BioMedWomen

Clinical and BioEngineering for Women´s Health

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Preface

This book contains the abstracts and fulltexts of the Invited Lectures, Thematic Sessions, and Contributed Papers presented at the International Conference on Clinical and BioEngineering for Women's Health—BioMedWomen, that took place in June 20–23th 2015, in Porto, Portugal. BioMedWomen covered several fields of knowledge related to Women's Health, and brought together researchers from around the world. It included two Invited Lectures, three Thematic Sessions and 54 Contributed Papers.

The Invited Lectures focused on two topics affecting women worldwide: the Biomechanics of Female Pelvic Floor and its applications in the clinical practice (Margot Damaser, PhD) and the Bio-Psycho-Social Model of Women's Health (Heather L. Rogers, PhD).

BioMedWomen gathered the clinical and bioengineering perspectives from different professionals: gynecologists, urologists, physical therapists, nutritionists, sport scientists, radiologists, neurologists, engineers, dermatocosmetologists, gerontologists, psychologists, dentists, among others. Students, residents and postgraduates of all medical specialization were invited to give their contribute and to share their knowledge.

This Conference included Institutional Organizers from the educational, research and clinical settings: the Faculties of Engineering, Medicine, Dental Medicine, Psychology and Educational Sciences, Nutrition and Sports of the University of Porto; the Institute of Science and Innovation in Mechanical and Industrial Engineering (INEGI); and the Centro Hospitalar de São João—EPE.

The Conference Chair would like to express gratitude for the Institutional Support given by the FCT (Fundação para a Ciência e Tecnologia), UNESCO (Comissão Nacional da UNESCO—Portugal), the portuguese section of the IEEE Women in Engineering, biomat.net, and the Atmosfera M (Montepio). Also, a word of appreciation for all the members of the Scientific and Organizing Committees, and to the Local Organizers. Finally, to all the Invited Lecturers, Thematic Session Organizers, Co-chairs, and to all the Authors for sharing their work and their knowledge in the context of the Women's Health and well-being.

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Temperature assessment in the drilling of *ex vivo* bovine and porcine cortical bone tissue

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ABSTRACT: Thermal damage in bone tissue is a common problem in drilling processes. The main goal of this work is to analyze the cutting conditions that generate the lower temperature, avoiding the occurrence of thermal bone necrosis. In this work, the effects of the drill speed and the feed-rate were studied during the drilling of cortical bovine and porcine bone tissue. In the *ex vivo* drilling operations, two methodologies were performed on several fresh femur bone samples.

The present study showed that the combinations of cutting conditions in the drilling process of *ex vivo* cortical bovine and porcine bone tissue, produced temperatures far below the critical values. It was concluded that the temperature increases with an increasing drill speed and decreases with high feed-rates. To the drill speed, the difference is less clear than that the feed-rate. The drilling temperatures on the bovine samples were higher than porcine samples.

1 INTRODUCTION

In medicine there are several surgical procedures that could affect the human bone tissue, mainly due drilling, cutting or screwing operations of bone tissue. The post-operative success of these surgeries is widely dependant on many factors, and also the temperature generation during the drilling bone process (Fernandes et al. 2014; Fernandes et al. 2015). The main concern in bone drilling is the thermal damage of the bone tissue induced by inappropriate parameters such as drill speed and feed-rate during surgical procedures. Thus, it is important to understand and to improve the drilling conditions and all the involved variables, to reduce the heat generated and consequently minimize the bone damage. Eriksson and Albrektsson indicated that thermal necrosis in cortical bone from living rabbits occurred when this one reached a temperature of 47°C for 1 minute (Eriksson and Albrektsson 1983). Other authors showed that temperature values above 55°C for a period longer than 30 seconds can cause great irreversible lesions in bone tissue (Tu et al. 1999; Hillery et al. 1999). Currently, the evolution of temperature during the drilling of bone tissues is of great interest and has been examined mainly in animal models. The most of these studies concentrate especially on the long bones from bovine or porcine animals. These bones have characteristics that best resemble to human specimens (Aerssens et al. 1998, Yuehuei et al. 2000). There are many ways to measure the temperature during the drilling process of the bone. The most common instruments to measure the temperature are the thermographic camera and the thermocouples. The thermographic camera is a very sensitive and effective method for measure superficial temperature changes (Bedrettin et al. 2009). Therefore, in this work, the influence of the drill speed and feed-rate on evolution of the temperature in drilling bone process, was studied using the thermographic camera. The main goal was making a qualitative analysis of the obtained results in animal models, for further optimization of the cutting conditions that will allow achieve the lower temperatures and consequently improve this type of surgical procedures.

