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Effect of Various Parameters on the Temperature Distribution in Conventional and Diamond Coated Hollow Tool Bone Drilling: A Comparative Study

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Abstract

Bone drilling is performed around the world in surgical operations to repair the fractured parts of bones. Significant amount of heat is generated during the bone drilling process which may be one of the causes of thermal necrosis and osteonecrosis. In the present research work drilling experiments were performed on the porcine bone. Efforts were made to reduce the cutting temperature while drilling with the diamond coated hollow tool and the results were compared with the temperature obtained when drilling performed using twist drill bit. Temperature during the bone drilling was measured by embedded thermocouples method which were placed at a location of 1.0, 1.5 and 2.0 mm from the drilled site. Results showed that hollow tool generated lower temperature with respect to the drill bit and temperature continuously decreased with the increase in radial distance from the periphery of drill hole. It was also observed that lower spindle speed, feed rate and drill diameter generated lower temperature for both the drill bits.

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1. Introduction

Bone drilling is a very common surgical procedure which is used in hospitals. It is used to insert the screw in the bone to repair the fractured parts of broken bone. Fractured parts of bones are immobilized and aligned using the implants. Therefore drilling is essential step to make a hole in the orthopaedic surgery operations. It is a mechanical process in which significant temperature is generated between the tool and the workpiece. If this temperature increase to threshold value then it may be the cause of thermal necrosis in the bone [1–4]. In this regard, various studies have been conducted to minimize the rise in temperature in the bone drilling process, which are summarized below.

Bertollo et al. [5] performed an experimental study on fresh porcine femora using a constant rotational speed and drill bit diameter of 3.2 mm. They found that using a 3-fluted drill bit with point angle 44° could reduce the change in temperature as compared to 3 fluted drill bit with 83° point angle and 2 fluted drill bit. Rise in temperature was measured by infrared thermal imaging camera. Udiljak et al. [6] also compared the effect of two types of drill bits (classical surgical drill and two phase drill bit) on the rise in temperature. Their experimental results showed that maximum rise in temperature using a classical surgical drill bit and two phase drill was 97.7°C and 78.5°C respectively as recorded by IR camera.

Harder et al. [7] performed a comparative study of change in the temperature with a steel drill bit and steel drill bit coated with zirconium oxide. They concluded that both types of drill bits generated the same amount of heat with different irrigation methods. They also reported that internal cooling irrigation technique generated a minimum rise in the temperature as compared to external cooling method.

Soriano et al. [8] conducted an experimental study on the bovine cortical bone using different types of drill bit geometries and constant drill diameter of 5.3mm. Their study showed that temperature could be reduced with increase in rake angle and decrease in the margin thickness of the drill bit. In another study, Soriano et al. [9] reported that surgical drill bit generated a higher temperature as compared to industrial drill bit when drilling a bovine bone. Temperature was recorded by the IR camera for both the investigations.

Gehrke et al. [10] performed experiments to investigate the effects of irrigation/cooling system and its movement on the temperature, during bone drilling. They carried out in vitro study on the bovine ribs. It was concluded that double irrigation method with an intermittent system produced less increase in the temperature during bone drilling as compared to external irrigation technique.

Li et al. [11] performed bone drilling simulation studies which showed that rise in the temperature depended upon the rotational and feed speed. They also reported that temperature could be further reduced by step drill as against twist drill bit with irrigation or without irrigation. Further, they concluded that temperature could be reduced by mist cooling technique as against normal cooling method.

Augustin et al. [12] performed an in vitro experiment on porcine femura bone using a central composite design technique. Their experimental study showed that rise in the temperature could be reduced by using internally cooled drill bit. In another experimental work, Augustin et al. [13] reported that heat generated during bone drilling could be reduced by using external irrigation method with all the combination of defined input parameters.

Lee at al. [14] introduced a thermal model for bone drilling and reported that maximum temperature significantly increased with increase in the feed rate, rotational speed, point angle and depth of cut and decreased with increase in the drill diameter and helix angle. They also summarized that maximum rise in the temperature could be reduced by irrigation method. Maani et al. [15] developed a mathematical model which was validated with the parametric study. Their results showed that temperature increased with increase in the feed rate, spindle speed, point angle and drill diameter and decreased with increase in the helix angle.

Alam and Silberschmidt [16] investigated the effect of ultrasonic vibration parameters on the temperature and compared their findings with the conventional drilling (CD) process. They reported that temperature could be reduced by ultrasonic drilling (UAD) as compared to CD. Similar experimental results were published by Shakouri et al. [17].

The literature presented above reveals that researchers around the world have tried to reduce the temperature in the bone drilling process. In this study, authors have tried to achieve the same using a hollow drill tool bonded with abrasive particles.

2. Experimental procedure