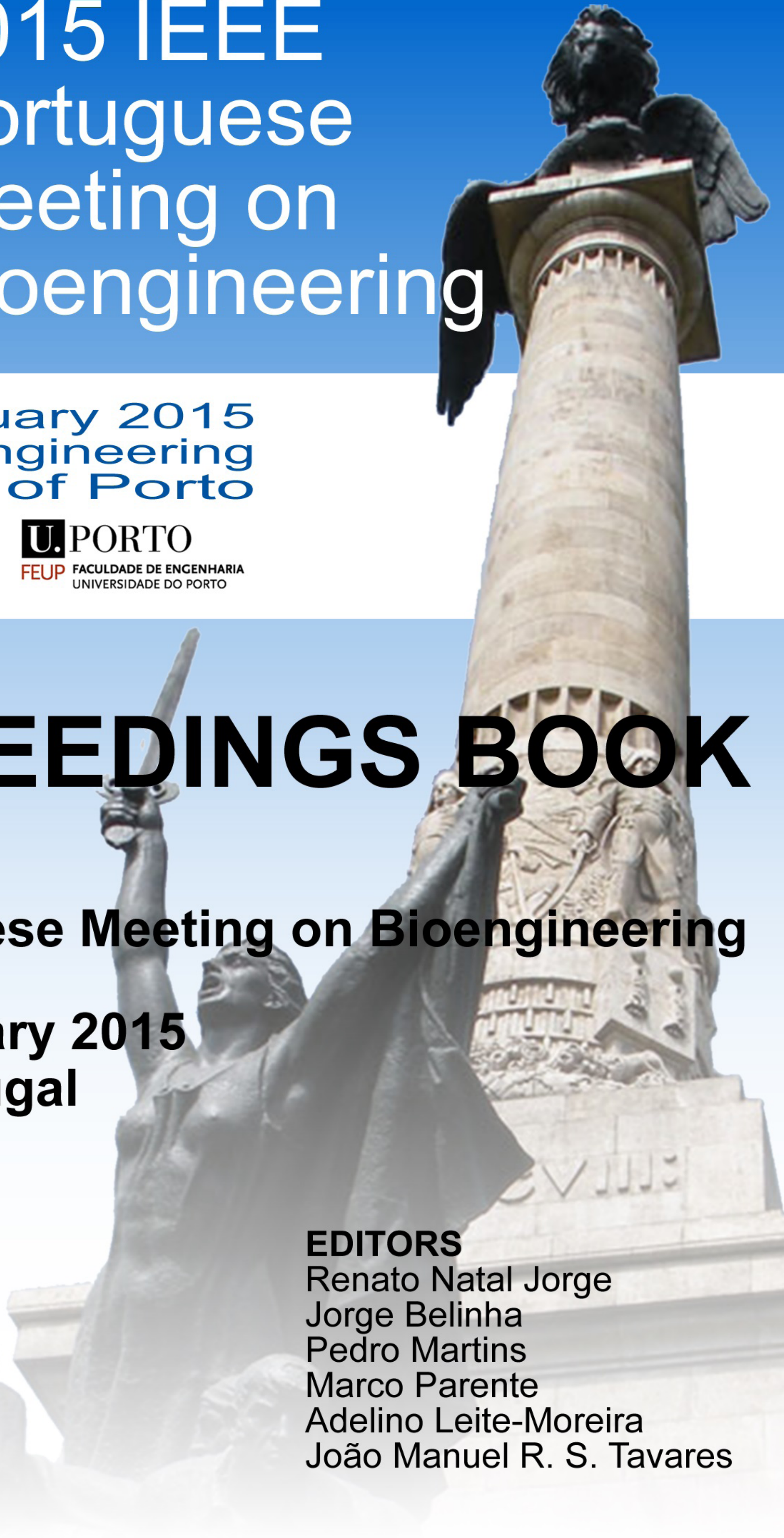
4th 2015 IEEE Portuguese Meeting on Bioengineering

