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USING AN IMPACT HAMMER TO PERFORM BIOMECHANICAL MEASUREMENTS DURING OSTEOTOMIES: STUDY OF AN ANIMAL MODEL

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ABSTRACT

In rhinoplasty, osteotomies are carried out to cut bone tissue and reshape the bony nasal vault using an osteotome (bone chisel) impacted by a surgical mallet. Such intervention are particularly difficult to master as the surgeon often has to perform them without any visual control. Our group has developed an instrumented hammer able to perform biomechanical measurements during osteotomies. The proof-of-concept had been obtained *in vitro* in a previous study [1]. The objective of this study was to validate the method *ex vivo* using an animal model. Osteotomies were performed on the nasal bones of seven rabbit heads and the instrumented hammer recorded a signal for each impact. The results showed a significant correlation between an indicator derived from the signal and the displacement of the osteotome in the bone tissue, as well as significant differences in the values of the indicator between the nasal and frontal bones. The results suggest that such a device could be used as a decision support system for surgeons during their osteotomies.

1. INTRODUCTION

Osteotomies are surgical procedures used during rhinoplasty, among other interventions in maxillofacial and orthopedic surgery, in order to cut bone tissue [2], [3]. They are typically performed using an osteotome (bone chisel) and a surgical mallet. Despite their routine use in clinical practice, osteotomies still present a number of risks [4] due to the lack of visual control. A preliminary study performed by our group has shown that a hammer instrumented with a force sensor could be used to retrieve information on the mechanical properties (material type and thickness) of plates of various composite materials [1].

The aim of the present study was to determine whether such approach could be employed in an animal model in order to i) follow the movements of the osteotome in the bone tissue, and ii) detect the arrival of the osteotome at the frontal bone (which corresponds to the end of the osteotomy pathway).

2. MATERIALS AND METHODS

2.1 Sample Preparation

The animal model selected for this study was the New Zealand White rabbit since it is widely used to model rhinoplasty [5] as well as osteotomies [6], [7]. Seven rabbit

heads were collected from the National Veterinary School of Alfort (Maisons-Alfort, France). For each head, an osteotomy was performed on both the left and right nasal bones using the instrumented hammer (see Fig. 1).

2.2 Experimental Procedure

The osteotomies consisted in series of hammer impacts on the osteotome, alternating between strong impacts (in order to cut bone tissue) and weak impacts (in order to perform localized measurements without modifying the position of the osteotome relatively to bone tissue). For each impact, a signal $s(t)$ corresponding to the evolution of the impact force in time was recorded through the piezoelectric force sensor.

2.3 Data Processing

A first indicator, τ , was derived from the signal, and corresponded to the time between the first two peaks of force in $s(t)$. For the strong impacts, a second indicator D , corresponding the displacement of the osteotome with each impact, was measured using the video footage of the experiments.

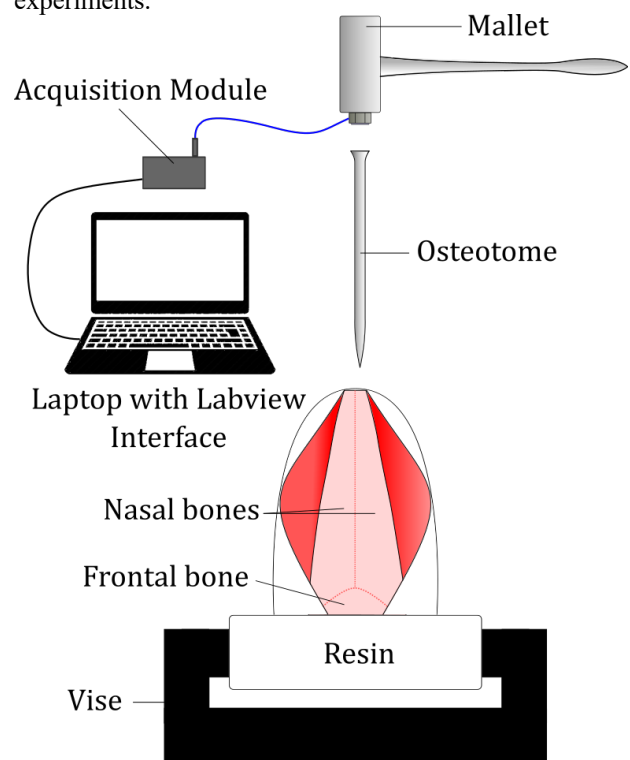


Figure 1. Experimental setup for the realization of the osteotomies.

