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EXPERIMENTAL STUDY ON THE EFFECT OF POINT ANGLE ON FORCE AND TEMPERATURE IN ULTRASONICALLY ASSISTED BONE DRILLING

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ABSTRACT

Drilling of bone is a common surgical procedure in orthopeadics to produce holes for screw insertion. The force and temperature rise in bone drilling are two important factors affecting the outcome of the process. The present work attempts to investigate the effect of drill point angle on the level of force and temperature in bone in the presence of ultrasonic vibrations imposed on the drill along the drilling direction. The effect of ultrasonic frequency and amplitude of vibration on drilling force and temperature was studied using two types of drills with different point angles. The drilling force and temperature were found to be strongly influenced by the drill point angle. The drill with larger point angle caused more force and temperature compared to the drill with smaller point angle. Ultrasonic frequency above 15kHz was observed to produce more temperature in bone for both types of drill geometries. This study found drill with smaller point angle favorable for safe and efficient drilling in the bone.

INTRODUCTION

Bone drilling is one of the most common and oldest surgical procedures performed in orthopaedics, maxillofacial, oral, and trauma surgery for centuries. Complex kinematics and friction involved in bone drilling process may cause mechanical and thermal damage to the bone tissue leading to postoperative complications [1]. Large cutting force during the process may result in microfractures in the bone surrounding the cutting area [2]. In addition, large drilling force and torque are the prime reasons for drill breakage during surgical procedure [3]. Several studies have researched the effect of drilling parameters and drill geometry to improve the outcome of the process [4-7]. A comprehensive review on the bone drilling process describing parameters affecting bone temperature is briefly discussed in a recent study [8].

Recently, ultrasonically assisted drilling (UAD) in bone has been proposed for minimal invasion. In UAD, high frequency vibrations are superimposed on the drill in the drilling direction. The technique has been found to reduce the drilling force, torque, bone temperature and resulted in better surface finish compared to conventional drilling (CD). Some recent studies proposed UAD in bone due to it's enhance cutting mechanism which can minimize drilling force, torque, temperature in bone and micro-cracks in the drilling region [9-11].

Measurement and control of drilling force and temperature rise in bone are critical to the outcome of the process. The effect of point angle on the level of force and temperature in CD of bone has been widely discussed in the literature [7,8,12]. Despite strong dependency of drill geometry on the performance drilling process, previous studies did not investigate the effect of drill point angle on drilling force and bone temperature in UAD. The present paper studies the effect of point angle on the level of force and temperature in bone in the presence of ultrasonic vibrations. The point angle is an angle included between the cutting lips projected upon a plane parallel to the drill axis and parallel to the two cutting lips. The influence of ultrasonic frequency and amplitude

of vibration on the drilling force and temperature rise in bone using drills with point angles of 118° and 90° is investigated and discussed.

MATERIALS AND METHODS

The middle and harder portion of the femoral bone known as cortical bone was selected as a candidate material for drilling experiments. Drilling thrust force was measure using two-component dynamometer (Kistler type 9271A). Two types of standard twist drills having 4.5mm diameter with point angles of 118° and 90° were used in drilling experiments. An infrared camera (Thermosensorik InSb 320 SM/M, Germany) was used for temperature measurements in drilling experiments. The main feature of the experimental set up was the design of ultrasonic transducer for imposing vibrations on the drill. Experimental set up for ultrasonic bone drilling is shown in Figure. 1.

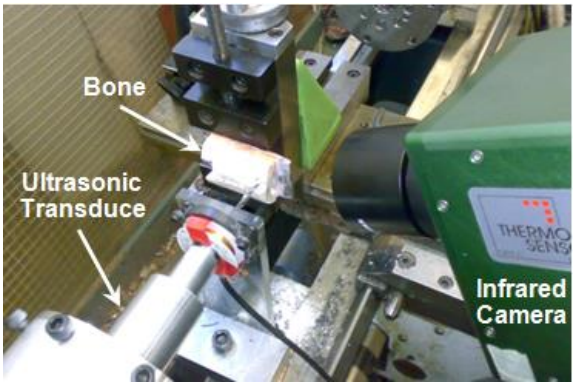


Figure 1. Experimental set up for force and temperature measurements in UAD

RESULTS AND DISCUSSION

3.1 Effect of frequency and amplitude on drilling force

The effect of ultrasonic frequency and amplitude on the level of drilling force was investigated. To study the effect of frequency on drilling force, the amplitude of vibration, drill speed and feed rate were kept constant. Similarly, to find the effect of amplitude of vibration on the drilling force, frequency, drill speed and feed rate were kept at constant values. The drilling force was found to decrease linearly with increase in frequency imposed on the drill for both types of drills. The effect of frequency and amplitude on drilling force for both types of drills is shown in Figure. 2. The drill with large point angle produced more force compared to the one with small point angle. The force was observed to decrease from an average value of 47N to 21N when the frequency was increased from 5kHz to 25kHz using drill with larger point angle. Similarly, the force was dropped from 37N to 14N, for similar increase in frequency using drill with smaller point angle. The effect of amplitude of vibration on drilling force was rather insignificant for the range of amplitudes used in experiments. The average rise in drilling force with increase in amplitude from 5 micrometers to 25 micrometers was not more than 5N for both types of drills.

