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ON THE EFFECT OF BONE MICROSTRUCTURE IN DRY DRILLING OPERATIONS

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Introduction

Drilling operations are frequently carried out to place screws for the fixation of implants or prosthetic parts during a surgical process. However, because of the bone temperature elevation during drilling, an osteonecrosis phenomenon can occur. Many experimental works have been devoted to the analysis of the influence of drilling conditions on the increase of bone temperature [1-3]. However, very few works have been focused on the relationship between the bone microstructure and the effect of cutting conditions on cutting temperature. Karaca et al [4] have measured the bone mineral density (BMD) of calf bone samples and they have showed that the drilling temperature increases with BMD. In the present work, we analyze the influence of the bone microstructure and cutting conditions (cutting speed and feed rate) on the bone temperature and cutting forces. A large range of drilling conditions is investigated.

Methods

To analyse the effect of cutting speed and feed rate on thrust forces and temperature in bone drilling, tests were performed on approximately 70mm-long and 10mm-wide bone samples extracted from the dyaphyseal area of porcine femurs. In the present work, 4 mm depth dry drilling tests were carried out on an industrial machining centre using a surgical drill tool of 3.2 mm diameter. Axial cutting forces or thrust forces (Z direction) were measured using a KISTLER Minidyn 9256C dynamometer. Bone temperature was measured by two K-type thermocouples. Micro tomography scans (EasyTom, RX Solutions, France) were carried out for each bone specimen before and after drilling operation. Scans post treatment was performed with AVIZO version 9.0 software (FEI VSG, France). The bone cylindrical area machined by the drill was deduced from pre and post experimental scans. To determine the Bone Volume Fraction (BV/TV), a batch process was executed on AVIZO. The selected values of cutting speeds varied from 2 to 32 m/min and from 20 to 160 $\mu\text{m}/\text{rev}$.

Results

For cutting speed of 5 m/min and feed of 40 $\mu\text{m}/\text{rev}$, Fig. 1(a) shows typical signals of axial force, torque and measured temperature during drilling. It can be observed that the axial cutting force presents a maximum which is shown to be related to the transition between the cortical and the cancellous bone. A

maximum temperature of 80°C is obtained from the thermocouple situated at 0.5mm from the drilled hole. An illustration of the relationship between the bone microstructure and the evolution of cutting force in drilling is reported in Fig. 1(b). A direct correspondence is observed between the evolution of the thrust force and the bone volume fraction.

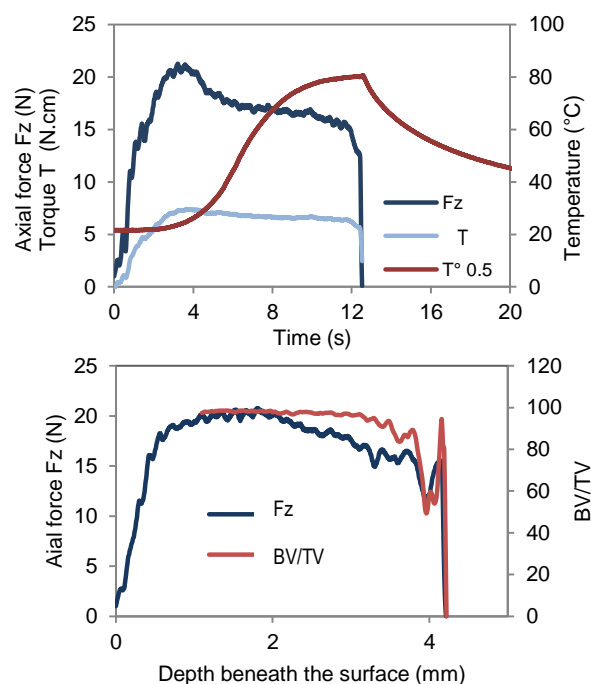


Figure 1: (a): Typical thrust force, torque and temperature signals (b) A correlation between the bone microstructure and the measured cutting force

Discussion

The results of this analysis show that the bone response to drilling is directly correlated to its microstructure. Other results provided by this preliminary study indicate that the influence of cutting conditions (cutting speed and feed rate) on the temperature elevation and cutting forces also depend on the bone microstructure. These observations can partly explain the fact that in the literature, contradictory trends are often reported about the influence of cutting parameters during bone drilling.

References

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