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# Book of Abstracts



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## Drilling of bone: numerical and experimental investigations

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### Abstract

Implant failures and post-operative problems may occur after implant placement as a result of the inappropriate conditions during drilling. The analysis of different materials and drilling parameters is crucial to reduce the bone damage and contribute to the success of this medical interventions. In this research, the effect of drilling parameters on the generated stresses and temperatures in the bone during the process was investigated. Experimental methods were performed using synthetic and biological materials. Also, a numerical model was developed and calibrated using a three-dimensional elasto-plastic dynamic finite element method. The examined variables were the drill speed, the feed-rate and the drill bit diameter. Results indicated that the temperature and stresses increased with increase in the drill speed and drill diameter and decreased with increase in the feed-rate. The experimental results permit to calibrate the numerical model, which could be used for any dynamic analysis according this procedure.

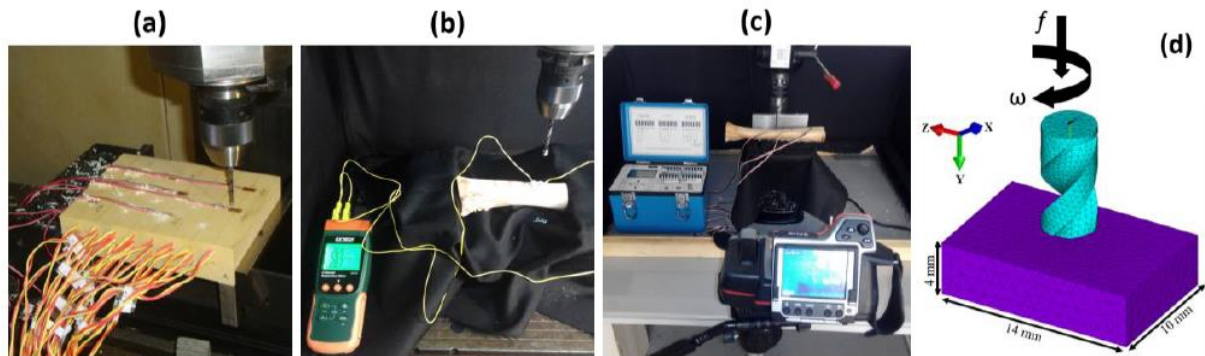
**Keywords.** Bone drilling, temperature, stress, drilling parameters.

### 1. Introduction

Bone fracture or tooth replacements are a common public health problem due mainly to age factors and accidents. The fracture repairing or dental implant placement require the use of drilling procedures in the bone, as a preparation for mounting screws, prosthesis attaching and bone fractures fixation. During drilling, mechanical work resulting from the friction between the drill bit and the bone tissue is transformed into thermal energy which leads to increase of bone temperature as well as cutting tool (Gupta and Pandey 2016). Besides the negative thermal impact, high drill speed with higher cutting forces and tool vibrations can also cause mechanical damages on the bone microstructure, resulting in microcracks formation and bone fracture. It has been proven that drilling parameters such as drill bit geometry, drill speed and feed-rate have direct relationship with the quality of bone during the drilling procedure (Fernandes et al. 2015; Fernandes et al. 2016; Fernandes et al. 2017; Fernandes, Fonseca, Natal et al. 2017).

In the present study, experimental and numerical investigation are developed in order to find more details about the effects of drill speed, feed-rate and drill bit diameter on temperature, strains and stresses evolution during drilling. Different experimental tests were performed using three test material: synthetic bone (solid rigid polyurethane foams from Sawbones Pacific Research Laboratories, Inc., Vashon. WA, USA), animal bone (bovine femurs) and human bone (human cadaveric tibiae). The materials were instrumented with multiple thermocouples and strain gauges to measure the temperature distribution and the level of strains, respectively (Figure 1). Temperature control in the cutting tools were carried out using a thermal camera (ThermaCAM 365, FLIR Systems) at distance of 1.5 m from the drilling area.

Subsequently, a numerical study was conducted using a nonlinear transient dynamic finite element code. The numerical models aim to simulate the drilling process and to predict the bone damage, while taking into account of the drilling parameters ( $f$  = feed-rate and  $\omega$  = drill speed), as show in Figure 1(d). The performed numerical analyses were correlated with experimental results in order to validate the results and gain new knowledge. The drilling tests were conducted for drill speeds rates of 520, 600, 800, 900, 1200 and 1370 rpm; feedrates of 0.42, 0.83 and 1.25 mm/s; and drill bit diameters of 4, 5 and 6 mm (all of them were twist drill bits with a point angle of  $118^\circ$  and helix angle of  $30^\circ$ ). All experiments started from room temperature (approximately  $20^\circ\text{C}$ ) without applying cooling at the drilling zone. The holes were performed in a computer numerically controlled (CNC) system and a vertical drilling machine.



**Figure 1:** Experimental and numerical procedures: (a) polyurethane foam, (b) bovine femur, (c) human cadaveric tibiae and (d) numerical model for drilling.

## 2. Results and Conclusions

Results identified the drill bit diameter as the most critical parameter for inducing higher temperatures and stresses in bone drilling. The increase in drill speed caused increase in bone temperature and stresses during drilling. With the increase in feed-rate, increase in bone temperature and stresses are lower. Validation of the numerical models was carried out comparing numerical results and experimental results with good accuracy

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