kgK	Cortical	1260
	Trabecular	1490

4- NUMERICAL MODEL: RESULTS

- Numerical model without irrigation only the heat flux is considered.
- Numerical model with water irrigation, in addition, the convection effect is considered, (the convection heat transfer coefficient is equal to 100W/m²K and the bulk temperature environment equal to 5ºC).
- Results through all time-temperature history in nodal positions, near to the drill hole. The grey zone represents the bone damage on the threshold of 55ºC.
- The numerical model without irrigation in all nodal positions gets the threshold value of damage after 7s. And with irrigation presents no damage.
- Through all layer, the model without irrigation has an increase equal to 20ºC. And with irrigation has an increase equal to 8ºC near at the drill bit, on the surface.

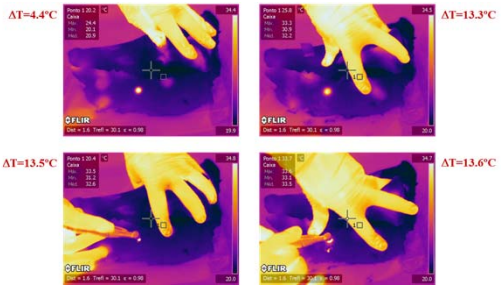


- Extension of the bone damage (ash zone) at the end of a drilling process (10s).

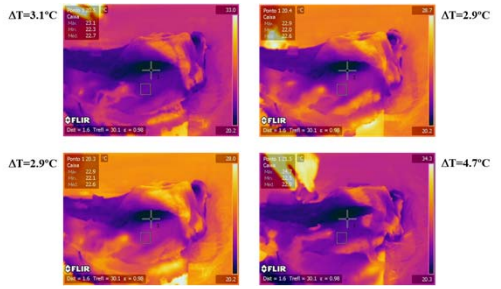


5- EXPERIMENTAL MODEL: RESULTS

- Two different tests were produced, with and without irrigation during the drilling process. The recorded temperatures are measured in the pig mandible surface.



- The increase is equal to almost 14ºC, relative to the initial temperature (20ºC).



- The increase is almost equal to 5ºC, relative to the initial temperature (20ºC).

6- CONCLUSIONS

- Comparing the increase of temperature between all methodologies, the range is similar when using the numerical model with and without irrigation.
- Model without irrigation rises above 55ºC through all drill hole, while with irrigation the thermal necrosis effect vanishes.
- The numerical model could be a technique to induce appropriate results without using in-vivo models.

[1] Hillery et al, Materials Processing Technology J, 92-93:302-308, 1999. [2] Basiaga et al, Acta of Bioengineering and Biomechanics, 13(4):29-36, 2011. [3] Hillery et al, IMC-13:33-42, Ireland, 1996.

3rd Portuguese Bioengineering Meeting
20th-22nd February, 2013
University of Minho

Acknowledgements to the companies that made possible this work: Implantec, Dmc group and 3i-implants innovation.

INSTITUTO POLITÉCNICO DE BRAGANÇA

UFMG UNIVERSIDADE FEDERAL DE MINAS GERAIS

3rd Portuguese Bioengineering Meeting
University of Minho, Campus de Gualtar, CP2-B1
20th - 22nd February 2013

Program

20th February 2013		
Time	**Theme**	**Speaker**
9:00	Opening session Esc. Engenharia/Centro Algoritmi/DEI IEEE-EMBS Portugal Chapter	Graça Minas Paulo Pereira/ João Monteiro / Fernando Ribeiro Isabel Rocha
Special Session - Third Cycle Offerings in Bioengineering		
9:30	MITPortugal - Bioengineering Program – Universidade do Minho	Eugénio Ferreira
9:50	Doctoral Program in Bioengineering Doctoral Program in Biotechnology Doctoral Program in Biomedical Eng. at Instituto Superior Técnico	Raúl Martins
10:15	Doctoral Program in Biomedical Eng. at Universidade do Minho	José Ferreira Machado
10:35	Doctoral Program in Biomedical Eng. at Universidade de Coimbra	Miguel Morgado
11:00	**Coffee-break / Master thesis Poster Session**	
Special Session - Master Thesis in Bioengineering		
11:30	Study of the effects of electrospun poly(epslon-caprolactone)/gelatin matrices on human mesenchymal stem cell culture	Beatriz J.C. Monteiro
11:50	Piezoelectric transducer system for improving mixing in 96 well microplates	Luis R. Silva
12:10	Optimisation of synthesis, purification and reformulation of (R)-[N-Methyl-11C]PK11195 for *in vivo* PET imaging studies	Vítor H. Alves
12:30	**Lunch**	
Special Session - Innovation Makers		
14:00	TecMinho – Academic Entrepreneurship	Augusto Ferreira
14:30	INL – International Iberian Nanotechnology Laboratory	Paulo Freitas
15:00	Dr. Campos Costa, SA – Medical Physics Dept.	Maria Carmo Baptista
15:30	**Coffee-break / Poster session**	
16:00	Biotecnol, SA	José Luis Moreira
16:30	Orthos XXI	Antonio Ribeiro / Susana Marques
17:00	Divmac Health Solutions	João Lacerda Cardoso
17:30	Biomode – Biomolecular Determination, SA	Carina Almeida
18:00	Closing remarks	

