Thermal Effects in Bone From Milling and Sawing

A COMPARITIVE STUDY

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Summary: Temperature measurements were made in bovine bone using two different instrument sets: the typical saw blade with cutting block, and a mill cutter with cutting template. The choice of tool and guide has a significant impact on the temperature as measured at the surface and at specific depths under the planned resection.

Introduction

Saws are ubiquitously used today in orthopaedic surgery. Milling bone surfaces is a relatively new method of preparing bones for a prosthesis. Several factors influence the thermal effects seen in the bone due to cutting its surfaces. It was the intent of this second study (The first study was conducted using porcine tibias) to see what variation may be attributed to the type of tool used while cutting bovine bone. Our results show that temperature gains are significantly lower when the bone is milled instead of sawed. Additional testing is planned on human cadavers.

Materials and Methods

Cutting tests were conducted on the epiphysis of 400-425 lb bovine tibias in October 1994, in the Zimmer Biomechanics Laboratory. The calves were slaughtered at a local butcher one day before testing and their tibias were left at ambient temperature for 24 hours prior to testing. A new tool (cutter or sawblade) was used for each resection of 14 bones. Three different measurement methods for recording the temperatures were utilized in this study.

A custom horizontal drill guide was used to drill holes at depths of approximately 2mm, 3mm, and 4mm beneath the planned tibial resection at locations shown in Figure 1 for both the milling and sawing experiments. Three iron constantine, (J-type model), thermocouples, with a temperature range of 20° to 50°Celsius (C) (accuracy ±.5°C), were then inserted into the holes in the tibia as the first method of measurement. Temperatures were recorded at ten-second intervals for each of the three thermocouples.

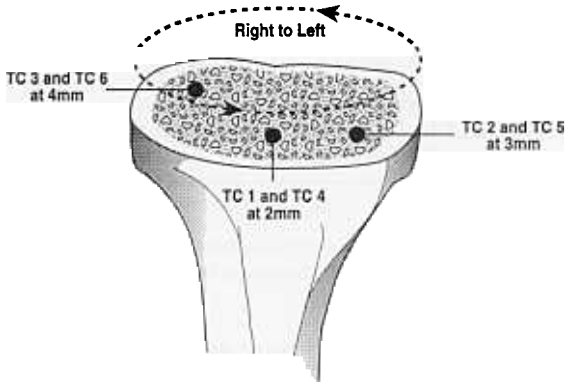

FIGURE 1

Thermocouple (TC) Location and Depth (In Millimeters)

Measurements were also made of the bone and tool before and after resection. We then utilized a one surface microsensor temperature probe, (K type Model 8800 8 from Omega Technology), with a temperature range of 0°C to 100°C (accuracy ± 1°C). Several areas on each cut surface were probed, but only the highest readings were recorded. Figure 2 depicts the average temperature gain for each set of seven bones, milled or sawed.

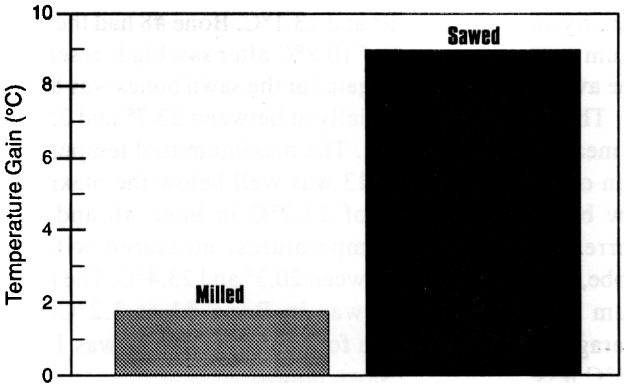

FIGURE 2

Temperature Gain In Bovine Tibias
(Surface Probe Data From 14 Bones)

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An Infra-Red (IR) camera, and its auxiliary equipment, was used as a third measuring method for continuous temperature monitoring of all of the experiments. A standard VCR tape recorded the IR's output for the experiments on bones 3 through 14.

The *NexGen*™ Milling Instruments were used for the resection of tibias 1 through 5, 13, and 14. *Hall*® cutters, (catalog number 5052-203) were used to resect the tibia from right to left (Fig. 1), following the *NexGen* surgical technique and the temperature measurements were recorded (Fig. 3).