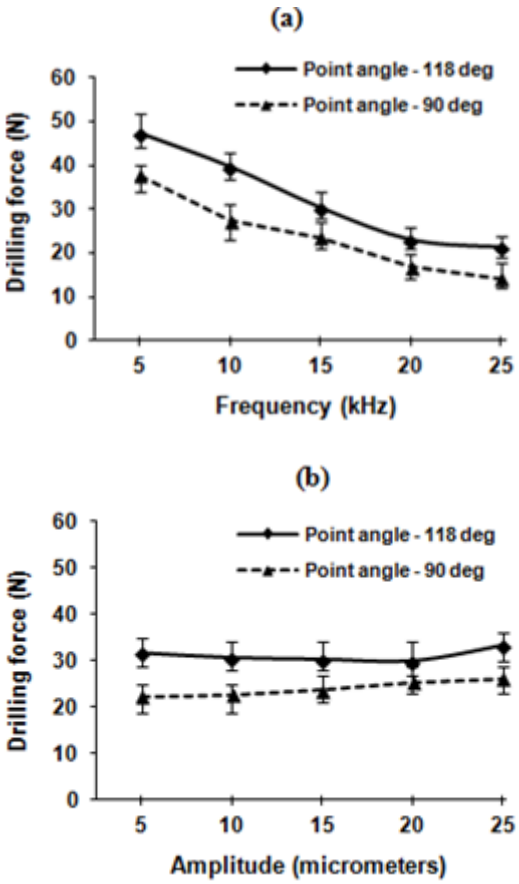
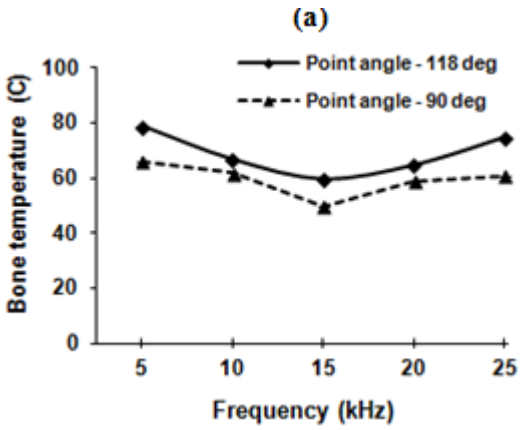


Figure 2. (a) Effect of ultrasonic frequency on drilling force (amplitude 10μm, drill speed – 2000 rpm, feed rate – 50mm/min), (b) effect of amplitude of vibration on drillng force

(frequency – 15kHz, drill speed – 2000rpm, feed rate – 50mm/min)

3.2 Effect of frequency and amplitude on bone temperature

To study the effect of ultrasonic frequency and amplitude on bone temperate, the drilling speed and fed rate were kept at 2000 rpm and 50 mm/min respectively. The effect of ultrasonic frequency and amplitude on bone temperatures is shown in Figure. 3. The average bone temperature was observed to drop when frequency was increased from 5kHz to 15kHz. However, an increase in bone temperature was noted when frequency above 15kHz was used. Bone temperature was found to drop from a mean value of 79°C to 60°C when frequency was changed from 5kHz to 15kHz using drill with larger point angle. Bone temperature was increased from 60°C to 75°C when frequency was increased from 15kHz to 25kHz. Similar behavior was also observed using drill with smaller point angle. The effect of ultrasonic amplitude on bone was found insignificant up to 15μm. A small increase in bone temperature was recorded when amplitude was varied from 20μm to 25μm.



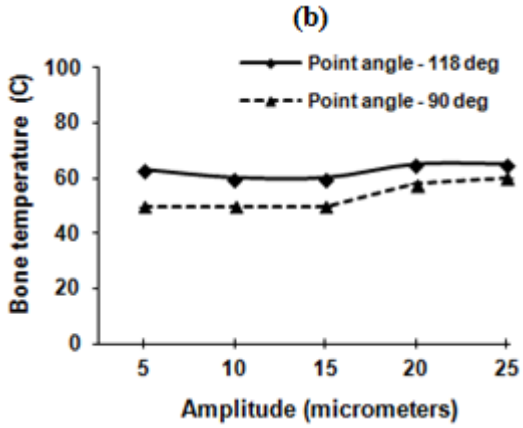


Figure 3. (a) Variation of bone temperature with ultrasonic frequency (amplitude 10μm, drill speed – 2000rpm, feed rate – 50mm/min), (b) variation of bone temperature with amplitude of vibration (frequency – 15kHz, drill speed – 2000rpm, feed rate – 50 mm/min)

DISCUSSION

A slight drop in bone temperature up to frequency of 15kHz was due to the pulsating action of the drill which reduced average friction between the drill and the bone. The amount of heat dissipation due to higher vibrations of the drill (frequency above 15kHz) produced higher temperature in the bone. An increase in bone temperature at amplitude above 15μm was due to the increase in contact time (contact ratio) between the drill and the bone. That condition allowed the cutting edges of the drill to remain in contact with the bone for more time which caused more heat generation in the drilling zone. The influence of ultrasonic frequency on bone temperature observed in this study was similar to the results obtained in another study [9]. Smaller point angle allowed the drill to penetrate with more ease preventing walking of the drill. However, small point angle may cause less portion of the cutting lip involved in the cutting action. Hillery [13] and Augustin [14] found no significant effect of point angle on temperatures in CD of bone. Karmani [6] recommended drill point angle ranging from 110° to 118° for bone drilling.

CONCLUSION

Drill with smaller point angle is suitable for

lower effort in UAD of bone. Ultrasonic frequency up to 15kHz may be used to produce lower drilling force and temperature in bone. The right selection of ultrasonic parameters together with optimum drill geometry may be used for minimal invasive bone drilling in orthopeadics. This study suggests the use of efficient cooling system when high frequency vibration is used in bone drilling.

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