Abstract of PhD Thesis

"Development Of Rotary Ultrasonic Bone Drilling Machine And Experimental Investigations On Human Cadaver Bone"

Mr. Ravinder Pal Singh (2016MEZ8543)

Bone injury has become a common medical issue experienced by a person's average life span. The reason may be because of old age, injuries in sports, industrial injury or accidents on road, etc. Bone healing is a slow process and requires the immobilization of the injured part of the body for the growth of bone tissues. To immobilize the fractured bone, the metal plate are used to hold the bone together. These metal plate which holds the bone together is fixed to it with the help of screws which are inserted in the predrilled holes. Hence, the bone drilling process becomes essential for orthopedic medical surgery. During drilling, the bone remains in contact with a high-speed rotating tool and the mechanical rotational energy is converted into heat energy. The friction between the rotating tool and the bone generates heat at the drilling site. The temperature rise at the drilling site is also due to poor thermal conductivity of bone, which usually lies between 0.2-2.27W/mK. High temperature in bone may lead to reduced synthesis of proteins and permanent death of bone cells (osteonecrosis). It has been reported that the exposure of bone to a temperature of 47 ºC results in the permanent death of the osteocytes (bone cell). Thermal osteonecrosis plays a significant role in the failure of osteosynthesis process.

To overcome the aforesaid problem a novel bone drilling method has been introduced recently named as RUBD. In the present research, the major goal is to develop an efficient, compact and light weight bone drilling machine, working on the principle of rotary ultrasonic machining (RUM) and orthopedic drilling which can eliminate thermal osteonecrosis, microcracks and reduce the cutting force and torque. The experimental investigations were performed on human cadaver bones by the developed RUBD machine to find out change in temperature, force, torque, and microcracks.

The developed RUBD machine was used to perform the drilling experiments by different techniques: RUBD and conventional surgical bone drilling (CSBD) on different types of human bone i.e. hard bones (femur and tibia) and soft bone (fibula). The comparative study revealed that RUBD technique offered a lower force, torque, temperature and minimum microcracks, making it a potential process for bone drilling in orthopedic surgery. The drilling experiments were planned and carried out on human femoral bone using design of experiments (Response Surface Methodology). Analysis of variance (ANOVA) was carried out to find the effect of process factors such as rotational speed, feed rate, drill diameter and diamond abrasive grit size on the force, torque and temperature. Statistical models were developed for the force, torque and temperature rise with 95% confidential interval and confirmation experiments have been carried out to validate the models. Microcracks developed during drilling process were characterized by scanning electron microscopy (SEM).

Thermal necrosis was also examined by the histopathological and ultrastructural examination for the RUBD and results were compared with the CSBD method. It was also found that RUBD generated a much lower temperature, as compared to the CSBD, and the structural integrity of the bone cells were maintained in RUBD process. The effect of the drilling parameters on the microcracks and pullout strength was also evaluated. The obtained results showed that the increase in the length of microcracks led to decrease in the strength of the bone screw bond; hence, there is a strong correlation between the microcracks and the pullout strength of the bone screw.