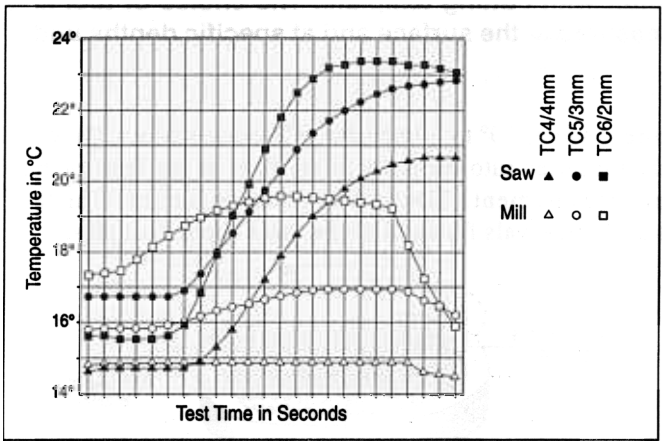

FIGURE 3

Temperature Profile in Bovine Bone
as Measured by Thermocouple at Three Depths

The *MG II*® instruments were used for the resection of tibias 6 through 12. *Hall* saw blades, (catalog number 5071-572) were used to resect the tibia from right to left, following the *MG II* surgical technique and the time and temperature measurements were recorded.

Results

The saw blade tool temperature was initially between 21.4° and 25.8°C. The maximum tool temp gain was 21.7°C after resecting bone #6 and #10. This gain is smaller in this experiment than that in the existing literature[3] and may be attributed to the thinner cortical rim found in the bovine bone tested as compared to that typically found in human bone. The corresponding tibial bone temperature was initially at between 21.9° and 23.1°C. Bone #8 had the maximum temperature gain of 10.8°C after saw blade resection. The average temperature gain for the sawn bones was 8.3°C.

The mill tool was initially at between 23.7° and 25.6°C as measured by the probe. The maximum tool temperature gain of 10.6°C in tibia #13 was well below the maximum saw blade temperature of 21.7°C in bone #6 and #10. Corresponding tibial temperatures, measured with the probe, were initially at between 20.3° and 23.4°C. The maximum temperature gain was in Bone #4 at 3.2°C. The average temperature gain for the milled bones was 1.5°C; 6.8°C less than that of sawn bones.

For sawn bones, temperature gains at 2mm under the resection, as measured by thermocouple TC1 or TC4 were an average of 3.2°C. At 3mm under (TC2 or TC5), the temperature gains were an average of 3.3°C and at 4mm (TC3 or TC6) the average gain was 1.7°C. Bone #7 was excluded from the analysis due to technical errors in placement of the thermocouples and from a change in technique (left to right). Location, as well as depth of the thermocouples, obviously influenced the temperature gain as can be seen by the small difference between the measurements recorded at 2mm and 3mm locations.

For milled bones, temperature gains at 2mm under the resection, were an average of .6°C. At 3mm under, the temperature gains averaged .2°C, and at 4mm, the average gain was .003°C (negligible). All gains for milling were less than those from sawing.

The infrared camera ran continuously during the experiments and the output was recorded, (for bones 3 through 14), directly onto a standard VCR tape. Because it uses the background as a reference, the scale is best used to determine temperature gains (in °C), not absolute temperatures, as can be seen in the film. Temperature gains could not be easily seen when the bones were milled due to the neglible temperature increase. The bone chips appear to be 12°- 20°C hotter than the bone. For sawn bones, the tibial piece when sawed off had temperatures about 12°- 16° hotter than the uncut bone. For bone #8, the temperature gain was close to 30° and the rise remained 10°C or over for close to 1 minute, suggesting that necrosis probably would have occurred.

Discussion

A temperature of 44-47°C has been established in the literature as the limit at which bone necrosis starts to occur if kept at that temperature over one minute.[1] Since bone in surgery is initially at 37°C, a temperature rise of more than 10°C (47-37) would initiate possible damage. Because of the difficulty in trying to maintain the test specimens at 37° we chose an "in situ" necrosis limit of anything over 10° as the limit at which necrosis may begin.[2]

From experiments on the bovine bones, the sawn bones showed a larger temperature gain than milled bones. The average surface temperature gain when sawing was 8.3°C as compared to 1.5°C for those bones which were milled. All three measuring methods showed an increase in temperature gain when comparing sawing to milling. Independent t-tests were performed on each temperature characteristic measured and the appropriate P-values calculated. ANOVA was used to test for differences in testing conditions. All of the statistics indicate that only sawing versus milling has a significant effect on temperature gain measured in bone. Our study suggests that a surgeon concerned with bone necrosis would benefit using the milling instruments over the traditional saw blade for all applicable surgery.

Conclusion

Although the temperature measurements and standard deviation may be different due to the different thermal characteristics between bovine and human bone, we expect to see a very similar temperature gain differential between sawing and milling in cadaver studies. The conclusions drawn from this study justify further studies to determine if a link exists between a decrease in thermal injury and better surgical outcomes.[4]

References

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97-2100-08 Rev. 1 5MZ Printed in U.S.A.