2 METHDOLOGIES

Drilling tests were carried out using animal models through *ex vivo* studies. Clinical and laboratory procedures were used to evaluate the temperature rise on several fresh femur bone samples. The clinical procedure was performed in Veterinary Hospital of UTAD (University of Tras-os-Montes e Alto Douro) using the clinical conditions involved in such proceedings. The laboratory procedure was performed in Mechanical Laboratory at IPB-ESTiG (Polytechnic Institute of Bragança) using a CNC machine to try simulate the clinical conditions but with total control of the involved parameters. The results in both procedures were analysed and compared.

2.1 *Bone sample preparation*

The study samples consisted of fresh bones (bovine and porcine femurs). These bones were chosen due to its mechanical properties similar to human bone. In total, eight bovine and three porcine femurs were obtained from a local butchery, where have been previously cleaned (muscle removed), Fig. 1.

The bones were obtained after the calves were sacrificed at the age of 9–12 months. In the clinical procedure, only bovine bone samples were used and the tests were performed immediately after obtaining the bones. The femurs were kept untouched and the holes were made respecting a real surgery procedure. In the experiments performed in Mechanical Laboratory were used both bovine and porcine bones. In this case, the samples were prepared appropriately in order to obtain just the cortical bone tissue of the femurs. These tests were performed few days after obtaining the bones. It is important to prepare the femurs appropriately, and keep their property until the day of the tests. In order to retain the characteristics and properties, the samples were prepared according to the guidelines established by Yuehuei and Robert (Yuehuei et al.2000). All samples were kept moist in saline solution with gauze swabs and stored in plastic bags at −4°C before the tests. To realize the experiments, the periosteum was removed from the outer surface of the bone samples, as it clogs the drill flutes. All the epiphysis were removed and the mid-diaphysis columns were obtained using a hacksaw. Also the bone marrow was removed, leaving only the cortical tissue (Fig. 2).

The bovine samples were 120–150 mm in length with an average thickness of the cortical of 7–9 mm, while the porcine bones were 80–95 mm in length and 4–6 mm of cortical thickness. All samples were divided to accommodating several drilled holes.

Figure 1. Fresh femurs bones samples: (a) bovine; (b) porcine.

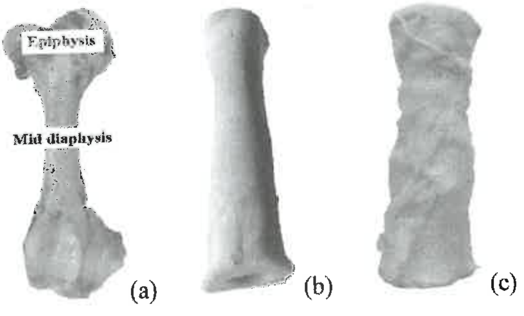

Figure 2. (a) Fresh bone; (b) sample cut from mid-displaysis and (c) sample with gauze swabs.

2.2 *Clinical procedure*

This *ex vivo* study was performed at Veterinary Hospital to simulate the clinical conditions involved in drilling process of long bones. Eight bovine fresh femurs were divided to receive six holes with 20 mm between them. The holes were made with an appropriate tool to orthopaedic surgeries (ComPact Air Drive II) from Synthes Companies, shown in Fig. 3.

This air-driven power tool, dedicated to traumatology, allows a maximum drill speed of 900 rpm. All drilling procedures were performed by one surgeon, for one operative standardization. For the purpose of this study, a conventional drill bit with Ø4 mm and point angle of 118° was used. The temperature was measured in drill bit with a thermographic camera (ThermaCAM 365, FLIR Systems) at a distance of 1.5 m from the drill bit. The camera allowed to ob-tain thermal images before and after of drilling. In order to obtain the feed-rate, the time of drilling and the hole depth were measured with a depth gauge. The average of feed-rate for all holes was calculated and the values are represented in the Table 1.

2.3 *Laboratory procedure*

In the laboratory, the *ex vivo* study was performed using a CNC machine with total control of the involved parameters. The same eight bovine femurs and three porcine femurs were used but with just the cortical tissue. In order to replicate the clinical procedure, the same drill bit and cutting conditions were employed. The selection of the cutting parameters and drilling depth of the holes were chosen through the means values obtained clinically. Table 2 shows the drilling parameters employed on CNC machine.

