

# THE EFFECTS OF DRILLING FORCE ON CORTICAL TEMPERATURES AND THEIR DURATION: AN IN VITRO STUDY

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**INTRODUCTION:** The stability of orthopaedic fixation devices depends partially on the quality and the quality of the host bone and even minimal loss of bone at the implantation site due to necrosis may weaken the purchase of surgically placed screws and pins, causing them to loosen post-operatively. One cause of necrosis is thought to be the generation of excessive heat during surgical drilling procedures. Prior studies have demonstrated how parameters such as force, irrigation, and instrument type influence cortical bone temperatures. Although there is widespread agreement that a sharp, coolant irrigated cutting tool effectively limits excessive drilling temperatures, there still is disagreement as to how drilling forces affect the cortical bone temperatures and their duration of application.

The goal of the current study was to better understand how differences in drilling techniques affect the maximum temperatures produced in nearby cortical tissue. Specifically, the two hypotheses tested were as follows: (1) increasing the force of the drill on the bone would result in a decrease in maximum cortical temperatures and (2) increasing the force on the drill would result in a decrease in the amount of time these maximum temperatures remained above 50 °C.

**METHODS:** Six cortical bone specimen were obtained from mid-shaft sections of fresh frozen human cadaver femora. The average (± standard deviation) age of the donors was 64 ± 4 years. All soft tissues were stripped from the specimens using surgical instruments to expose the bone. Radiographs and gross examinations confirmed that the specimens were visually free of significant osteopenia and musculoskeletal disease. Regions of bone thinner than 7 mm and thicker than 11 mm were not included in the study. Three 0.27 mm diameter, teflon insulated thermocouples were used to measure cortical temperatures at locations of 0.5 mm, 1.0 mm, and 2.0 mm from the drilling tract. A specially designed 6.5 cm x 2.5 cm x 0.3 cm steel template was used to control the location of the thermocouples relative to the drill tract. A 4.0 mm diameter hole placed in the center of the template held the position of the drill bit constant. Three holes, each 1.0 mm in diameter, placed 0.5 mm, 1.0 mm and 2.0 mm edge to edge laterally from the central hole provided accurate insertion of the three thermocouples. The drill bits were 20 cm long, 3.2 mm diameter standard surgical twist drill bits. Drilling was done on a variable rate drill press with a constant speed of 820 rpm, a rate closely correlated with drill speeds used clinically.

Each bone specimen was secured into a partially submerged water bath maintained at 37°C to simulate body temperature. The thermocouples were put into place, the drill bit was lowered onto the bone, and the selected force was applied to the drill press. The drill press was then turned on and the bit was allowed to penetrate the cortex. As soon as the drill bit punched through the outer cortex into the medullary space, the drill press was turned off and the drill bit was allowed to remain in the bone for the duration of the data collection.

A total of 50 trials were completed, 10 for each force (57, 74, 83, 93, 130 N) were tested. Data was checked for normality to determine if parametric or non-parametric statistical tests were needed. Statistical analyses was done using a GLM ANOVA detect significant differences in both bone specimens and drilling forces. If no significant differences were found in bone specimens, a one-way ANOVA calculated significance values for drilling forces. Statistical power was confirmed at 0.8 and statistical significance was predetermined at  $p \leq 0.05$ . Confidence intervals were reported at 95%.

**RESULTS:** Significant temperature differences were recorded in all three of the thermocouple locations as drilling forces were varied. Overall, increasing the load resulted in a significant decrease ( $p=0.001$ ) in maximum cortical temperatures. In addition, an increase in the drilling force resulted in a significant decrease in the average duration of temperature elevations above 50 °C. No measurable differences in the specimens used during the experiment ( $p=0.999$ ). As expected, the cortical temperatures recorded by the thermocouple positioned 0.5 mm from the drilling site were always higher than those recorded by the thermocouples located either 1.0 mm or 2.0 mm from the drilling site.

This thermocouple is closest to the drill bit and reflects temperatures most similar to those at the drill bit interface. In addition, it is closest to the region where bone necrosis, due to excessive heat generation occurs. As such, it is of primary importance to clinicians and researchers investigating the effects of thermal necrosis. Data presented in the Table was recorded by the thermocouple located 0.5 mm from the drill bit.

There were significant decreases in the average cortical temperature as loads increased from 57 to 83 N, 83 to 93 N and 83 to 130 N. However, increasing the force from 57 to 74 N and from 74 to 83 N did not significantly lower temperatures. The thermocouple positioned 0.5 mm from the drilling tract also recorded a significant decline in the duration of cortical temperatures above 50 °C as the load increased. Drilling with 57 N resulted in temperatures remaining above 50 °C for 48 seconds, while drilling with 74 N reduced this duration to 3 seconds. Moreover, as loads continued to increase to 130 N, the duration of temperatures above 50 °C decreased to zero.

**Table: Temperature recorded with forces 0.5 mm from drilling site.**

Force[N]	Count	Temperature[C]	Different from Groups
57	10	67.2+14.4 (47.8-84.5)	83 N, 74 N, 57 N
74	10	47.7+ 3.6 (41.3-53.5)	83 N, 74 N, 57 N
83	10	47.2+ 4.9 (41.7-55.1)	130 N, 93 N, 57 N
93	10	35.2+ 1.2 (33.9-36.9)	130 N, 93 N, 57 N
130	10	34.7+ 1.5 (33.0-37.1)	130 N, 93 N, 74 N

**DISCUSSION:** The purpose of the current work was to investigate how the force of the drill on the bone affects both cortical temperatures and their duration above 50 °C. The results of the current study show that as drilling forces increases, not only does the maximum temperatures achieved decrease, but also does the duration above 50 °C. These results contradict a study which found that as forces were increased, the cortical bone temperatures decreased (3). A later article reported that as drilling forces increased, cortical temperatures increased (4). Other work reports that as force increased, so did cortical temperatures (2). Although temperatures were found to increase with force when a drill speed of 1800 rpm was used, the researchers reported that when faster speeds of 2400 were used, temperatures decreased as forces increased. Thus, cortical temperatures may be dependent both on the drilling force and rate of rotation. In addition, burrs, rather than surgical twist drill bits were selected as the cutting tool in this study. Dental burrs, due to an increased surface area at the drill bit interface may generate much more frictional heat as compared to drill bits. Thus, the results of this study may not be comparable.

However, the results of this study support the findings from several other studies. A report that as forces increased, temperatures decreased (3). Furthermore, these researchers found that as force increased, durations of temperature elevation also decreased from more than 60 seconds to 20 seconds (3). Brisman found that when drilling force increased, the maximum temperatures decreased significantly(2). Matthews and Hirsch found that when forces increased from 20 N to 118 N, cortical temperatures decreased (1). In this same study, as force increased, the duration of temperature elevation decreased from 35 seconds to near zero(1).

In conclusion, the results of the current study demonstrate that by the application of a larger force to the drill, both the maximum cortical temperatures and their duration above 50 °C may be effectively reduced, decreasing the incidence of thermal necrosis in the surrounding cortical bone.

#### REFERENCES:

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