A Cadaveric Study of Bone Tissue Temperature During Pin Site Drilling Utilizing Fluoroptic Thermography

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Introduction: Heat-induced injury of bone tissue has been shown to occur when the bone sustains a temperature of 47°C for greater than 60 seconds, or 50°C for 30 seconds. Necrotic bone tissue may create conditions favorable to bacterial infection and hardware loosening. Graduated drilling is a technique of external fixator pin placement that aims to minimize thermal necrosis by pre-drilling the pin site with a 3.5 mm drill bit prior to placement of a self-drilling 5.0 mm Schanz pin. The majority of research examining bone tissue temperature during drilling is published in the dentistry literature and uses bovine or porcine bone. Generally there are two methods used for bone tissue temperature measurement during drilling: direct recording with thermocouples or indirect estimating with infrared thermographic cameras. This study employed an alternative method of temperature recording. Fluoroptic thermography uses a temperature sensitive phosphorescent sensor attached to the end of an optical fiber through which pulses of light are transmitted, causing the sensor to be excited. The instrument detects and calculates the decay time of the fluorescence after each pulse. Decay time varies precisely with the temperature of the sensor, providing the basis for accurate temperature measurement to the tenth of a degree Celsius over a range of 0 to 120°C with a 0.25 sec response time. Utilizing fluoroptic thermography the bone tissue temperature was measured during pin site drilling of intact cortical human cadaver bone with a combination of one-step drilling, graduated drilling, and one-step drilling with irrigation. The aim of this study was to use fluoroptic thermography to evaluate the need for graduated drilling or irrigation in order to avoid causing thermal injury to bone tissue. We hypothesized bone tissue temperature will exceed the threshold temperature for heat-induced injury with one-step drilling of a 5.0 mm Schanz pin in the tibia.

Methods: Utilizing fluoroptic thermography in cross-sections of human cadaver tibia, we examine the change in bone tissue temperature at the drill sites. The cortical density of the cadaveric specimen was determined by computed tomography. The tibial diaphysis was segmented into 8 segments 3 cm in length starting 8.5 cm distal to the lateral tibial plateau. A drill press capable of 1440 rpm at a constant force was used to perform the drilling. The constant force applied by the drill was measured as 21.2 lbs at the drill bit. A sensor probe placed in the cortex 0.5 mm adjacent to the drill tunnel measured the bone tissue temperature throughout the drilling process. The Luxtron FOT Lab Kit, an optic thermometry system, collected temperature data in 0.25 second intervals over a period of at least 90 seconds. Bone tissue temperature was examined with four drilling trials at each of the 8 segments of the tibial diaphysis: 3.5 mm drill bit, 5.0 mm Schanz pin, 5.0 mm Schanz pin in 3.5 mm pre-drilled entry site, 5.0 mm Schanz pin utilizing irrigation. In order to account for the ex-vivo nature of our study, a rise in bone tissue temperature greater than 10°C above the starting bone tissue temperature was used to represent a change that would exceed the threshold for heat-induced injury, as body temperature is known to be
37°C. The data collected were analyzed and statistics were performed utilizing chi-square, ANOVA, and Tukey HST tests.

Results: One-step drilling using a 5.0 mm Schanz pin without irrigation resulted in a bone tissue temperature rise that would exceed the threshold temperature for heat-induced injury in 5/8 trials. The remaining three trials, one-step drilling with a 3.5 mm drill bit, a 5.0 mm Schanz pin with irrigation, and graduated drilling of a 5.0 mm Schanz pin in a 3.5 mm pre-drilled entry hole, resulted in 1/24 trials that maintained an elevated temperature for a duration that would result in thermal injury. This difference was found to be statistically significant (p = 0.003). Additionally, the use of irrigation significantly reduced the maximum bone tissue temperature achieved in one-step drilling of a 5.0 mm Schanz pin (p = 0.02). Maximum temperatures achieved amongst the other groups were not found to differ significantly from each other. One-step drilling with a 3.5 mm drill bit achieved maximum temperature significantly faster than with graduated drilling and drilling with irrigation using a 5.0 mm Schanz pin (p <0.01). Power analysis revealed the study to have a power of 0.84.
Discussion: One-step drilling with a 5.0 mm Schanz pin into cortical bone produces elevated bone tissue temperatures that are sustained long enough to produce heat-induced injury to bone tissue. However, when one-step drilling with a 5.0 mm Schanz pin is performed while utilizing external irrigation, the temperatures generated do not exceed the threshold to produce thermal injury to bone tissue. Although it took less time to reach the maximum bone tissue temperature with a 3.5 mm drill bit, the temperature was not sustained long enough to create heat-induced injury. While the maximum temperatures generated did not differ significantly between the two one-step drilling trials without irrigation, the temperature was sustained for a duration long enough to produce thermal injury with the 5.0 mm Schanz pin. This extended duration of elevated temperature could be due to the fact that the pin remained in the bone after drilling had stopped, whereas the 3.5 mm drill bit was removed from the bone after the hole had been created.

Significance: Using real-time temperature data recording with fluoroptic thermography and human cadaver tibia, our findings support the notion that one-step drilling with a 5.0 mm Schanz pin generates bone tissue temperatures that can result in thermal necrosis of the surrounding bone. Furthermore, this study has shown that in addition to graduated drilling, one-step drilling with a 5.0 mm Schanz pin can be accomplished safely with the concurrent use of external irrigation allowing for expeditious pin placement in a time-sensitive operation.

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