Comparison of Cortical Bone Drilling Induced During Self-Drilling Schanz Pin Insertion

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Objectives: There exists little significant data regarding the heat production induced during Schanz pin insertion into the cortical bone. This study compared the heat produced during insertion of a Schanz pin with and without the use of pre-drilling. It was hypothesized that the temperature rise throughout the process would be more significant when no pre-drill was applied to the drill site.

Methods: Schanz Pins (5.0 mm) were driven into room temperature bovine cortical bone by a battery powered Stryker 4200 Surgical Drill. The drill was rigidly fastened to a servo-controlled linear actuator to deliver a constant feed rate (1 mm/s). Two k-type thermocouples were embedded 2 mm from the surface at 1 mm and 2 mm from the outer diameter of the pin.

Results: Several data sets had to be omitted from calculations because of induced noise. This left the results statistically insignificant for both the 1 mm and 2 mm drill site. Due to low number of valid data the test performed was the Mann-Whitney test instead of the typical t-test.

Conclusions: Procedural changes and additional testing must be performed to achieve more significant results. There were several sources of error that can be improved upon.

Key Words: Schanz Pin, drilling, bone drilling, osteonecrosis, thermal drilling effects, external fixations.

INTRODUCTION

External fixations are a common tool used in orthopaedic surgery. They are often used for temporary stabilization of fractures to the femoral bone. Schanz pins are a common tool for creating rigid external fixtures with the cortical human bone. The external fixtures can be used to open fractures when further debridement is necessary. This is of particular importance in polytraumatized patients who cannot initially have their bone definitely fixed.

The heat induced during the process is of particular importance because of resulting thermal osteonecrosis. Formally, osteonecrosis is bone death caused by poor blood supply. It is most common in the hip and shoulder, but can affect other large joints. The absence of blood supply and bone death causes collapse and nonhealing. Specifically, thermal osteonecrosis is complex condition that is theorized to be induced by heat generation. Thermal rise causes a depletion in osteocytes, reduction in blood flow, and increased local osteoclastic activity. Osteoclasts are cells that have the ability to degrade both inorganic calcium matrix and organic collagen matrix. Thermal osteonecrosis ultimately results in a weaker bone with lower probability that it will heal itself.1-4, 6

Temperature and exposure time for osteonecrosis have been studied at length. Temperatures above 70°C have been shown to result in instantaneous necrosis. At temperature of 55°C irreversible necrosis of osteocytes occurs after 30 seconds, and at 47°C after 60 seconds1-4, 6, 8. Drilling depth and cortical bone thickness significantly influence the heat production. The heat generated from the friction between the pin and the bone is directly proportional to the insertion depth as the work done against friction is directly proportional to distance.

The aim of this study was to test the heat generation, in terms of temperature rise, of both direct Schanz pin insertion and pre-drilling. The testing was to be performed on cow bone. Results would yield a benchmark for subsequent human bone testing. Recommendations for procedural changes will be made.

MATERIALS AND METHODS

Experimental Setup and Sample Preparation

The selected tool was a commercially available 5 mm diameter Schanz pin and a 4 mm diameter pre-drill drill bit. The pin was driven
Comparison of Schanz Pin Insertion into the bone using a battery powered Stryker 4200 Surgical Drill, which is also commercially available. The drill was fixed to a 3-axis servo-controlled linear actuator as shown in Figure 2. This drill, along with the “quick change” attachment, provides us with a realistic setup. The drill was operated at maximum speed and advanced in the Z-axis at a constant feed rate of 1 mm/s. These parameters were chosen for their repeatability.

Tool wear was considered for by inspection and the rotation of available Schanz pins. Excess debris was removed after each test. Tool wear can produce higher temperature generation values than expected if not monitored.

The test samples were prepared from the same bovine femur bone. First, excess tissue was removed from the bone for consistency and drill path. The bones were cut into discs and then again into smaller samples. Bone marrow was removed. The samples were milled to a uniform 5 mm thickness and were roughly 35 x 35 mm. Each sample contained 6 drill sites. A pilot hole and thermocouple hole were predrilled using a computer controlled high-precision drilling machine and a 0.38 mm diameter drill bit. The thermocouple holes were each 2 mm deep. There was a hole for measuring the temperature at both 1 mm and 2 mm from the outer edge of the pin as shown in Figure 2. The pilot hole was 1 mm deep to ensure the drilling tool was located in the proper position relative to the thermocouples. K-type, 36-gauge thermocouples were used and data was collected using a data acquisition system by Omega Engineering Inc. A 20Hz sampling rate was used to properly capture the change in temperature. Thermocouples were fastened to the test setup and fixed in a spring-like geometry to ensure contact with the bottom of the hole.

