
Bone Cut Accuracy and Flatness From Milling and Sawing

A COMPARATIVE STUDY

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Summary: Cutting errors which occur during bone preparation, prior to implantation, have three primary causes. The first is due to the relative motion between the cutting guide and the bone, caused by vibration of the cutting tool. The second is due to saw blade bending or "skiving", and the third is due to motion of the cutting tool as it moves on or through the cutting guide. At least three studies with saw blades¹⁻³ have been done to determine anteroposterior toggle of a saw blade in use with cutting blocks, but none have been done to date using milling cutters with the dynamic stability offered by the *NexGen™* milling instruments. The maximum cutting error with saw blades was more than 2mm as compared to less than .5mm with milling. The average "flatness" of the sawn femoral surface was .013 inches (.3mm) and .003 inches (.1mm) for the milled surface. The results of this study indicate that cutting errors can be minimized by using mill cutters and by anchoring the cutting guide more securely; such as with the *NexGen MICRO-MILL™* Instrumentation System.

Introduction

Saw blades are still used in the majority of orthopaedic procedures today while alternative cutting methods are being investigated. Milling bone surfaces is a relatively new method of preparing bones for a prosthesis. Accurate bone cuts are facilitated by accurate instrumentation sets and good surgical technique. Even with precise instruments, it is possible to make less than optimal cuts, particularly on the femoral side. Whether cementing or choosing cementless components, accurate and flat fit of the components to the bone is a must for a satisfactory outcome.

It was the intent of this study to see the extent of variation in bone cut accuracy and flatness that could be attributed to the choice of the resection tool used for surgery.

Materials and Methods

The bones were from 400-425 lb bovines that were slaughtered within 24 hours of the start of these experiments.

The milling studies were performed in the Zimmer biomechanics laboratory. *Hall®* Surgical (Zimmer) Cutters (catalog number 5052-203), along with the *MICRO-MILL*

Hand Piece were used to resect the femur and (then also used for) the tibia. A new cutter was then used for each subsequent femur-tibia set for bones 17a, 18a, 19a, 20a, and 25t, 26t, 27t, and 28t. The "a" bones corresponded to the femurs and the "t" to the tibias.

The sawing studies were done in the same laboratory. *Hall's* Oscillating Saw and Saw Blade, (catalog number 5052-272) were used to resect the femur and (then also used for) the tibia. A new saw blade was then used for each subsequent femur-tibia set for bones 29f, 30t, 31f, 32t, (33f was not included in this study due to technical difficulties) 33t, 34f, and 35t. The "f" corresponded to the femurs and the "t" to the tibias.

Measurement scans of the milling template, milling femoral guide, and all the bones were done using a Browne and Sharpe model MICROVAL, a manual coordinate measuring machine (CMM). A 6mm diameter probe was used with the CMM with a calibrated accuracy of +/- .0002". Bones 28t and 32t were also measured using a Federal Indicator (with a calibrated accuracy of +/- .00005") with an electronic gage head attached to a high amplification output. A .030" diameter probe was used for the indicator. Four scans were done of each femur. These measurements began at the anterior flange and ended at the posterior flange and were done for each of the following positions: medial central cancellous, lateral central cancellous, (referred to as the central scans), and the medial and the lateral cortex, (referred to as the m-l scans). Measurements of the sawing instrumentation and all the sawn bones were made using the same equipment as that described for the milling experiments. Four scans were done of each tibia. The measurements began at the lateral cortex and ended at the medial cortex at four positions: anterior, central-anterior, central-posterior, and posterior.

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All measurements were then loaded into Computer Vision (drafting) software for analysis. Maximum cutting errors for both sawing (Figure 1), and for milling (Figure 2), were also plotted. The dotted lines represent where the instrument was designed to cut at nominal. The solid lines show the most variant cuts of the worst bone. The variance is measured from the last contact anteriorly and posteriorly that the implant and bone would have.

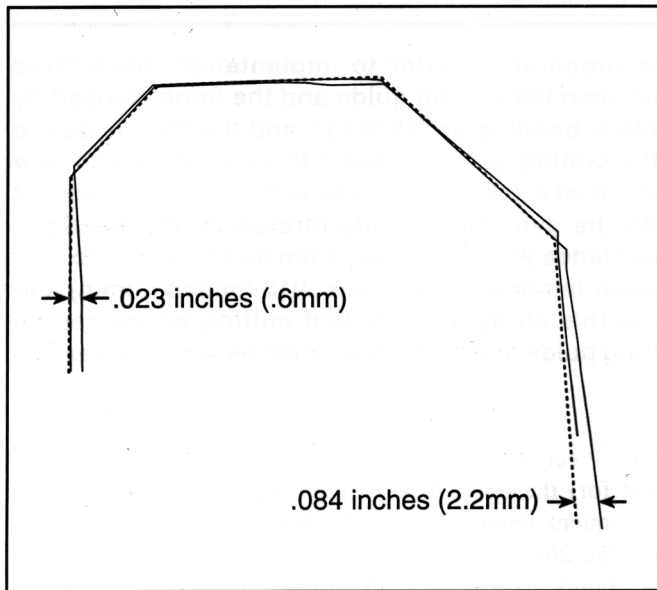


FIGURE 1
Saw Blade - M/L and Central Scans
Showing Maximum Deviation From Nominal Cut

