The effect of AO interfragmentary compression technique drilling order on heat generation in bone

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Statement of Purpose and Literature Review

Arbeitsgemeinschaft für Osteosynthesefragen (AO) interfragmentary technique involves a specific serial set of steps in order to achieve compression between bone fragments with a fully threaded cortical screw. This has been and remains a staple of orthopedic surgical education [1]. Interestingly, however, the decision to initially overdrill the near fragment or underdrill both the near and far fragments is a surgeon-dependent decision [2-4]. One consideration potentially influencing this decision might be the generation of heat, and subsequently osteonecrosis. Variables of heat generation include the feed rate, initial drill bit temperature, and rotational speed [2, 5]. Feed rate (in/min) has been observed within several studies to affect temperature building and will increase osseous temperature as its value increases [2, 5, 7]. Consequently, as a hole deepens it is recommended to decrease the drill feed rate [6]. In a study by Augustin et al, drill bit size also had significant effects on heat production during drilling. It was specifically observed that a larger overdrill bit caused a larger rise in heat production [8]. Based on these previously studied characteristics of drilling, our investigation hypothesized that underdrilling through deeper, additional layers of cortices, followed by overdrilling with a large drill bit would cause the most heat to be produced within bone.

The purpose of this study was to evaluate the effect of overdrilling versus underdrilling's sequential order on the amount of heat produced during interfragmentary compression. The primary objective was to compare the temperature rise when underdrilling preceded overdrilling to the temperature rise when these steps were reversed. We believe that evaluating these results might increase knowledge on the best AO interfragmentary technique practices.

Methodology

Twenty thawed bovine rib bones were utilized for the purposes of this investigation. Bovine rib bone was selected because of its bicortical nature, as well as its similarity to human bone with respect to tension, compression, and torque [9].

The baseline temperature of each bone was initially recorded utilizing a non-contact digital laser infrared thermometer positioned 10 centimeters from the surface of the bone (Etekcity LaserGrip 774 Infrared Thermometer, Anaheim, CA). This device measures to a precision of 0.1 degrees Celsius. An underdrill was considered a 2.5mm drill bit from the Synthes small fragment set (Depuy Synthes, Warsaw, Indiana). An overdrill was considered a 3.5mm drill bit from the Synthes small fragment set (Depuy Synthes, Warsaw, Indiana).

Twenty-five trials were first performed with the 2.5mm bit through both the near and far cortices, and then subsequent overdrill through the near cortex with the 3.5mm bit. Each drilling trial was performed with continuous temperature monitoring. The highest reading observed during each drilling trial was recorded as the primary outcome measure.

Twenty-five trials were then performed with the 3.5mm bit through the near cortex, and then subsequent underdrill through the near and far cortices with the 2.5mm bit. Again, each drilling trial was performed with continuous temperature monitoring and the highest observed reading was considered the primary outcome measure. Descriptive statistics from measurements were performed and included the mean, standard deviation and range. Comparative statistics were additionally performed between groups with the independent t-test. A level of significance was defined as $p<0.05$.

Results

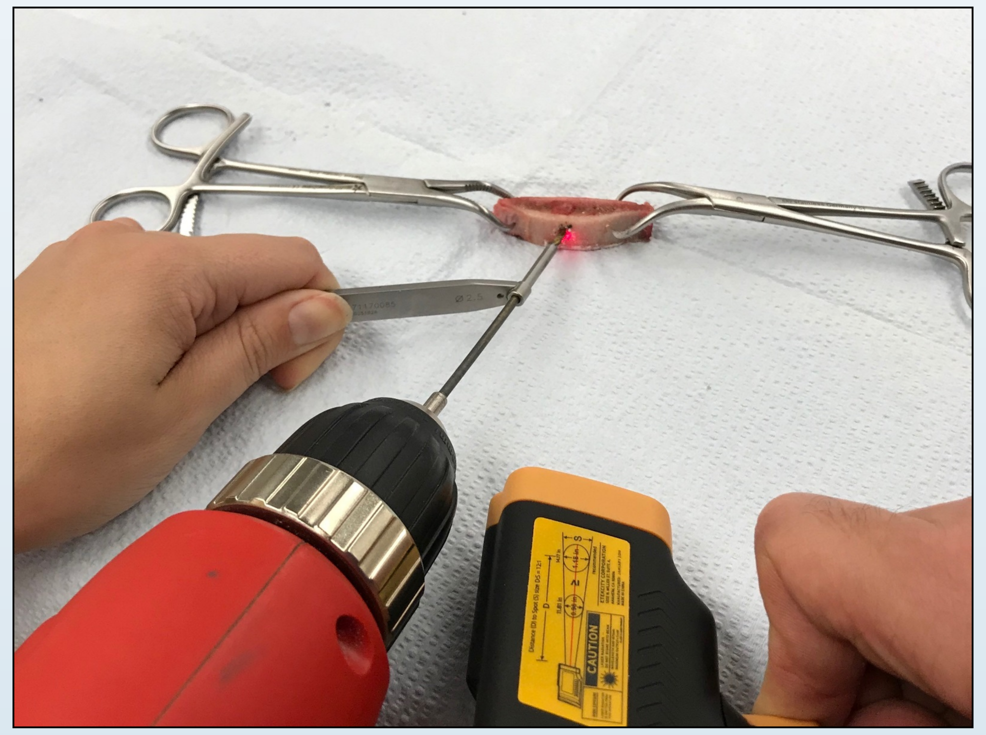
The bone width measured a mean ± standard deviation (range) of 1.1 ± 0.22cm (0.8-1.4). The baseline temperature of the bone was 23.2 ± 1.37º Celsius (20.8-26.9).

