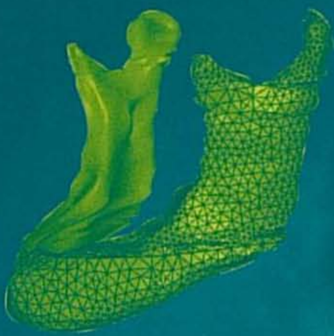

BIODENTAL ENGINEERING

III

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EDITORS

CRC Press
Taylor & Francis Group
A BALKEMA BOOK

PROCEEDINGS OF THE III INTERNATIONAL CONFERENCE ON BIODENTAL ENGINEERING, PORTO, PORTUGAL, 22–23 JUNE 2014

Biodental Engineering III

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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

Typeset by V Publishing Solutions Pvt Ltd., Chennai, India
Printed and bound in Great Britain by CPI Group (UK) Ltd, Croydon, CR0 4YY

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: 978-1-138-02671-1 (Hbk)
ISBN: 978-1-315-75178-8 (eBook PDF)

Biodental Engineering III – Natal Jorge et al. (Eds)
© 2014 Taylor & Francis Group, London, ISBN 978-1-138-02671-1

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Preface

Dentistry is a branch of medicine with peculiarities and diverse areas of action, being commonly considered as a very interdisciplinary area. The development, validation and clinical use of more competently techniques and technologies have been of great demand and interest.

The purpose of these BIODENTAL Conferences on Biodental Engineering, initiated in 2009, is to solidify knowledge in the field of bioengineering applied to dentistry promoting a comprehensive forum for discussion on the recent advances in the related fields in order to identify potential collaboration between researchers and end-users from different sciences.

This book contains the full papers presented at the 3rd International Conference on Biodental Engineering (BIODENTAL 2014), which was held in Póvoa do Varzim, Porto, Portugal, in June 22–23. The conference had 2 Invited Lectures, and 72 contributed presentations, which were selected by the conference scientific committee, and originated from 14 countries: Belgium, Brazil, China, Chile, Ecuador, France, Germany, Greece, Italy, Poland, Portugal, Romania, Spain and the United States of America.

During BIODENTAL 2014, several topics and applications were addressed, including biomechanical disorders, orthodontics, implantology, aesthetics, dental medicine, medical devices and medical imaging.

The conference co-chairs would like to take this opportunity to express their gratitude to the conference sponsors, all members of the conference scientific committee, invited lecturers, session-chairs and to all authors for submitting and sharing their knowledge.

R.M. Natal Jorge
J.C. Reis Campos
Mário A.P. Vaz
Sónia M. Santos
João Manuel R.S. Tavares
(*Conference co-chairs*)

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Thematic sessions

Under the auspicious of Biodental 2014, two Thematic Sessions were organized:

Bone tissue remodelling numerical analysis

Jorge Belinha, *Instituto de Engenharia Mecânica, Pólo FEUP, Portugal*
António Completo, *Departamento de Engenharia Mecânica, Universidade de Aveiro, Portugal*

Biomaterials in oral rehabilitation

Ricardo de Souza Magini, *Universidade Federal de Santa Catarina, Brazil*
Julio Souza, *Universidade Federal de Santa Catarina, Brazil/Universidade do Minho, Portugal*
Cesar Benfatti, *Universidade Federal de Santa Catarina, Brazil*
Claudia Volpato, *Universidade Federal de Santa Catarina, Brazil*
Márcio Fredel, *Universidade Federal de Santa Catarina, Brazil*
Filipe Silva, *Universidade do Minho, Portugal*
Bruno Henriques, *Universidade do Minho, Portugal*
Mihaela Buciumeanu, *Universidade do Minho, Portugal*

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Scientific committee

All works submitted to BIODENTAL 2014 were evaluated by an International Scientific Committee composed by 55 expert researchers from recognized institutions:

- Afonso Pinhão Ferreira, *University of Porto, Portugal*
- André Correia, *University of Porto, Portugal*
- António Completo, *University of Aveiro, Portugal*
- Carla Roque, *IDMEC, Portugal*
- Christopjh Bourauel, *Bonn University, Germany*
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- Reis Campos, *University of Porto, Portugal*
- Renato Natal Jorge, *University of Porto, Portugal*
- Sampaio Fernandes, *University of Porto, Por*tugal
- Stephen Richmond, *Cardiff University, UK*
- Yongjie Zhang, *Carnegie Mellon University, USA*

Contributed papers

Biodental Engineering III – Natal Jorge et al. (Eds)