21st February 2013			
Time	**Theme**	**Speaker**	**Chairman**
Session Topic **Biomedical Imaging, Radiology and Image Processing**			
9:00	**Keynote Speaker** ***MyHealth – New tools in healthcare systems***	**Nuno Sousa**	Carlos Silva
9:30	Image analysis in radiology and nuclear medicine	R. Faustino	
9:45	RPC-PET: Experimental sub-millimeter resolution and whole-body reconstruction	P. Martins	
10:00	**Keynote Speaker** ***The role of Biomedical Engineering in Translational Research in Neuroscience***	**Miguel Castelo-Branco**	
10:30	**Coffee-break / Poster Session**		
Session Topic **Biomedical Imaging, Radiology, Image Processing and Biomedical Signal Processing**			
11:00	Voxel-based morphometry analyses in Alzheimer's disease	A. M. Matos	Carlos Lima
11:15	Orthogonal ray imaging: from dose monitoring in external beam therapy to morphologic imaging with scanned megavoltage X-rays	Hugo Simões	
11:30	Improved 3D retinal vascular Tree Segmentation	P. Rodrigues	
11:45	Partial volume correction in PET using probabilistic gray matter MR maps	João Lima	
12:00	Using EEG/fMRI to study the role of Gamma-band oscillations in ambiguous perception	João Castelhano	
12:15	3D reconstruction of the retinal vascular network morphology from optical coherence tomography	P. Guimarães	
12:30	**Lunch**		
Session Topic **Biomaterials, NanoBiotechnology, Biomolecular, BioProcess Engineering and BioInformatics**			
14:00	**Keynote Speaker** ***20 Years Softlithography - Its impact on Life and Materials Science***	**Hans-Georg Braun**	Cecília Calado
14.30	Functionalized gold nanoparticles for drug delivery	Sílvia Coelho	
14:45	A hybrid systems framework to design standard biological parts for synthetic biology	R. Portela	
15:00	Adsorption of intact DPPG liposome on rough polyelectrolyte multilayers	Andreia Duarte	
15:15	Quality by design in bioprocess optimization: a comparison of methodologies	M. von Stosch	
15:30	**Coffee-break / Poster Session**		
Session Topic **Bioinstrumentation, Biosensors and Neuroengineering**			
16:00	**Keynote Speaker** ***Endovascular renal artery denervation in hypertension treatment***	**Pedro Silva Cunha**	Miguel Morgado
16.30	Design, fabrication and modeling of a cuff electrode for peripheral nerve stimulation	L. Gonçalves	
16:45	Corneal metabolic imaging by FAD autofluorescence lifetime	A. Batista	
17:00	An overview of modeling and simulation for Lab-on-a-Chip applications	S. O. Catarino	
17:15	A stent-graft endoleakage monitor: telemetry system based on inductive–coupling transmission for implantable pressure sensors	Cristina Oliveira	
17:30	EEG-signals based control strategy for prosthetic driving systems	Sara Sequeira	
17:45	All-solid-state batteries: an overview for bio applications	R. Sousa	
18:00	Closing remarks		