With the underdrill first technique, the temperature of the bone increased to 25.61 ± 2.21º (22.4-30.1) with the initial 2.5mm bit and to 24.97 ± 1.77º (22-30) with the subsequent 3.5mm bit. These differences were noted to be statistically significant ($p<0.0001$) compared to the baseline temperature measurement.

With the overdrill first technique, the temperature of the bone increased to 25.66 ± 2.25º (22.8-30.7) with the initial 3.5mm bit and to 25.73 ± 1.81º (22.7-29.3) with the subsequent 2.5mm bit. These differences were noted to be statistically significant ($p<0.0001$) compared to the baseline temperature measurement.

No difference was observed when considering the mean change of temperature between an initial 2.5mm or 3.5mm bit (+2.48ºC vs. +2.36ºC; $p=0.8027$). No difference was observed when considering a second step 2.5mm or 3.5mm bit (+2.42ºC vs. +1.83ºC; $p=0.2226$). However, a trend was observed that the underdrill step tended to heat the bone more than the overdrill step regardless of order ($p=0.14$), potentially indicating the size of the drill bit was of less consequence then the amount of time the drill bit was in contact with the bone, although time was not measured as a specific outcome measure.

Figure 1: Placement of the bone, drill, guide and laser thermometer during testing.



Three participants were necessary for data collection. One student held the bone in place by securing the pictured clamps. Another student held the laser thermometer at a constant 10cm distance, while observing the temperature readouts. A final student held the drill guide and fed the drill into the bone at a constant speed and pressure.

Table 1: Descriptive statistics for the variable of temperature (in degrees Celsius) for each combination of parameters

Baseline Temperature	23.2ºC
Underdrill first (2.5mm)	**+2.48ºC**
Overdrill second (3.5mm)	**+1.83ºC**
Overdrill first (3.5mm)	**+2.36ºC**
Underdrill second (2.5mm)	**+2.42ºC**

Discussion

In a result that trended toward statistical significance, the underdrill first technique generated more heat in comparison to the subsequent overdrill. No statistically or apparent clinically significant differences or trends were observed with the overdrill first technique. These results might indicate that the number of cortices drilled, and not the specific size of the drill bit, has the most effect on heat generation when performing AO interfragmentary compression technique.

These results follow established basic principles of heat generation. The deeper the hole, the greater the tendency and chance for bone debris to pack and clog the flutes of the drill, thus creating friction and heat. Therefore, a steady feed of the drill through two cortices vs. one will generate more bone chips and more heat, no matter which order the steps are completed in. Additionally, the extra time it takes to drill through both cortices logically leads to increased temperatures.

The highest temperatures observed during the entirety of data collection was 30.7°C, well below the 47°C needed for thermal osteonecrosis. However, the average baseline temperature of the bones was about 14°C below the normal human body temperature of 37°C. Therefore, it is unclear how these specific results would apply in vivo, although thermal necrosis has certainly been recognized as a potential complication with bone drilling [2-8]. It is also true that many surgeons choose to suppress temperature increase during drilling by utilizing irrigation. This practice might both physically cool the bone, as well as wash away bone chips that cause friction and heat. These potential limitations represent interesting potential avenues of further investigation on this topic.

It is our hope that the results of this study remind physicians that although these two steps are relatively interchangeable, this does not imply that they are exactly the same. Each technique has relative advantages and disadvantages, and heat generation is one important variable that should be taken into consideration by foot and ankle surgeons.

References

[1] Müller ME, Allgower M, Willenegger H. Manual of internal fixation. Springer-Verlag, New York, 1970.

[2] Pandey RK, Panda SS. Drilling of bone: A comprehensive review. *Journal Clinical Orthopaedics and Trauma*. 2013 Mar; 4(1):15-30.

[3] Ilg P, Ellis E. A comparison of two methods for inserting lag screws. *Journal of Oral Maxillofacial Surgery*. 1992; 50: 119-123.

[4] Augustin G, Zigman T, Davila S, Udilljak T, Staroveski T, Brezak D, et al. Cortical bone drilling and thermal osteonecrosis. *Clinical Biomechanics*. 2012; 27:313-325.

[5] Feldmann A, Wandel J, Zysset P. Reducing temperature elevation of robotic bone drilling. *Medical Engineering and Physics*. 2016; 38: 1495-1504.

[6] University of Florida, Department of Mechanical & Aerospace Engineering. Drilling Speeds and Feeds, EML2322L—MAE Design Manufacturing Laboratory [PDF]. Retrieved from: https://mae.ufl.edu/designlab/LabAssignments/EML2322L-DrillingandMillingSpeedsandFeeds.pdf

[7] Pirjamalineisiani A, Jamshidi N, Sarafbidabad M, Soltani N. Assessment of experimental thermal, numerical, and mandibular drilling factors in implantology. *British Journal of Oral and Maxillofacial Surgery*. 2016; 54: 400-404.

[8] Augustin G, Davila S, Udilljak T, Staroveski T, Brezak D, Babic S. Temperature changes during cortical bone drilling with a newly designed step drill and an internally cooled drill. *International Orthopaedics (SICOT)*. 2012 Jan; 36: 1449-1456.

[9] Cezayirlioglu H, Bahniuk E, Davy DT, Heiple KG. Anisotropic yield behavior of bone under combined axial force and torque. *Journal of Biomechanics.* 1985; 18(1): 61-69.

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