The assessment of the generated temperature by the drill bit in the bone tissue

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R. Cerqueira
Rui Cerqueira Médico-Dentista, Celorico de Basto, Portugal

ABSTRACT: This work aims to evaluate the generated temperature in bone tissue during a drilling process. Different clinic visits were carried out to follow-up a dental implantology and collected thermographic images for reading the temperature generated during the drilling. Simultaneously an experimental procedure was adopted with the acquisition of four blocks of *Sawbones* with similar properties to the trabecular and cortical bone and different densities. The goal of this experiment resulted in a drilling process to assess the generated temperature on the drill and simultaneously on the bone material. The obtained results allow to conclude that a more dense material reaches highest values. Regarding the temperatures recorded in the drill, the largest heating is also recorded in denser bone. In clinical practice the temperature average in the drill are lower (not exceeds 33°C) than the conducted in the experiments (42°C for denser cortical), since the process occurs with fluids irrigation.

1 INTRODUCTION

Science and technology applied to health are meant to enhance the quality of the human life. In dental implants placement the variables that affect the bone drilling process are: speed, material, diameter, length and geometry of the drill point, (Fonseca et al. 2014; Fonseca el al. 2013, Monteiro et al. 2013). There are several researches on how to avoid adverse effects on the bone patient structure.

Hillery's research supported the earlier findings of Lundskog highlighting that necrosis can be induced if the bone is exposed over 30 s at tempera-tures above 50°C (Hillery, 1999). In general, the literature indicates that if the temperature rises above 55°C, in a period of 1,5 minutes, several weeks will be needed for a new bone regeneration process (Sousa, 2009). In the process of drilling the question is the need, or not, of irrigation processes. Augustin et al. 2008, studied the thermal osteonecrosis and the bone drilling parameters. The study aimed to evaluate the influence of different parameters of drilling with increasing temperature of the bone. With this study it was possible to ascertain that when using external irrigation the temperatures were lower, not reaching the critical temperature (T > 55°C). Without irrigation, the temperature for the same combination of parameters was between 31,4–55,5°C. When a drill bit with a diameter of 4.5 mm was used to drill with higher speeds, temperatures above the critical value were recorded. If the feed rate is high, a less temperature increased in the bone is verified. Thus, they were able to conclude that the external irrigation is the most important factor of cooling. The increase in diameter and in drill speed caused an increase in the temperature of the bone (Augustin et al. 2007). According to Salgueiredo et al. 2009, the use of irrigation processes can lead to a decrease of temperature in the bone until 4°C.

The main goal of this work is to evaluate the developed temperatures in bone tissue due to a drilling process, and verify the hypothesis of the thermal necrosis occurrence. Experimental methods were used in the laboratory based on the use of thermography and thermocouples during bone drilling in different materials. The follow-up of patients was also performed during the dental implants placement for data collecting from thermographic images.

2 MATERIAL AND METHODS

2.1 *Material*

In this study for the experimental setup, four blocks from Sawbones, a computer, a data acquisition MGC Plus system, type K thermocouples, a video camera, a thermographic camera and a CNC programmed machine for drilling blocks were used.

The drills used by CNC in experimental setup have an angle of 118°, once in the literature it is stated that the lower temperatures were generated for drills with this value (Basiaga et al. 2011). The four blocks from Sawbones with different densities (+D and –D) have similar properties to the human bone (cortical C or trabecular T), Figure 1.

Regarding the material densities, the cortical most dense has 800 kg/m³ and the less dense is equal to 80 kg/m³. The most dense trabecular material has a density of 320 kg/m³ and the less with 120 kg/m³.

2.2 *Clinical component*

Dental health professionals who perform the drilling process for placing a dental implant has a follow-up protocol on the use of required drills. These drills have a specific length and diameters depending on the diameter and the length of the implant.

The procedure used at the clinic who collaborated on this study was the following: first is performed a drilling point with a drill called spear; then some perforations are performed with twist drills and different diameters, depending on the area of the mandible/maxilla of each patient; after the open hole is placed the implant. The drilling speed is 800 rpm and the location of the mandible/maxilla with drilling is irrigated with saline at room temperature. During the clinical study a thermographic camera was used for temperature measurement on the drill during the drilling process. Figure 2 represents an example of these images.

Table 1 represents the temperatures obtained in the drill, during the follow-up for four patients.

Analyzing the Table 1 the temperature of the drill was never greater than 32,7°C. Whereas the temperature generated in the bone is not higher than the temperature in the drill, it is concluded that never occurred thermal necrosis.

