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Thermal Changes in Human Bone Following Osteotomy by Three Different Devices – a Histological Analysis Using Different Staining Protocols

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Osteotomy is a common step in surgery. Chisels, drills and ultrasound machines are commonly used. Recently, high-energy lasers have been introduced. Heat and related mechanical damage during osteotomy can impair bone healing. Therefore, thermal osteonecrosis greatly affects the postoperative outcome. So, the **aim** of our study was to compare the thermal changes occurring in human bone after *in vivo* bone cutting using three different devices. Well-defined histological signs of thermal changes were demonstrated in all samples. Based on the observed results, it can be concluded that despite cooling systems, it is not completely possible to prevent thermal changes in human bone by its *in vivo* osteotomy.

Key words: drilling, Er:YAG laser, human bone, piezosurgery, thermal changes

Introduction

Osteotomy is a common step in surgery. Motorized rotary and oscillating cutting tools have been developed, allowing precise and direct cutting. However, conventional osteotomies have several drawbacks: the requirement for relatively high open exposure, the risk of tissue overheating, leading to possible thermal necrosis [10]. Heat and thermal osteonecrosis greatly affect patients' postoperative outcome, possibly causing infections [8], implant loss and delayed healing [2]. To reduce these complications, laser- and ultrasound-based osteotomy have been developed. Several *ex vivo* studies on animal bone [11] have recently focused on the heat production during osteotomy. However, conflicting conclusions regarding the effect of temperature on bone tissue can be seen by comparing *in vivo* and *ex vivo* studies [14]. Wächter et al. [14] revealed lower bone temperature in *in vivo* samples because bleeding can evacuate more heat energy than in *ex vivo* settings. Researchers have concluded that *in vivo* studies are essential for understanding how bone healing occurs after osteotomy and how blood flow and biological factors fit together [11].

In our opinion, the results of *ex vivo* animal models cannot be transferred mechanically to clinical practice. There are many similarities and differences regarding bone parameters concerning animal species and between animals and humans [1]. Thus, the **aim** of our study was to compare the direct thermal impact of three different cutting devices on human bone.

Material and Methods

Human bone biopsies for analyses of thermal changes following conventional drilling, laser and ultrasound osteotomy were taken during surgical removing of mandible third molars. Patients who were taking bone morphology affecting drugs or antibiotics for current acute local infection at the time of operation or who had chronic bone disease were excluded. All patients were informed about surgery, postoperative time and possible complications. The research has been carried out in accordance with Declaration of Helsinki. The research design was approved by an ethical committee. All participants signed an informed consent.

The following instruments were evaluated in the study: an Er:YAG laser (2.94 μm LiteTouch, Light Instruments®, Israel), an ultrasound unit (Woodpecker Ultrasurgery®, China) and a conventionl drilling device (W & H Surgical Handpiece®, Austria). A standard setup for bone manipulations were used according to the manufacturer's instructions. All biopsies were obtained by the same oral surgeon. Bone fragments were placed in 10% buffered formalin solution. Following decalcification, 5 μm thick sections were stained with Hematoxylin – Eosin and Toluidine Blue and examined under an optical microscope.

Results

Although all examined osteotomes were fitted with a cooling system, histology signs of thermal changes were observed in all samples. Sections obtained by traditional drilling showed poor peripheral carbonization and a low-grade thermal damage was clearly visible on all staining methods. Piezosurgery bone biopsies demonstrated bone incisions with minimal thermal damage established on the specimens stained with Toluidine Blue in contrast to the Hematoxylin - Eosin staining. Bone fragments obtained with an Er:YAG laser showed also peripheral thermal changes, but no melting was observed at the edges of the incisions; even osteocytes near the incision were unchanged (**Fig. 1**).

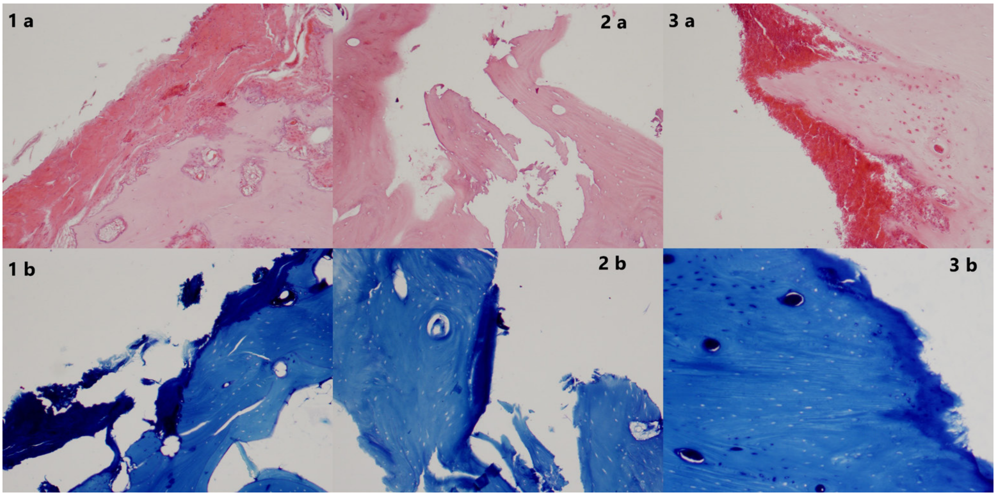

Fig. 1. Images of human bone specimens (× 10): **1** – a conventionl drilling device; **2** – an ultrasound unit; **3** – an Er:YAG laser; **a** – Hematoxylin - Eosin; **b** – Toluidine Blue.

Discussion

To date, histology is the gold standard for study of heat-related bone necrosis, as it allows *in situ* analysis of the cells [7]. The temperature effects on bone tissue have been studied and it was found that heat stress inhibited osteoblast regeneration and caused bone resorption and adipocyte conversion, thus inhibiting bone healing [6]. The excessive frictional heat generated during osteotomy could impair the turnover activity of bone tissue by causing hyperemia, necrosis, fibrosis, osteocytic degeneration and increased osteoclastic activity [13].

Traditionally, rotating instruments, such as burs, have been used for osteotomy. However, disadvantages are related to the use of these traditional systems, including bone overheating and damage to adjacent tissues [10]. The absence of certain thermal alterations of tissue caused by the conventional rotary device used in our study was probably due to the low speed and constant irrigation, as explained in a study by de Mello et al. [5].

In presented trial, the overheating of bone samples with the ultrasound device compared to the other two osteotomes was an unexpected finding, established not by the conventional Hematoxylin-Eosin, but by Toluidine Blue staining. Previous findings by Szalma [12] on bone overheating with ultrasound devices were questioned by Zheng [15] in an additional *ex vivo* model. He found that the temperature of the cortical bone during ultrasound-assisted osteotomy was lower than during rotational drilling [11, 15].

Laser osteotomy is a heat-induced cavitation effect creating cavitation-bubbles. Once the water in bone tissue is consumed, the heat energy cannot be transformed into kinetic energy anymore and thus leads to carbonization and necrosis of the adjacent bone layers [4]. It has been suggested that the Er:YAG laser is probably the least destructive of the bone cutting lasers because it generates light at an energy level that is readily absorbed by water and thus minimizes carbonation and adjacent tissue necrosis [3]. The microanalysis of the surface of bone following laser ablation showed little evidence of thermal damage and any char layer appeared to be restricted to a minimal micrometric zone [9].

Conclusion

Our study proved that despite the evolution of bone cutting devices bone trauma is ever-present. The verified direct changes in human bone could be used as a set point for further research comparing bone healing dynamics and the quality of new bone formation in humans following bone surgcry.

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