26-28 February 2015
Faculty of Engineering
University of Porto

IEEE EMB Portugal Chapter · IEEE Portugal Section · U.PORTO FEUP Faculdade de Engenharia Universidade do Porto



PROCEEDINGS BOOK

2015 IEEE
4th Portuguese Meeting on Bioengineering
ENBENG
26-28 February 2015
Porto - Portugal

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Preface

This book contains the abstracts and full papers presented at the IEEE 4th Portuguese Meeting on Bioengineering (ENBENG) organized by the IEEE Engineering in Medicine & Biology Society (EMBS) Chapter of the IEEE Portugal Section that was held in "Atmosfera m", in the city of Porto, between 26th and 28th, February of 2015.

The Portuguese Meeting on Bioengineering is one of most important meetings organized in Portugal related with the Bioengineering field and where students and researchers present and discuss the preeminent work developed in Portugal in the field. The meeting has been organized since 2011: the first was held in Lisbon, in 2011; the second in Coimbra, in 2012; and the third occurred in Braga, in 2013.

ENBENG2015 had 107 works submitted, from which 52 were accepted for oral presentations distributed by 10 sessions, and 31 as posters. The submissions involved authors from several Portuguese Institutions, which shows the importance of the Bioengineering and Biomedical Engineering in Portugal nowadays. Additionally, 9 submissions were from foreign countries. The received contributions address several topics related to Bioengineering, including Biomaterials, Nanobiotechnology, Tissue Engineering, Biology of Stem Cells and Regenerative Medicine, Bioprocess Engineering, Bioinformatics Engineering and Biomolecular Engineering, Biomechanics and Computational Biology, Biomedical Signal Processing, Radiology and Biomedical Imaging, Image Processing, Bioinstrumentation, Biosensors and Neuroengineering, Medical Robotics and Human-Machine Interface, Clinical Informatics, Modeling of Physiological Systems, Domicile Autonomy Assistance and Education in Bioengineering, which emphasis the multidisciplinarity of the field.

We would like to thank to all the Sponsors, members of the Scientific Committee, Invited Lecturers and Authors for sharing their work and Participants for contributing to the effective discussion forum established during the meeting. Finally, we acknowledge the Portuguese Chapter of the IEEE Engineering in Medicine & Biology Society (EMBS) for the privilege that was the organization this edition of The IEEE Portuguese Meeting on Bioengineering and for the support offered.

Porto, February 26th, 2015

The Organizing Committee:

Renato M. Natal Jorge

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Pedro A. L. S. Martins

Marco P. L. Parente

Adelino Leite-Moreira

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(Universidade do Porto & INEGI)

Introduction of the Chair of IEEE-EMBS Portuguese Chapter

The IEEE Engineering in Medicine & Biology Society (EMBS) is the world's largest international society of biomedical engineers. It is committed to the application of engineering sciences and technology for the advance of medicine and biology, to the promotion of the Engineering professions that aim to improve health and enhance quality of life and the development of their professionals, as well as to promote multidisciplinary scientific and technical events for dissemination of knowledge.

In Portugal it is represented by its Portugal Section Chapter, which congregates Portuguese IEEE-EMBS members and has the goal of promoting synergies between the engineering and the life sciences for their development, through the generation of knowledge and its application in an integrated and multidisciplinary way.

In the last ten years there has been a huge increase of the academic offer in the areas of Biomedical Engineering, Biological Engineering and Bioengineering. Presently, Portugal has more than one thousand graduates in these areas and there are also hundreds of students currently attending the corresponding undergraduate and graduate programs.

It is our belief that the objectives of the IEEE-EMBS stated above correspond to the needs and aspirations of the growing community of Portuguese professionals in the areas of Biomedical Engineering, Biological Engineering and Bioengineering. We believe that the IEEE-EMBS Portuguese Chapter is the organization with better conditions to promote these professionals and carry out the dissemination of knowledge in these areas.