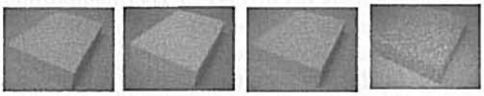

Figure 1. Blocks from Sawbones (C+D, C–D, T+D, T–D).

Figure 2. Dental clinic and thermography.

Table 1. Values of temperature of the drill bit °C.

Patient 1	Patient 2	Patient 3	Patient 4
29,1	26,8	29,3	28,5
29,3	29,1	27,8	28,4
30,0	26,7	28,9	27,9
27,6	26,6	29,9	26,4
27,0	24,9	29,9	26,1
30,5	25,1	28,5	28,1
		32,7	27,8
		30,8	27,8
			27,2
			26,8

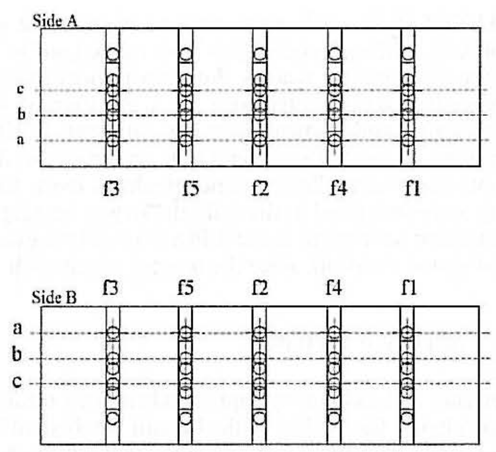

Figure 3. Schema of the block sides.

2.3 *Experimental setup*

A CAD drawing in SolidWorks was elaborated, with all indications to be used during the process of drilling on the CNC machine, Figure 3. In each block, and on one side, 5 drillings are made with only one drill (Side A) and the opposite (Side B) are performed 5 drillings but for different passages of drills. Figure 3 is a schematic drawing of the blocks sides (Side A and B) where a, b and c represent the lateral holes for thermocouples and f1, f2, f3, f4 and f5 represent the sequence of drilling during the process.

The thermographic camera will analyze the temperature during the drilling process on the bit, and the thermocouples will recording the temperature values in different materials and positions. Figures below show different images of drillings in different materials and the respective thermographic images.

Figure 4. Drilling in the C+D and thermography.

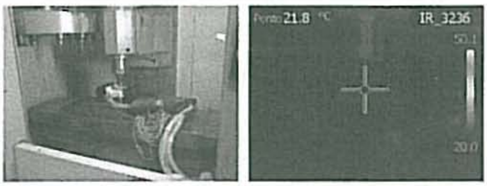

Figure 5. Drilling in the C−D and thermography.

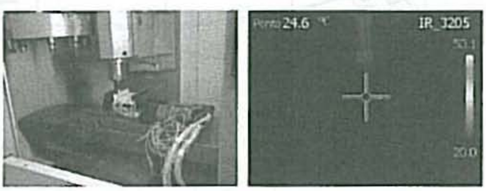

Figure 6. Drilling in the T+D and thermography.

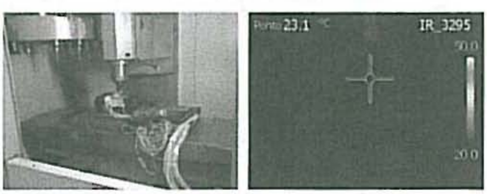

Figure 7. Drilling in the T−D and thermography.

2.3.1 *Temperature analysis on the drill*

With the use of the thermographic camera, temperature values were recorded in the drills at the end of the drilling, on the surface block.

Table 2 shows the number of samples, the mean and standard deviation of the temperatures values for different drills during the drill in different materials.

Analysing the average values it turns out that for material "C+D" the highest temperature was recorded using the drill with a diameter of 4 mm, followed by the 2 mm and finally the drill with 3 mm.

Regarding material "C−D" the drill bit with a diameter equal to 4 mm achieves the highest temperature, but the drill with 3 mm registers a temperature slightly above the drill with a diameter of 2 mm.

Table 2. Temperatures obtained in 3 phases of drilling (Side B).