22nd February 2013			
Time	**Theme**	**Speaker**	**Chairman**
Session Topic **Biomechanics and Computational Biology**			
9:15	An elastostatic analysis of the incisor using a meshless method	S. F. Moreira	José Machado
9:30	Constituive modelling of the annulus fibrosus: Numerical Implementation and Numerical Analysis	Clara Cavalcanti	
9:45	Multi-implant prosthesis analysis using a meshless method	H.M.S. Duarte	
10:00	Mechanical properties of breast implants	Nilza Ramião	
10:15	Rapid prototyping technique applied to surgical guidance of second reconstruction surgery of defective mandible	Chen Yadong	
10:30	**Coffee-break**		
Session Topic **Medical Robotics, Ambient Assisted Living and Modeling of Physiological Systems**			
11:00	**Keynote Speaker** ***Comanipulation for assistance to surgical gesture***	**Guillaume Morel**	Cristina Santos
11:30	Developing a timed navigation architecture for hospital delivery robots	Jorge Silva	
11:45	Wireless sensor networks for biomedical applications: Quality of serviçe, admission control and lifetime-extending challenges	Carlos Abreu	
12:00	From optical coherence tomography to Maxwell's equations	Ana Silva	
12:15	Application of finite difference time domain method	N. F. Mohammad	
12:30	**Lunch**		
Session Topic **Bioinstrumentation, Biosensors and Neuroengineering**			
14:00	**Keynote Speaker** ***The role of bionanotechnology in the development of new vaccines for infectious diseases***	**António de Almeida**	Luis Gonçalves
14.30	Chitosan-alginate microparticulate delivery system for an alternative route of administration of BCG vaccine	Liliana Caetano	
14:45	Application of an electronic nose to monitor *Pichia pastoris* cultures expressing a single chain antibody fragment (scFv)	J.M.L. Dias	
15:00	Low level laser therapy on injured rat muscle	M. Mantineo	
15:15	Clinical diagnosis of patellofemoral disorders: The role of bioengineering	Ana Leal	
15:30	**Coffee-break**		
Special Session **Bioengineering Education / Remote and Virtual Laboratories**			
16:00	**Keynote Speaker** ***Learning challenges, engineering the interoperability between brain and the Internet***	**R. Jardim-Gonçalves/ Fernando Ferreira**	Celina P. Leão
16:30	Remote Physiological Systems (RePhyS) Laboratory: a didactic learning environment	C. Barros	
16:45	A novel approach to understand bioengineering and health science: the role of webometric analysis for the creation of new knowledge	L. Marques	
Special Session **Women in Engineering**			
17:00	**Keynote Speaker** ***From the lab to the market: the challenges for scientists.***	**Carina Almeida**	Celina P. Leão
17:20	***Diversity, Creativity, mentoring,...What WiE can do?***		
18:00	Closing remarks		

Poster Session 20th February 2013		
ID	**Theme**	**Presenter**
Master Thesis		
T01	Biomechanical modeling and simulation of the Spider Crab (*Maja brachydactyla*)	Rita Rynkevic
T02	Pre-clinical validation study of optical probes for hemodynamic parameters assessment	Inês Santos
T03	Biomechanical study of a fetus during a vaginal delivery	M. Elisabete Silva
T04	Biomechanical properties of breast tissue: the elastic properties of the breast skin	Nilza Ramião
T05	Quantitative computed tomography versus densitometry in diagnostic of Osteoporosis	MJ Maciel
T06	Monitoring of bedridden patients: development of a fall detection tool	Maria Vilas-Boas
T07	Dose optimization in CT, in nuclear medicine and in PET-CT procedures	Ana Nunes
T08	Diabetic peripheral neuropathy assessment through corneal nerve morphometry	Iulian Otel
T09	Photoplethysmographic logger with contact force and hydrostatic pressure monitoring	Pedro Santos
T10	A socially assistive robot for people with motor impairments	Manuel Pinheiro
T11	Robotic implantation of intracerebral electrodes for deep brain stimulation	C. Faria
T12	A self-tunable dynamic vibration absorber: Parkinson's disease's tremor suppression	C. J. Teixeira
T13	Automatic system for determination of blood types using image processing techniques	Ana Ferraz
T14	Influence of the robotic exoskeleton lokomat on the control of human gait: an electromyographic and kinematic analysis	Filipe Barroso
T15	3D Reconstruction of a spinal motion segment from 2D medical images: objective quantification of the geometric accuracy of the FE mesh generation procedure	S. Cortez
T16	Development of a RF contactless respiratory rate monitor	João C. André
T17	Point-of-care testing device for analysis of Diabetes Mellitus	J. A. Oliveira
Under graduated - 5th Year – Master Thesis Project		