As it was tested in the clinical procedure, only the thermographic camera was used to measure the

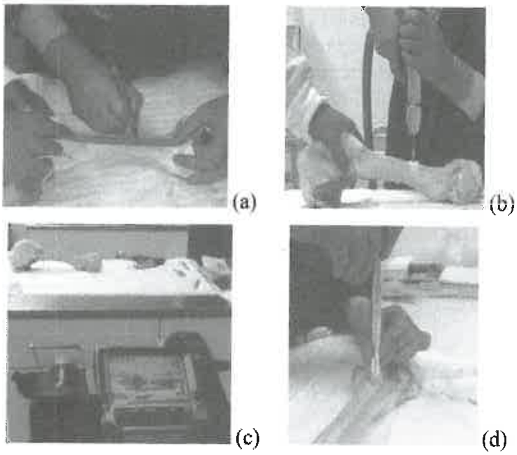

Figure 3. Clinical procedure: (a) measuring (b) drilling process, (c) thermographic camera, (d) measure the depth holes.

Table 1. Average of feed-rates used in the clinical procedure.

Fresh bovine femurs	Feed-rate [mm/min]	
	Mean ± SD	[Range]
1 (n = 6)	17.77 ± 3.04	[14.54–22.50]
2 (n = 6)	29.73 ± 4.89	[23.44–36.0]
3 (n = 5)	42.87 ± 8.40	[30.83–52.50]
4 (n = 6)	45.22 ± 2.91	[42.27–49.09]
5 (n = 6)	49.94 ± 2.45	[47.50–53.33]
6 (n = 6)	55.23 ± 3.99	[52.50–63.0]
7 (n = 6)	58.76 ± 6.27	[53.33–70.0]
8 (n = 6)	64.24 ± 5.84	[55.0–70.0]

n number of the holes, *SD* Standard Deviation

Table 2. Parameters used in laboratory procedure.

Parameters	*Ex vivo* bovine bones	*Ex vivo* porcine bones
Drill diameter	4 mm	4 mm
Drill point angle	118°	118°
Depth of the holes	8 mm	5 mm
Drill speed [rpm]	800, 900	600, 800, 1200
Feed rate [mm/min]	50	25, 50, 75

temperature in drill bit, before and after of drilling process. The holes were carried out at room temperature without cooling and the distances between the holes were the same as that used in the clinical procedure (Fig. 4).

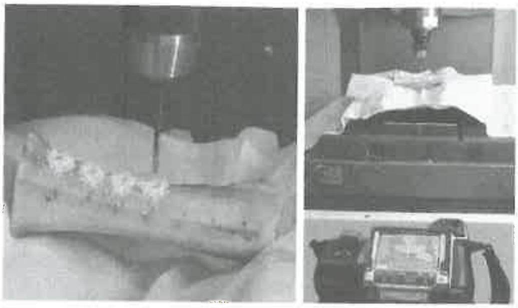

Figure 4. Drilling process in laboratory.

3 RESULTS AND DISCUSSION

During drilling of the tissue bone, the cortical tissue is the main part of the bone that generates higher temperatures. In the clinical procedures were observed the difficulties in maintaining a free-hand control of the drill, in some parameters involved, mainly the feed-rate. The main goal of this study is to understand the influence of different parameters during the drilling of the cortical tissue with total control of these parameters. The obtained results in this study were organized in two groups. In the first one, the temperature variation from clinical procedure and in the second one, the temperature variation from laboratory procedure. In the clinical procedure, through different fresh samples of bovine femur was analyzed the generation of heat to different situations of drilling. Table 3 presents the temperature values in the tool cutting, obtained in clinical procedure.

Significant temperature differences were recorded in the clinical procedure. Overall, increasing the feed-rate led to a significant decrease in maximum temperatures (Fernandes et al. 2015). However, the bovine femurs have an irregular geometry with different cortical thickness along the femur. It was found that the holes made near of the bone extremities (epiphysis), with lower cortical thickness, had lower values of temperature, while the holes made in the medial area of the bone (diaphysis), with higher cortical thickness, had higher values. The maximum value of ΔT in the drill bit was found to bovine femur 1, with a value equal to 33.90°C and the minimum value was found to femur 7 with a value equal to 7.0°C. None of the holes made clinically exceeded the maximum temperature of 55°C, considered as critical value according to the author Hillery (Tu et al. 203).

In order to evaluate the influence of drill speed and feed-rate with a total control of the parameters, different holes were made in bovine and porcine samples with different drill speeds and different feed-rates.

Tables 4 and 5 show the results obtained for all combinations of parameters in both animal models. In the results from Laboratory, it was found that the variation of the drill speed and the feed-rate influence the temperature generation in the cutting tool and consequently in bone samples. Thus, it was found that when increasing the feed-rate, the cutting tool temperature decreases (Table 5).

Table 3. Variation of temperature from drill bit, before and after drilling, in *ex vivo* bovine samples.