The IEEE Portuguese Meeting on Bioengineering (ENBENG), now in its 4th edition, is fundamental to fulfill IEEE-EMBS goals in Portugal. This event brings together people and entities from the academic, business and clinical areas, connected to the disciplines of Biomedical Engineering and Bioengineering, and it is a forum for the dissemination and promotion of their activities and for establishing synergies and opportunities for development and cooperation. It addresses a wide range of topics related to Bioengineering, reflecting the multidisciplinarity of the field, and focus on the participation of graduate students and young researchers providing them the opportunity to present their works.

In our opinion, the IEEE Portuguese Meeting on Bioengineering (ENBENG) is the ideal event to congregate the Portuguese community of Biomedical Engineering, Biological Engineering and Bioengineering. The IEEE-EMBS Portuguese Chapter is committed to the annual realization of this meeting and will spare no efforts to make it the leading occasion for bringing together the professionals and students from this growing community.

Miguel Morgado

Chair, IEEE-EMBS Portuguese Chapter

Procedings of the 2015 IEEE 4th Portuguese Meeting on Bioengineering, Porto, Portugal, 26-28 February 2015

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Analysis of stresses in drilled composite materials

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Abstract— **In this study, a three-dimensional dynamic model was built to simulate the drilling process in the composite materials. With an explicit dynamic simulation it is possible to obtain large structural deformation and to apply high intensity loading in a short time frame. Using this methodology, the influence of different cutting parameters were considered during the drilling process in typical composite materials. Also, similar tests were produced in laboratory using composite blocks. Each composite material was instrumented with strain gauges to obtain the strain in different surface positions during the drilling process. The results from the numerical methodology were compared with the experimental methodology. It was concluded when the feed-rate is higher the stresses and strains in the composite material are lower. The obtained numerical and experimental results were similar. Therefore the developed numerical model proved to be a great tool in this kind of analysis.**

Index Terms—stresses; bone damage; bone drilling

I. INTRODUCTION

In medicine there are many surgical procedures that involve the bone tissue, often entail cutting, drilling or screwing operations of the bone. The success of these surgeries is dependent of many factors and the bone damage degree generated during the drilling process. Several studies have been published about specific problems that cause bone damage during the drilling process. One of these problems is the cutting effort achieved during the process and is directly related with the drilling parameters, particularly, the drill speed, the feed-rate and the applied force [1]. It is essential to understand and to improve the cutting conditions and all the variables involved to minimize the bone damage. The finite element method has been one of most useful tools for simulate the drilling bone process and evaluate the tissue biomechanics during the drilling [2].

II. EXPERIMENTAL AND NUMERICAL MODEL

In this study, two different methodologies were used to evaluate the damage bone from cutting efforts in drilling process. In the experimental methodology were used strain gauges for obtain the surface stresses in three composite blocks from Sawbones with similar density to the cortical bone. During the experimental tests 18 holes with instrumented strain gauges (6 holes in each composite block) were produced, (Fig. 1).

Figure 1. Strain gauges application and the drill process.

All holes were made using a conventional drill bit with 4mm of diameter, 30mm of depth and a point angle equal to 118º. The distances between the edge of the drilled hole and the strain gauge were measured, as represented in Fig. 2.

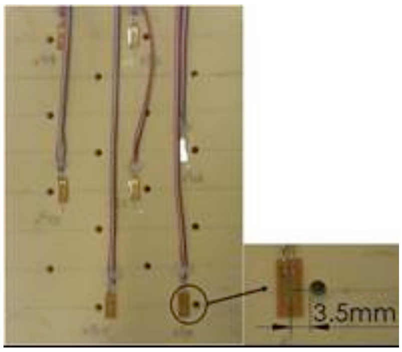

Figure 2. Distance between the edge of the drilled hole and the strain gauge.

The drilling parameters considered in this work are described in Table 1. Three different feed-rates were used, in order to evaluate the influence on the drilling process. All the other parameters were considered as a constant.

Table 1. Drilling parameters.