**Procedure**

The feed rate of 1 mm/s was chosen in emulation of cortical bone drilling experiments performed by Dr. Andrew C. Palmisano. During his testing he found the average feed rate, between 2 surgeons (resident and attending surgeon), to be 1.03 ± 0.27 mm/s.

Nine tests were performed for each of the two insertion methods to ensure a confidence interval greater than 95%. Using the 3-axis servo system the drill tool was able to be positioned precisely in each pilot hole before beginning testing. The bones were kept in a saline solution intended to emulate human blood. The bones and solution were kept at room temperature for increased repeatability. Before each sample was drilled the non-porous vise was filled with the saline solution such that it did not cover the surface. The drilling depth was set to 7 mm to ensure the pin went through the bone and was fully engaged. For the pre-drill method a 2 mm pre-drill was made followed by the 7 mm insertion.

![Figure 1.](image)

**Figure 1.** (A) Pilot holes arrangement on samples. (B) Sample secured in vise thermocouples in place.
RESULTS

Temperature data was used in calculations was the peak value throughout the drilling event and the temperature just before drilling began. The increase in temperature was found for each test and then averaged by their respected method. Tests with large amounts of noise were omitted from calculations as well as outliers from each method. The validity of the data was calculated using the Mann-Whitney U-test.

The temperature data was separated into the 1 mm and 2 mm sites and compared by the two methods. After the omissions we were left with just 6 tests for direct drilling and 5 for pre-drilling.

For the 1 mm site the temperature of pre-drilling was not statistically significant lower (21.27 ± 6.45°C) than the temperature of direct drilling method (29.59 ± 8.18°C), ρ > 0.05. At the 2 mm thermocouple site the temperature of pre-drilling method was not statistically significantly lower (16.90 ± 5.79°C) compared to the temperature of direct drilling method (20.57 ± 4.65°C), ρ > 0.05. These results, and more relevant data to Mann-Whitney test, can be seen in Figure 3 and 4, on page 4.

DISCUSSION

There are many factors that contribute to the temperature increase during Schanz pin insertion. This experiment was designed to hold all factors constant besides the two methods of direct insertion and pre-drilling.

Through the experiments I was not able to come to a clear conclusion for the application of these processes to bovine bone, finding the data collected to be statistically insignificant.

The error we encountered during the experiment came from several different places. First it is necessary to increase the pilot hole size for the insertion of the Schanz pin. The current size (0.38 mm) is not large enough to ensure that the pin is inserted at the proper location. This led to some omitted data where is showed the same temperature at both the 1 mm and 2 mm sites.

Another source of error was the quick change drill-chuck. Dr. Finney agreed that this is a less rigid fixture and could have induced some of the pin deviation we saw in the temperature data. Unfortunately this tool is necessary for the pre-drill method. We believe we saw more error during Schanz pin testing, opposed to other drilling tests (K-Wire), because of the larger size of the pin (5 mm).

It is important to note that although the data was not statistically significant there is a small difference in the average temperature generation between the two methods. This leads us to believe that with a refined procedure and more tests we could achieve significant data.
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Taylor J. Zdanowski, April 18, 2016

FUTURE PLANS

I would make several procedural changes to increase the validity of the data. First, it would be important to make larger pilot holes. Some of the data indicated that the pin had moved to be 1.5 mm away from each thermocouple and thus had to be omitted. The pilot hole size should be doubled.

I would also recommend the thermocouples be pasted to the bottom in order to ensure the validity of the data.

Dr. Finney and I plan to continue working together in the Wu Manufacturing Research Center through the summer and into the fall semester if necessary. The first step will be refining the procedure and re-testing on bovine bone. Once we can achieve significant data on bovine bone we will move to human bone testing.
ACKNOWLEDGMENTS
The author acknowledges Yao Liu and Daewoo Park for their help in bone sample preparation and data analysis. Dr. Fred Finney for his medical advice. Lastly, Dr. Albert Shih is for his continued involvement and guidance.

REFERENCES