Bovine	Feed-rate [mm/min]	ΔT [°C] Mean ± SD	[Range]
1 (n = 6)	17.77	28.17 ± 6.21	[19.20–33.90]
2 (n = 6)	29.73	22.37 ± 4.44	[15.90–26.70]
3 (n = 5)	42.87	18.50 ± 5.48	[12.20–26.40]
4 (n = 6)	45.22	16.32 ± 1.72	[14.0–18.10]
5 (n = 5)	49.94	20.46 ± 5.95	[10.0–24.90]
6 (n = 6)	55.23	14.90 ± 4.58	[11.0–23.30]
7 (n = 6)	58.76	14.37 ± 4.96	[7.0–20.20]
8 (n = 6)	64.24	15.12 ± 5.20	[8.70–21.40]

n number of the holes, *SD* Standard Deviation, ΔT Temperature variation.

Table 4. Variation of temperature from drill bit, before and after drilling, in *ex vivo* bovine samples.

Ex vivo bovine samples			
Drill speed [rpm]	Feed-rate [mm/min]	ΔT [°C] Mean ± SD	[Range]
800	50 (n = 23)	39.80 ± 6.57	[32.80–48.37]
900	50 (n = 25)	39.78 ± 2.08	[35.55–47.02]

n number of the holes, *SD* Standard deviation, ΔT Temperature variation.

Table 5. Variation of temperature from drill bit, before and after drilling, in *ex vivo* porcine samples.

Ex vivo porcine samples			
Drill speed [rpm]	Feed-rate [mm/min]	ΔT [°C] Mean ± SD	[Range]
600	50 (n = 7)	28.22 ± 6.20	[20.4–34.20]
1200	50 (n = 7)	36.60 ± 3.49	[31.0–41.20]
800	25 (n = 7)	26.42 ± 6.51	[15.90–33.90]
	50 (n = 5)	18.36 ± 1.82	[16.10–21.10]
	75 (n = 7)	18.87 ± 1.46	[16.80–20.80]

n number of the holes, *SD* Standard deviation, ΔT Temperature variation.

These results are in agreement with the clinical results. With regard to drill speed, the difference is not so significant. It is necessary to increase or decrease significantly this parameter to cause evident influences in the generated heat. Tables 4 and 5 show that just in drill speeds (600 and 1200 rpm) occurred a significantly rise of temperature in the cutting tool, while rotation of 800 and 900 rpm do not differ significantly.

Comparing the holes performed in different animal models, it is verified that the temperatures are higher in holes made in bovine samples, which would be expected since the cortical bone thickness is larger (7–9 mm) compared with porcine cortical bone thickness (4–6 mm).

4 CONCLUSIONS

The temperature rise analysis in the cutting tool coupled with different techniques and different ex vivo animal models is crucial to improve the drilling surgeries. The conditions of the bone drilling in clinical and laboratory environment were assessed and the best cutting conditions to produce low temperatures were found. It was shown by clinical and laboratory procedures that the feed-rate, the drill speed and the cortical thickness, are essential parameters in the prediction of temperature rise, and so reduce the damage level in the bone tissue. In this study it was found that the higher feed-rates have produced lower drill temperatures in both procedures. The drilling speed during bone drilling suggests no consistent trend (Pandey and Panda 2013). There was no significant change in the drill temperatures produced in drilling from 800 rpm to 900 rpm in bovine samples but in porcine samples it was found that the temperatures increases with increasing speed from 600 rpm to 1200 rpm.

It was also shown the temperature increased with the increase of the depth of the hole. The temperature generated in the drilling bovine samples was higher than that produced in the drilling porcine samples. This was expected, since the bovine bone is stiffer and the cortical bone tissue depth is greater than the porcine bone. As conclusion, appropriate control of drill conditions and the joining of the clinical and laboratory practice will allow to prevent the thermal necrosis and to improve the drilling surgeries.

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BioMedWomen 2015 – Clinical and BioEngineering for Women´s Health contains all author contributions presented at BioMedWomen 2015 (Porto, Portugal, 20–23 June 2015). International contributions from countries worldwide provided comprehensive coverage of the current state-of-the-art on different topics:

- Aging
- Physical Activity and Sports
- Physiotherapy
- Aesthetic and Reconstructive Surgery
- Urogynecology
- Imaging
- Biomechanics
- Nutrition
- Health Psychology
- Assisted Diagnosis and Treatment
- Tissue Engineering
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BioMedWomen 2015 – Clinical and BioEngineering for Women´s Health will be of interest to academics and to others interested and involved in clinical and engineering subjects related to women´s health.

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