	Drill bit diameter (mm)		
Material	ϕ 2	ϕ 3	ϕ 4
C + D	(5) 39,20 ± 1,68	(5) 37,84 ± 2,07	(5) 48,04 ± 1,98
C − D	(5) 21,84 ± 0,15	(5) 21,90 ± 0,36	(5) 22,58 ± 0,84
T + D	(5) 24,30 ± 0,62	(5) 24,52 ± 1,02	(5) 26,70 ± 1,33
T − D	(5) 22,28 ± 0,49	(5) 22,54 ± 0,80	(5) 23,44 ± 0,91

Note: N = Samples; M = Average; SD = Standard Deviation.

Table 3. Temperatures obtained in one phase drilling (Side A).

	Drill bit diameter (mm)
Material	ϕ 4
C + D	(4) 66,80 ± 0,99
C − D	(5) 24,24 ± 0,70
T + D	(5) 30,90 ± 2,13
T − D	(5) 23,54 ± 1,16

Note: N = Samples; M = Average; SD = Standard Deviation.

In relation to the material "T+D", the behaviour was similar to the "C−D" but with higher values, i.e. the drill bit with 4 mm has a temperature higher than the drill with 3 mm and this temperature higher than the drill bit with 2 mm.

The material "T−D" also has a similar behaviour to the material "C−D" although with higher temperatures, the drill bit with 4 mm has the highest temperature followed by the drill with 3 mm later by the 2 mm.

In general, it is possible to affirm that the highest recorded temperature was when using a 4 mm drill.

In Table 2 it can be seen that the higher temperature values are obtained with drill bit in the more dense material. In this material the drilling effort is higher compared to a less dense material, which means greater chip amount. For the standard deviation, it turns out that has higher values in the material "C+D". Also the drill bit with a diameter of 4 mm has a standard deviation higher than the values of the remaining drills, except in the denser material.

Table 3 shows the number of samples, the mean and the standard deviation of the temperature values obtained with a single drilling pass and with a diameter equal to 4 mm for all different materials.

Analysing the average values in table 3, the highest temperature recorded in the drill bit was in the material "C+D", followed by the material

"T + D", "C − D" and finally the "T − D". Once more, the denser material has the greater the temperature value. However the material "T − D" has a density higher than material "C − D", but as the first has a spongy structure there is a greater release of temperature. With respect to the standard deviation values, the highest value was recorded in the material "T + D".

2.3.2 *Temperature analysis in bone*

The use of thermocouples allows to read and record the generated temperature in the material.

As represented in Figure 3, thermocouples were placed at different distances from the main hole. The following figures show the results obtained with thermocouples, only to the hole 1 of all 4 blocks in question, considering the side B of the block that includes the 3 drilling passes.

Analyzing the figures 8 to 11 it is possible to check that the material with highest temperature values is the material "C + D", followed by the material "T + D", "T − D" and finally the "C − D". The material with highest density has high values of temperatures. It is verified that the drill bit with 2 mm provides greater warming in material, this drill produces a greater effort in relation to the drills used subsequently. The results on each block,

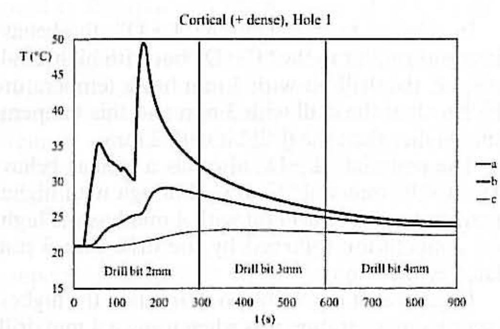

Figure 8. Material C + D, Side B.

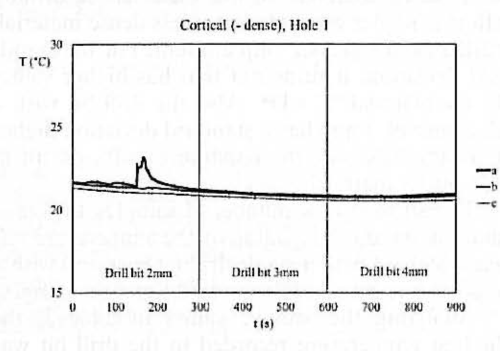

Figure 9. Material C − D, Side B.

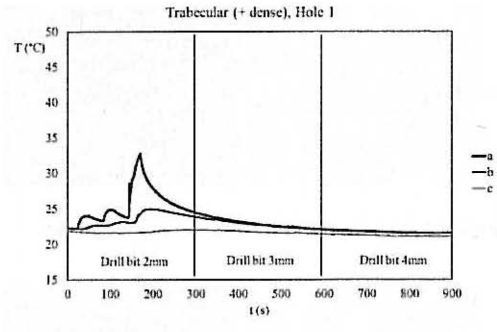

Figure 10. Material T + D, Side B.