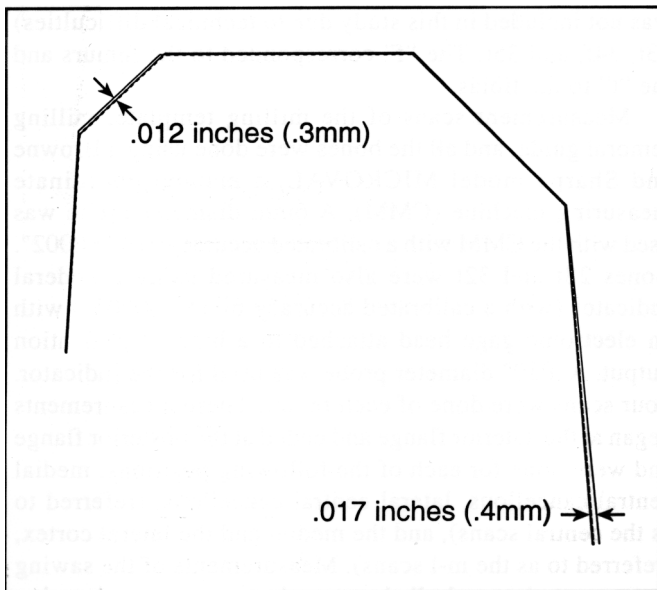


FIGURE 2
Milling - M/L and Central Scans
Showing Maximum Deviation From Nominal Cut

Milling Results

Zimmer's *NexGen* surgical technique and instruments were used to resect four femurs and four tibias. The average tibial "flatness" was .020 inches (.5mm) as measured from peak to trough, by the CMM. The tibial "flatness" of bone 28t was .0075 inches (.1mm) as measured from the lowest peak to the highest peak, by the Federal Indicator. The average (of all cuts) femoral "flatness" was .003 inches (.1mm) and ranged from .002 inches on the distal and anterior chamfer cut to .005 inches on the posterior condyle, done with the new thicker *Hall* Saw Blade, (catalog number 5052-201) with the *NexGen* Femoral Finishing Guide.

The maximum variation from the milled bone surface to the nominal: 1) distal cut is .007 inches (.2mm), 2) anterior chamfer cut was .009 inches (.2mm), 3) posterior chamfer was .015 inches (.4mm), 4) posterior flange was .022 inches (.6mm), and 5) anterior flange was .017 inches (.17mm). The posterior flange is not cut with the mill cutter, but with the .05" thick saw blade from *Hall*.

Compared to the angles of the nominal milling instrument, the average angles with respect to the distal cut of the femur are as follows: the anterior chamfer is within five minutes of a degree, the posterior chamfer is within eight minutes, and the posterior flange is within 20 minutes of a degree.

Sawing Results

Zimmer's *MG II*[®] surgical technique and instruments were used to resect an additional four femurs and four tibias. The average tibial "flatness" was .044 inches (1.1mm) as measured from trough to peak, by the CMM. Bone 32t's "flatness" was .020" or .5mm as measured from the lowest peak to the highest peak, by the Federal Indicator.

The maximum variation from the sawn bone surface to the nominal: 1) distal cut was .010 inches (.3mm), 2) anterior chamfer cut is .018 inches (.5mm), 3) posterior chamfer is .016 inches (.4mm), 4) posterior flange is .022 inches (.5mm), and 5) anterior flange was .065 inches (1.6mm).

Compared to the angles of the nominal saw guide instrument, the average angles with respect to the distal cut of the femur were as follows: the anterior chamfer was within 38 minutes of a degree, the posterior chamfer was within 32 minutes, and the posterior flange was within 81 minutes of a degree.

Discussion

Using the milling instrumentation on the tibia yielded a cut which was two times as "smooth" as the surface prepared with the saw blade (.020 vs. .0441 inches) (Figure 3). Milling the femur produced a cut which was almost four times as "smooth" compared to sawing (average of all milled cuts was .003 inches (.1mm) compared to .013 inches (.3mm) on the sawn cuts) (Figure 4).