Parameters	
Drill diameter	4mm
Drill length	30mm
Drill speed (ω)	800rpm
Feed-rate (v_f)	25, 50, 70mm/min

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Considering the experimental model, a three-dimensional dynamic numerical model was developed using LS-DYNA to simulate the drilling process. The numerical model uses the Finite Element Method (FEM) for the composite block and the drill bit, considering all variables in the drilling process. The geometry of the drill bit was built in SolidWorks program with same dimensions that drill bit used in the experimental model. The composite block with overall dimensions of 10x14x5mm was modelled as cortical bone specimen, as a part of the test composite material shown in Fig. 3.

Mechanical properties of the cortical bone and the drill bit were considered in this analysis and are summarized in Table 2 [3-6]. The drill bit was modelled as a rigid body in order to reduce the computing time and resources, with high stiffness (220-240 GPa) when compared with the cortical bone equal to 16 GPa [7]. The cortical bone behaviour was simulated using an elastic-plastic material, depending on the strain rate and the failure criterion of the material. The removal of bone during the drilling process was simulated by element deletion that occurs when the plastic strain of an element reached the limit [8]. LS-DYNA provides several criteria for removing elements during a numerical simulation.

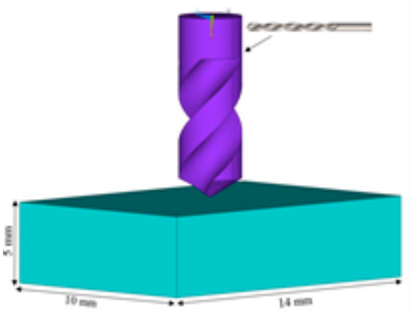

Figure 3. Geometrical configuration of the drill bit and the composite block.

Table 2 Mechanical properties used in FEM analysis.

Properties		Drill bit	Cortical bone
Density (kg/m^3)		7850	800
Young's Modulus (GPa)		200	16.7
Poisson's ratio		0.3	0.3
Yielding Stress (MPa)		—	27
Tangent Modulus (MPa)		—	2083.3
Hardening Parameter		—	0
Cowper-Symonds model			
	C	—	0.13
	P	—	0.0001
Failure Plastic Strain		—	0.0021

The numerical model was meshed using *SOLID164* elements (8 nodes with three degrees of freedom at each node in X, Y, Z directions), as show in Fig. 4. This element is used in explicit dynamic analyses only.

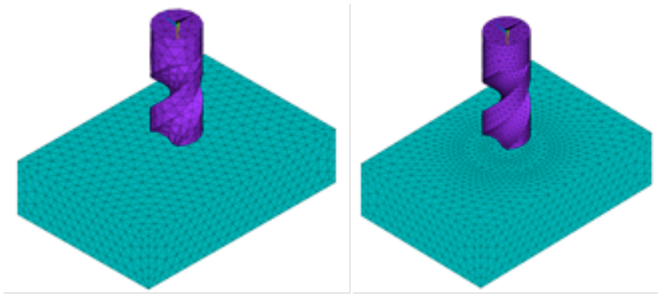

Figure 4. Mesh of drill bit and the composite block used in FEM analysis.

Several mesh convergence study was carried out to obtain a more suitable model for this kind of simulation. A mesh size discretisation of cortical bone was obtained in the vicinity of the drilled place with size equal to 0.5mm for the finite elements edge, and a coarse mesh was used in the block away from the location of the drill bit. The composite block was kept fixed in all vertical faces, while the drill bit was constrained to rotate only about its own longitudinal axis with a specified speed and feed-rate downwards into the composite block. The numerical analysis was performed with the same drilling parameters used in the experimental model as shown in Table 1 and represented in (Fig. 5).

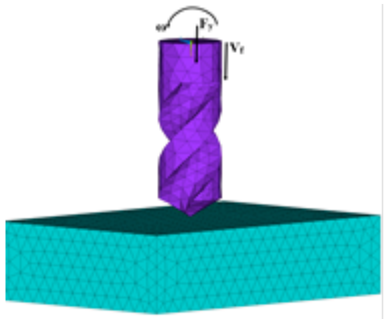

Figure 5. Boundary conditions of the numerical model.