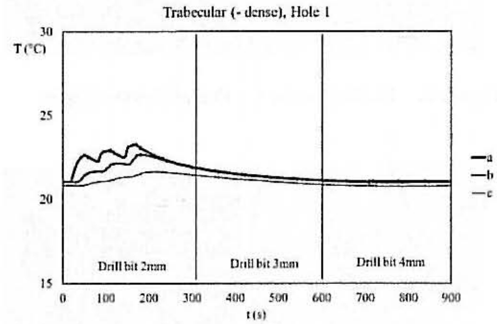

Figure 11. Material T − D, Side B.

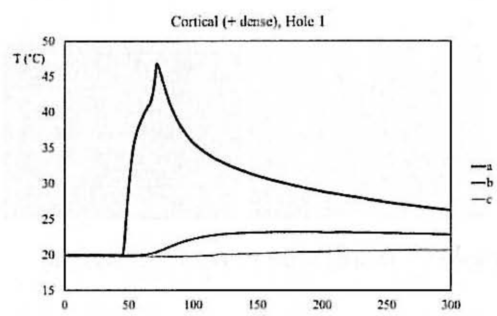

Figure 12. Material C + D, Side A.

side A, and for the thermocouples, considering one drilling phase, are presented in Figures 12 to 15, for hole 1 of each material as an example.

On the drilling with a drill bit of 4 mm, Figures 12 to 15, it turns out that in material "T − D" there is a peak of high temperature. For the material structure with several cavities and low density, the thermocouple may have come into contact with the bit, giving rise to this peak. Disregarding this effect, the material "C + D" presents the highest temperature, followed by the material "T + D" and finally the "C − D". Comparing the results obtained in

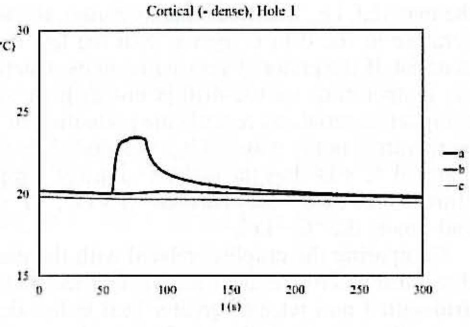

Figure 13. Material C − D, Side A.

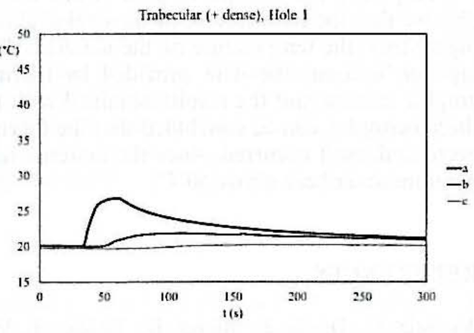

Figure 14. Material T + D, Side A.

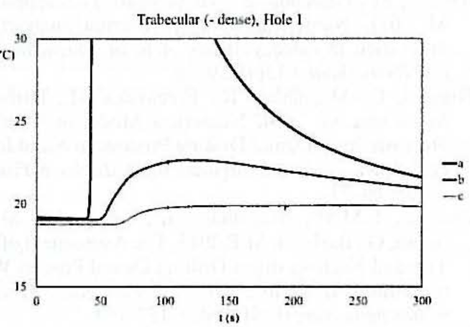

Figure 15. Material T − D, Side A.

the use of three drills for one passage, verifies that the denser materials have higher temperature with the drill bit of 2 mm and less dense materials have higher temperature when using the drill with 4 mm. So it is possible to conclude that in denser materials it is preferable to use larger diameter of the drill bits and in less dense materials smaller diameter of drill bits.

2.3.3 *Comparison between methods*

For the comparison between the two used experimental methods the temperature charts behaviour were obtained, in the drill bit and in the bone, for the different material densities. To proceed with temperature registration in the drill bit, only the values out the drill bit were obtained with the thermographic camera. Concerning the temperature in the bone, the average temperatures of the positions a, b and c (Figure 3) were obtained with the thermocouples.

Analysing the graphs relating to materials with higher densities, Figures 16 and 17, "C + D" and "T + D", with 800 and 320 kg/m^3 respectively, a similar behaviour was observed. However, in more dense cortical material, the temperatures were recorded higher compared to the denser trabecular.