Poster Session 21st February 2013		
ID	**Theme**	**Presenter**
Biomedical Imaging, Radiology, Image Processing and		
P01	Evaluation of dental implants using computed tomography	S. B. Goncalves
P02	Synthesis of [^{18}F] NaF, and [^{18}F] Fluorocholine using a fully automated chemistry module	J. Oterelo
P03	Cyclotron production of ^{68}Ga using a ^{68}Zn-based liquid target	Francisco Alves
Biomedical Signal Processing		
P04	Using of the ultrasound frequency dependent attenuation and Nakagami distribution for cataract evaluation	Danilo Jesus
P05	A real-time home ECG signal monitoring system	J. Candido B. Santos
P06	Multimodal co-registration of ocular fundus images	R. Bernardes
Biomaterials, NanoBiotechnology and Tissue Engineering		
P07	Immunoliposomes for Alzheimer's disease therapy: Nanocarriers to cross the blood-brain barrier and bind to amyloid beta-peptide	Joana A. Loureiro
P08	Energy efficiency management by use of nanoparticles in maize seedling growth: application of nanotechnology in agriculture	Hossein A. Farahani
P09	Synthesis of well controlled dendritic structures for biomedical applications	Adérito Amaral
P10	Development of a sensor network for mapping pressure fields at the prosthesis/limb interface	A. Ferreira
P11	Acoustic streaming mixer based on piezoeletric P(VDF-TrFE) for microfluidic applications	V. F. Cardoso
P12	Poly(Vinylidene Fluoride) scaffolds for tissue engineering applications	C. Ribeiro
Biomolecular, BioProcess Engineering and BioInformatics		
P13	Real-time plasmid monitoring of batch and fed-batch *Escherichia coli* cultures by NIR spectroscopy	Marta B. Lopes
P14	Analysis of oxygen transport enhancement by functionalized magnetic nanoparticles (FMP) in bioprocess	Filipe Ataíde
P15	Functional Enviromics of the *Yeast Pichia pastoris*	Inês Isidro
P16	Principal Medium Formulations of Chinese Hamster Ovary (CHO) cells	Mauro Luís
Bioinstrumentation, Biosensors and Neuroengineering		
P17	Experimental demonstration of induction by means of a transcranial magnetic stimulator coil immersed in a conducting liquid	Hugo Simões
P18	Electrochemical immunosensor for Amyloid Beta-Peptide detection: preliminary study	Pedro Carneiro
P19	Development of an Optical Coherence Tomograph (OCT) for small animal retinal imaging	Susana F. Silva
P20	Micro antennas for implantable medical devices	P. Anacleto
P21	Rh phenotypes analysis by spectrophotometry in human blood typing	J. M. Fernandes
P22	Do we benefit from dynamical and spatial consistencies in our visual context? A contextual cueing study	Margarida Guerra
P23	Spectroscopy and pH biosensors for the detection of gastrointestinal dysplasia	Sara Pimenta

Poster Session 21st February 2013		
ID	**Theme**	**Presenter**
Biomechanics and Computational Biology		
P24	The relevance of exercise in the strengthening of the pelvic flor muscles: finite element method modelling	Thuane Roza
P25	Implant shape influence on the mechanical behavior of breast implants: application to PIP implants	Rita Rynkevic
P26	Multivariate analysis of walker-assisted ambulation	M. Martins
P27	The assessment of the thermal necrosis due a drilling dental process with or without irrigation	E.M.M. Fonseca
P28	Numerical analysis of the bone tissue remodeling due the insertion of dental implants	A.S. Ferreira
P29	Comparing Principal Elementary Modes Analysis (PEMA) and Priciple Components Analysis (PCA): application to exoplysaccharide production by *Enterobacter* A47	Rodolfo Marques
Modeling of Physiological Systems		
P30	Computational model of the LGMD neuron for automatic collision detection	Ana Carolina Silva
Ambient Assisted Living		
P31	Development of a system for monitoring and tracking of physiotherapeutic movements in patients with neurological diseases	Tiago Martins
P32	Bimanual manipulation in anthropomorphic robots	J. Araújo
P33	Technology for autistic children	Sandra Costa
P34	Eye tracking system using particle filters	Ricardo Campos
P35	Improved biomedical device for spasticity quantification	João Ferreira
Imprints on Biomedical Engineering		
P36	Numerical analysis of a dental implant using a meshless method	J. Rafael Andrade
P37	Mathematical model for partial ventriculectomy	José Sérgio Domingues