Contact elements were used to simulate the contact between the drill bit and the cortical bone, and defined by the "Eroding" contact algorithm available in LS-DYNA. This algorithm allows one or both outer surfaces suffer damage in contact and continue with the remaining internal elements. The frictional contact between the drill bit and the cortical bone was modelled with a constant coefficient of friction equal to 0.3 [9]. The simulations require on average 72 hours on quad-core i7-4790k with 16 GB RAM.

III. Results and Discussion

The aim of this work was to investigate the levels of strains and stresses induced in the cortical bone, caused by a cutting tool. Experimental and numerical procedures were used and the results comparison were discussed. The strains were obtained during the drilling depth using strain gauges and the generated normal stresses were calculated at the composite blocks surface. Fig. 6 and 7 show the evolution of stresses obtained in six different holes performed with feed-rates equal to 25, 50 and 75mm/min, during the drill depth.

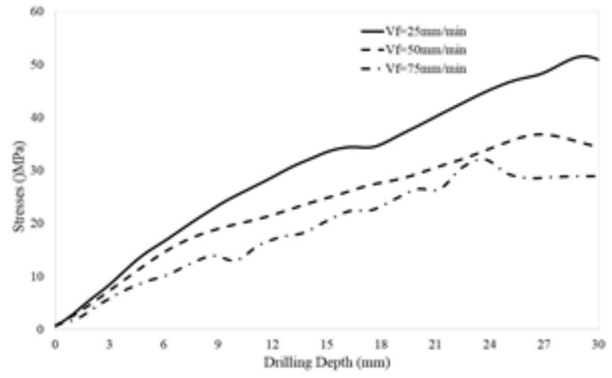

Figure 6. Normal stresses at different feed-rates, hole 1 (H1).

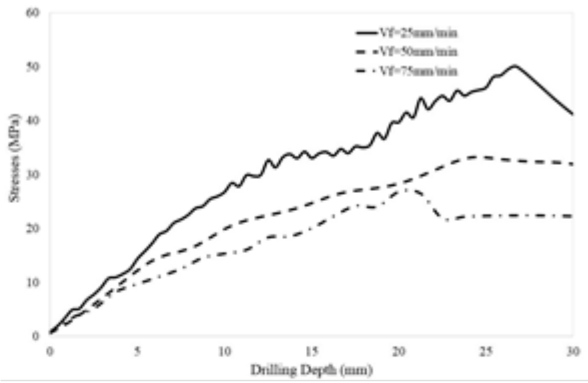

Figure 7. Normal stresses at different feed-rates, hole 2 (H2).

The experimental results show that generated stresses in the bone increase with tool penetration. The greater of the drilled hole depth, produces high stresses values generated in the bone. These results are in agreement with studies performed by Alam et al. [10].

Through of the different feed-rates, it was found that the increase of feed-rate decreases the generated stresses in the bone, as shown in Fig. 6 and 7. The maximum value of the stresses obtained in experimental model was approximately 50MPa at the end of the drilling depth with a feed-rate equal to 25mm/min.

In the numerical model were performed different numerical simulations with different feed-rates (25, 50 and 75mm/min) to compare the stresses results to the experimental method. Fig. 8 represents the levels of von Mises stresses in different stages of drilling until to complete the drilling of the cortical bone. For each feed-rate was considered an adequate time for complete penetration of the cortical bone (5mm).