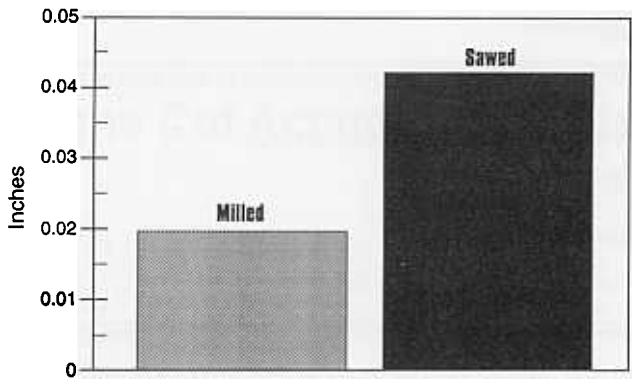


FIGURE 3
Average Flatness (Tibial)
Trough to Peak on 7 Bone Study

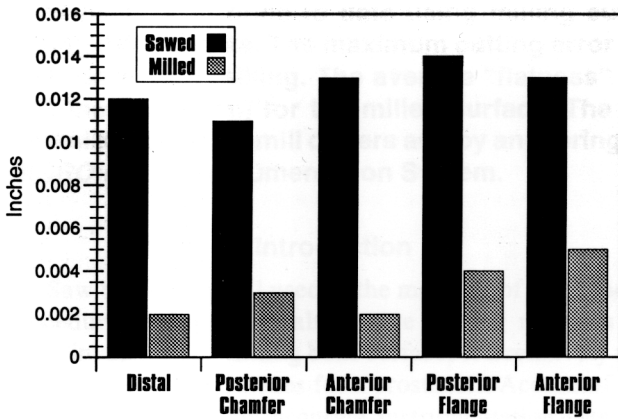


FIGURE 4
Average Flatness (Femoral)
Trough to Peak on 7 Bone Study

The repeatability of the cuts (Figures 5 & 6) were measured from the most anterior and posterior points of contact from which the bone and femoral implant will touch upon implantation. The repeatability measures the variation between all scans of all the cuts on different bones. Milling yielded a maximum variation of .023 inches on the anterior flange and .022 inches on the posterior flange. Sawing yielded more than twice the total variation with .101 inches (2.6mm) on the anterior flange and .034 inches (.9mm) on the posterior flange.

Cutting errors and surfaces which are not flat may cause unacceptable mismatch between the resected bone and the planned prosthetic implant. Mismatch may contribute to earlier loss of implant fixation. Accurate and flat cuts can be attained with good surgical technique, good fixation of cutting guides to the bone, and careful use of the resection instruments.

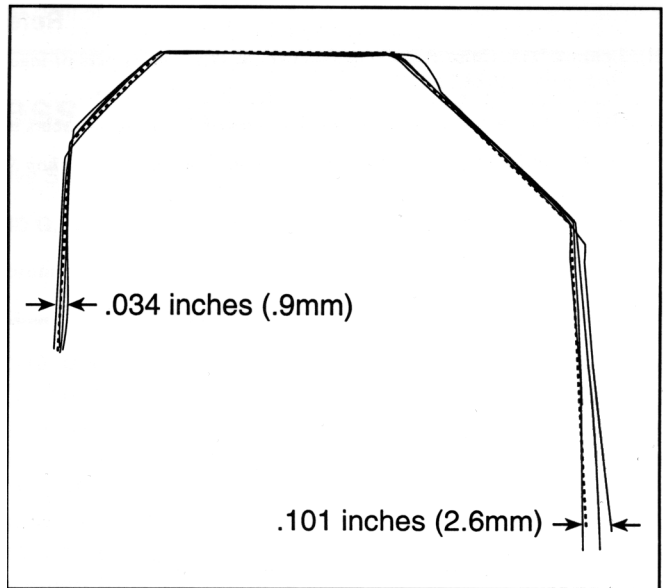


FIGURE 5
Saw Blade - Repeatability of Femoral Cuts

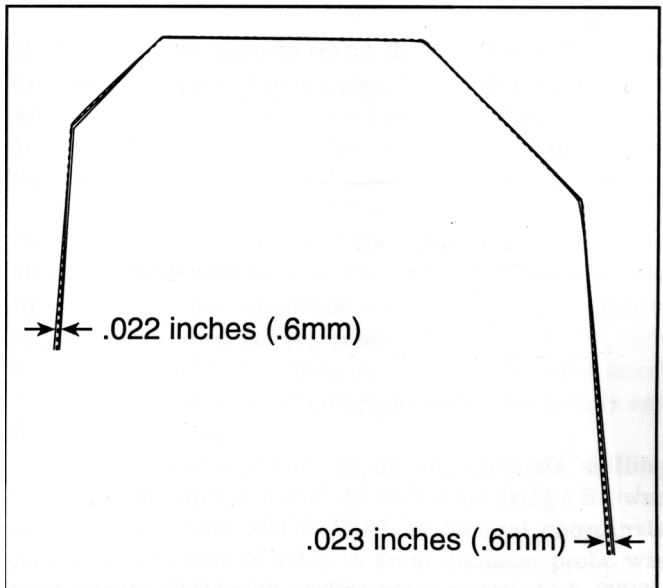


FIGURE 6
Milling - Repeatability of Femoral Cuts

References

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