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Journal of Bone Research

Opinion Article

Thermal Injury and Bone Debris During Osteotomy

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DESCRIPTION

The natural composite of bone has intricate structures and is sensitive to temperature changes. Osteotomy is a surgical procedure used to heal fractures and put implants that involves drilling and cutting into the bone. The heat deposition and mechanical trauma caused by frictions between the instruments and the bone, which readily result in thermal injury and consequently delay bone healing, are the main downsides of utilizing the present saws and drill-bits in orthopedic surgery. Continuous bone debris or tool breakage debris produced by mechanical tools further increases the likelihood that patients will contract infections or suffer iatrogenic injuries. In a hybrid machining method known as ultrasonic cutting, a traditional saw or drill bit is linked with a vibration pattern that has a defined amplitude and frequency. Even while cutting cortical bone with ultrasound can significantly lessen the cutting forces involved in the procedure, the mechanical vibration still results in tissue adhesion and heat damage to the bone tissue. The contactless interaction of laser beams with bone has attracted increasing interest because it provides for greater flexibility and accuracy during processing and presents a possible solution to increase the quality of the drilled bone while simultaneously minimising the impact of human factors.

The creation of heat during laser-bone interactions typically results in thermal injury to the surrounding tissue, carbonization caused by thermal processes, and fractures that obstruct healthy bone healing. The high temperatures cause the alkaline phosphatase in the bone to become denaturized (at 50°C and above) and the permanent death of the bone cells (for example, 47°C for more than 60 s). Bone is a dense biological substance with low heat conductivity. The heat produced during operations must therefore be dissipated *via* an external cooling system. Currently, normal saline is often dripped into the mechanical drilling area to cool it *via* natural convective heat exchange, but because of the insufficiency and unpredictability of the cooling, the nearby bone, arteries, and nerves might easily experience necrosis. During laser drilling, tissues were cooled using water-cooling, which uses a 50 μm diameter laminar water flow piercing a bone crater. However, this water flow-based cooling requires constant, considerable coolant pouring into the incision, which reduces drilling efficiency and causes the laser energy to be absorbed or blocked in the beam path. Water buildup in the laser-irradiated area also makes it harder to see in the surgical area. Additionally, natural convection-based heat transfer is the intrinsic heat transmission process of moving water or stationary water layers. Methods focused on raising the volume or flow rate of water are therefore unable to increase the convective heat transfer coefficient and meet the cooling requirements for laser bone drilling. For usage in laser bone drilling, there is a high demand for a cooling technique that can produce forced convection heat transfer without impeding the surgical procedure and that also maintains visibility in the operating room.

The production of bone debris during laser bone drilling is another obstacle that needs to be removed. The bone fragments produced during laser drilling are quickly carbonized and deposited on the surface or inner wall of the bone, which prevents continuous energy accumulation and hinders laser ablation. Orthopedic applications need the production of holes with sizes ranging from millimeters to even centimeters in depth, including osteotomies, pedicle screw pilot-hole drilling, prosthetic insertion, and osteotomies. With these deeper incisions, the shielding effect of accumulated bone debris on laser transmission is more pronounced. Because only bone debris that is smaller than 5 μm in size can be swallowed by the osteoclasts for bone restoration, the smear layer of bone debris that is created will delay bone healing and increase the likelihood of inflammatory reactions. Therefore, when effective deep laser drilling or cutting with great bioactivity is required, avoiding the production of bone debris during drilling is necessary.

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Received: 05-Jul-2022; Manuscript No. BMRJ-22-18916; **Editor assigned:** 08-Jul-2022; PreQC. No. BMRJ-22-18916 (PQ); **Reviewed:** 22-Jul-2022; QC. No. BMRJ-22-18916; **Revised:** 29-Jul-2022; Manuscript No. BMRJ-22-18916 (R); **Published:** 05-Aug-2022, DOI: 10.35248/2572-4916.22.10.184.

Citation: Perng GC (2022) Thermal Injury and Bone Debris During Osteotomy. J Bone Res. 10:184.