3. RESULTS

The results showed that low and repeatable values of τ were obtained for weak impacts. An ANOVA analysis showed that the values of τ in the frontal bone were significantly lower than in the nasal bone ($p < 10^{-10}$), as shown on Fig. 2.

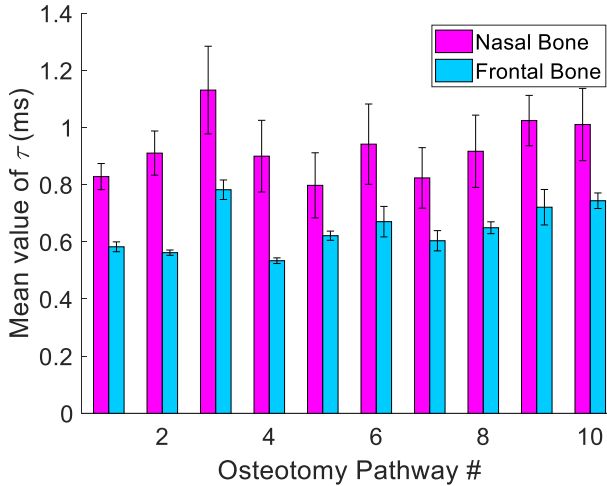


Figure 2. Averaged values obtained for τ in the nasal and frontal bones.

Moreover, when considering strong impacts only, a strong correlation was obtained between τ and D (see Fig. 3), with a spearman correlation coefficient $\rho^2 = 0,74$.

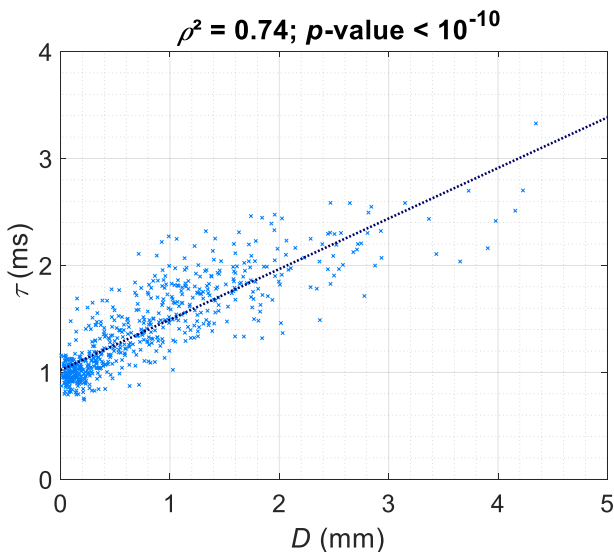


Figure 3. Relationship between τ and D obtained for the different pathways (all data pooled).

4. DISCUSSION

The indicator τ has previously been shown to be related to the biomechanical properties (stiffness and thickness) of the environment surrounding osteotome tip [2]. When the osteotome progresses through the bone tissue, it first induces a crack opening and then moves into the space created by the crack, which leads to a loss of overall rigidity of the system. Such phenomenon might explain the

correlation between τ and D . Similarly, the nasal and frontal bone have different biomechanical properties, the frontal bone being the most rigid and thick. Consequently, the transition between the two different environments is characterized by a change in value of τ .

These results suggest that the instrumented hammer could use the values of τ measured for each impact to i) track the movement of the osteotome in the bone tissue and ii) detect the transition between the nasal and frontal bones, which corresponds to the end of the osteotomy pathway.

5. CONCLUSION

The study of the animal model provides encouraging results, which will later need to be confirmed on anatomical subjects. This paves the way for the development of an instrumented hammer that could assist surgeons in their decision-making process during rhinoplasty procedures.

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