With regard to materials with lower density also there are a similar behaviour, Figures 18 and 19. In this case, material "C − D" has a density of 80 kg/m^3 while the "T − D" has a density of 120 kg/m^3. The method that has a greater variability is the measurement of temperatures in drill bits.

Analyzing the Figure 20 and the recorded temperature, material with a higher density, i.e. "C + D", has the highest values. For the remaining materials "T + D" and "C + D" the recorded temperature are higher than of the lower density. It is possible to conclude that for more dense material and without cavities, greater is the temperature recorded on the drill bit. This is justified by the greater effort required by the drill bit during cutting and chip amount production. For recorded

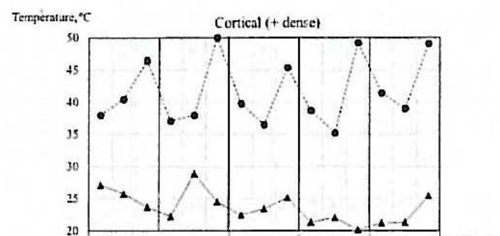

Figure 16. Comparison of methods for material C + D.

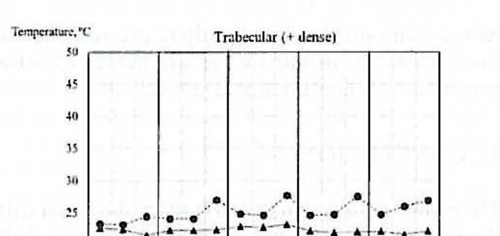

Figure 17. Comparison of methods for material T + D.

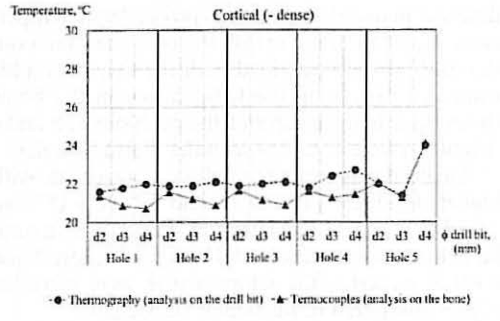

Figure 18. Comparison of methods for material C − D.

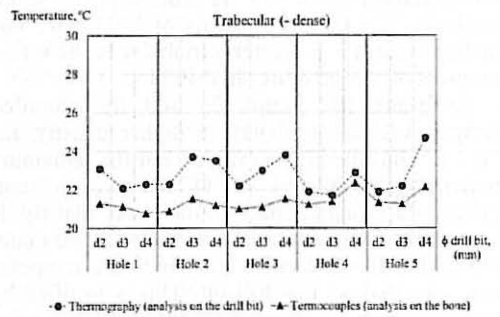

Figure 19. Comparison of methods for material T − D.

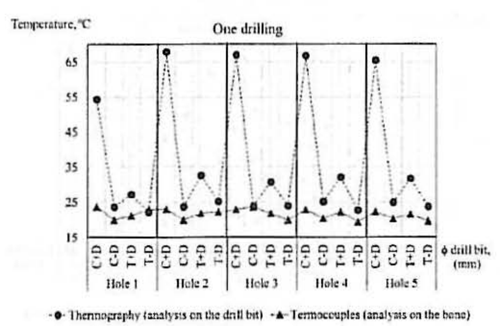

Figure 20. Comparison of methods for all materials.

temperature on the material there are some variations. However in most cases the denser material presents the highest temperature values.

3 CONCLUSION

The results obtained in dental surgery show that with the use of irrigation and combining different drilling parameters, the thermal necrosis does not occurs once the temperature did not exceed the 32,7°C.

Given the experimental setup, it is possible to conclude that the temperature increases in the drill, is according the density and the structure of the material, i.e., if the material is denser, the temperature in the drill is higher than the less dense material. If the material has cavities in its structure, the temperature on the drill is not as high as in compact material. As regards the evaluation of the temperature in the material it is concluded that the material "C + D" has the highest values of temperature, followed by the material "T + D", "T − D" and finally the "C − D".

Comparing the graphics related with the use of three drill bits for single drill, it is verified that the drill with 4 mm releases greater heat in less dense materials and the drill with 2 mm releases more heat in denser materials.

Comparing the two methods it is possible to observe that the temperature in the drill is always higher than the temperature of the material. Taking into account the data provided by thermographic camera and the results obtained with the thermocouples, can be concluded that the thermal necrosis doesn't occurred, since the material temperature never been above 50°C.

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