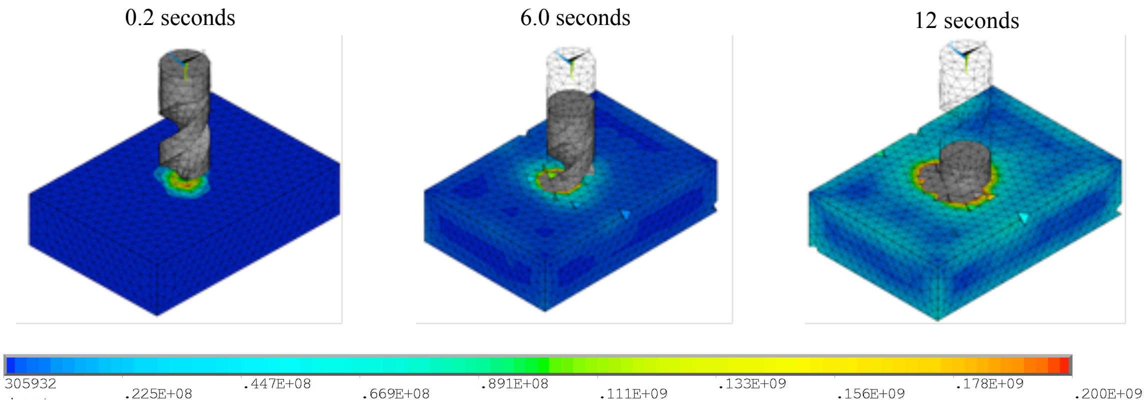

Figure 8. von Mises stresses (Pa) for different time instants (v_f= 20mm/min).

Also in the numerical model, with the progress of drill penetration, the level of von Mises stresses in the bone increases, reaching a maximum value when the drill bit penetrated completely the cortical bone. The level of maximum stress was found in the drilled area and its immediate vicinity.

In order to compare the numerical with experimental results, different nodal positions were considered and the average of the normal stresses were calculated. Table 3 shows the mean of normal stresses located near of each hole obtained experimentally and numerically. The calculated distance between the edge of the drilled hole and the strain gauge was also considered in both methodologies.

According the results present in Table 3 it was found that in both methodologies when the feed-rate parameter increases the stresses and strains in the composite materials decreases. It was also found that for the most remote areas of the drilling zone the normal stresses in bone surface are lower. The levels of maximum stresses were found near of the drilled area vicinity, as already observed in the numerical model, Fig. 8. The numerical model was validated using the experimental model, and both methods are in agreement.

Table 3. Normal stresses (MPa) in experimental and numerical models.

Feed-rate (mm/min)	Experimental							Numerical
	H1	H2	H3	H4	H5	H6	**Average**	
V_f=25	14.87 (L=3.5mm)	14.32 (L=4.0mm)	13.77 (L=4.0mm)	11.57 (L=5.5mm)	11.52 (L=5.5mm)	11.09 (L=5.5mm)	**12.86**	**12.88**
V_f=50	17.90 (L=3.0mm)	16.98 (L=3.0mm)	12.25 (L=3.5mm)	10.70 (L=4,0mm)	8.51 (L=4,5mm)	7.86 (L=5.0mm)	**12.37**	**11.85**
V_f=75	11.03 (L=3.5mm)	9.07 (L=4.0mm)	8.80 (L=4.0mm)	8.40 (L=4.0mm)	7.48 (L=4.5mm)	7.42 (L=4.5mm)	**8.70**	**8.68**

H_i drilled hole number, L distance between the edge of the drilled hole and the strain gauge

IV. Conclusions

There are several studies in the literature about the influence of the different parameters in bone drilling processes, however there is no clear agreement between different authors. In this study two different methods were used to evaluate the stresses distribution in the cutting region and in vicinity areas, obtained for different drilling parameters. Using different feed-rates it was possible to verify a decrease of stresses and strains in composite materials when the feed-rate is higher. As foreseen, the normal stresses in the far hole regions were lower than near of the hole region.

In this study the three-dimensional finite element model proved to be a great analysis tool to simulate the bone drilling dynamic process, useful to evaluate the performance of surgical tools alternatively to the hard theoretical work. The numerical model should be applied in various cases of drilling, considering different variables and allowing to obtain quickly and accurate results in all involved variables.

Acknowledgment

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