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Detection of Microcracks During Bone Cutting Using Acoustic Emission Techniques

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Detection of Microcracks During Bone Cutting Using Acoustic Emission Techniques

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Introduction

Surgeons may use a number of cutting instruments such as osteotomes and chisels to cut bone during operative procedures.

The initial loading of cortical bone during the cutting process results in the formation of microcracks in the vicinity of the cutting zone with main crack propagation to failure occurring with continued loading [1]; microcracking acts as a stimulus for main crack formation and has also been shown to occur during the propagation of the main crack [2]. It has also been reported that Acoustic Emission (AE) is generated due to microcrack formation and crack growth, prior to, and during final fracture in tensile loading of bovine [3] and human cortical bone [4].

In this study, we recorded the number of AE hits and AE signal amplitudes during monotonic indentation cutting of cortical bone, to correlate between the intensity and duration of the signals and micro and macro crack formation and propagation.

Materials and Methods

8mm cubes of cortical bone were cut at 3 load levels: corresponding to 0-60%, 60-90%, 90-100% of the mean peak cutting fracture load. The bone was loaded longitudinally by a 90˚ wedge indenter mounted on a Hounsfield Universal Testing Machine. Tests were conducted at a constant crosshead speed of 5 mm min^{-1} with crosshead position maintained for 30s after each of the loading phases.

AE signals were recorded using one miniature AE sensor (200-750 KHZ/ PICO) located at one side of the bone cube. A threshold value of 40dB and a fixed gain of 40dB with 0.1-1 MHz band pass filter were set [5]. The following AE parameters were recorded and analysed: number of AE hits, AE signal amplitude and AE duration. A subset of AE hits was also created, based on load levels.

Results and Discussion

Figure 1 shows the load/time and AE behavior during indentation cutting of a typical bone specimen. The right hand axis gives the number of AE hits that may be associated with microcrack formation and main crack propagation. We found that the majority of AE signals (i.e. 85%) occurred during the final loading phase (Table 1). In the immediate time period before and during fracture more AE signals were generated than has been previously reported in studies on tensile testing of bone [4].

Signals of both high amplitude and high duration (HH type) were mainly observed during final fracture (1400-1600N range), whereas AE signals observed prior to fracture (i.e. 1000-1400 N) were mostly low amplitude - low duration (LL type) [3]. We hypothesise that it may be possible to correlate between different type of AE signals (LL & HH type) and different deformation processes during cortical bone fracture.

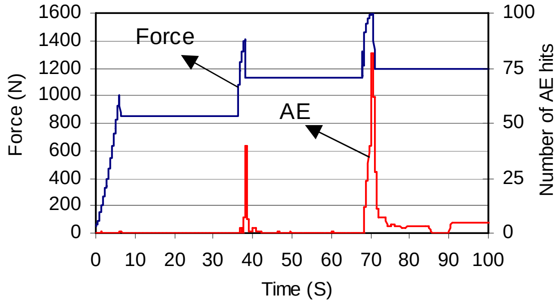

Figure 1: *Force and number of AE hits versus time during indentation loading*

Load Range	Total Number of AE Signals (%)	Total Number of High-amplitude Signals (%)
0-1000 N	Negligible	Negligible
1000-1400 N	15%	25%
1400-1600 N*	85%	75%

Table 1: *AE signals at chosen load levels.*
**AE after fracture load (1600 N) is included.*

Conclusions

This analysis shows that AE signals increase substantially during the loading phase just prior to fracture. Furthermore, we have shown that the majority of the high amplitude signals occur during the final loading phase also.

We conclude that this method is useful in monitoring the crack initiation and fracture during the cutting process and may be extended to distinguish between different deformations processes such as formation of microcracks and main crack propagation during cortical bone fracture by analysing the AE parameters such as amplitude and duration.

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