An internally cooled saw blade for bone cuts

Lower temperatures in 30 knee arthroplasties

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A saline-cooled saw, which has been shown to give good control of the heat generation during bone cutting under laboratory conditions, was tested in in vivo. With a saline flow of 80 mL/min, the maximum cutting temperature in 30 knee prosthetic operations was 32 (25–37) °C in the saw blade and respectively 30 (26–35) °C and 29 (26–34) °C 2 and 3 mm underneath the cut surface.

Because the temperature generated by conventional osteotomy equipment may exceed 70 °C, the use of our cooled double saw blade during joint replacement prevents heat osteonecrosis.

When preparing bone with power tools, high temperatures arise (Krause et al. 1982, Eriksson et al. 1984, Bruun and Andersen 1987, Toksvig-Larsen and Ryd 1989). Such high temperatures, generated by cutting the subchondral bone, which in arthrosis is often extremely hard, may cause localized necrosis (Eriksson 1984) in the bone tissue adjacent to a prosthesis. The subsequent fibrous tissue healing increases the risk of implant loosening and impairs bony ingrowth in porous implants (Ryd 1986, Haddad et al. 1987, Ryd et al. 1990).

We have previously shown that irrigation of the sawing area by physiologic saline during knee surgery had no cooling effect (Toksvig-Larsen and Ryd 1989). Modifications in saw blade design have to date failed to decrease the temperature down to biologically acceptable levels, but in experimental designs internally cooled blades have been promising (Toksvig-Larsen et al. 1991).

We report an evaluation of our internally cooled saw blade in clinical practice.

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Patients and methods

A saw blade was constructed using two standard 3M Maxi Driver™ oscillating L 122 saw blades adapted to each other and with inbuilt canals, so that a cooling agent could be led to the saw teeth to cool the bone in the cutting area and to clear the chips from the kerf (Figure 1). The saw blade was driven by a standard air-powered 3M Maxi Driver™ machine (16,000 rpm at 7 atmospheres pressure). The saw blade was connected to an arthroscopy pump delivering 80 mL/min of physiologic saline during 30 tibial cuts and 40 mL during five tibial cuts.

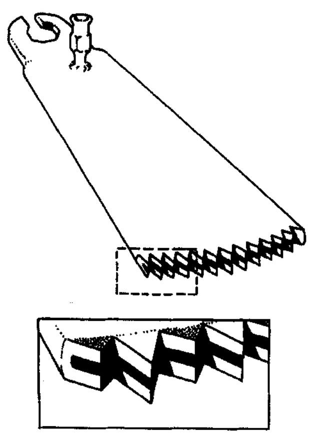

Figure 1. The internally cooled saw blade.

One measurement was excluded because of connection of wrong equipment between the pump and the saw, resulting in inconstant delivery of the cooling agent (Figure 2).

The temperature measurements were performed with thermocouples type copper-constantan—Exacon CN 7 (Exacon Scientific Instruments APS, Roskilde, Denmark)—connected to a pen recorder—BBC SE 460 (Brown Boveri Goerz Metrawatt, Vienna, Austria); temperature range 0–100 °C (total accuracy ± 1.0 °C). A thermocouple was embedded in the saw blade, with the measuring point 2 mm from the cutting edge. Two thermocouples were inserted into the tibia underneath the cutting surface in a standardized way. To achieve this, the jig V-B of the PCA™ Universal™ Total Knee Instrument System (Howmedica, Rutherford, NJ, USA) was modified with a number of holes 1 and 2 mm below the upper guiding surface. These holes served as guide holes for Steinmann pins of appropriate dimensions, used as drill bits. The redundant number of holes made it possible to choose a region of measurement corresponding to the area of most pronounced sclerosis, which we postulated should give the highest temperatures.

A methodologic study was done previously (Toksvig-Larsen and Ryd 1989), where the measuring points of the thermocouples were found to be placed 2 (0.2–3.5) mm and 3 (1.5–5.0) mm from the cut surface.

Due to technical difficulties, we could not record three parameters (saw blade, 1 and 2 mm) in all the measurements.

Eight arthrotic knees (Ahlbäck 1968) stages 1–3 had a PCA^{TC} unicompartmental knee and 27 stage 4–5 had a PCA™ Primary Total Knee prosthesis inserted using this internally cooled saw equipment in the bone preparation.

Results

The mean maximum temperature in the saw blade was 32 (25–37) °C (flow 80 mL/min). In the tibia the mean maximum temperature was 30 (26–35) °C and 29 (26–34) °C, respectively, at the 2- and 3-mm levels.

When the flow was reduced to 40 mL/min, the temperature in the saw blade was 32 (27–35) °C, and 28 (22–31) °C and 29 (25–31) °C at the 2- and 3-mm level below the cutting surface.

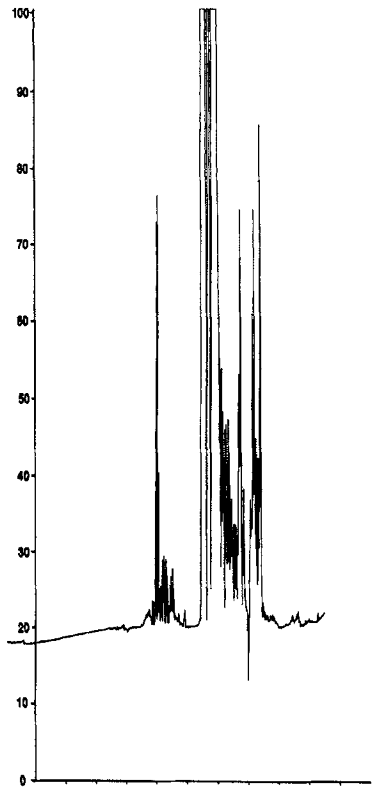

Figure 2. The effect of internal irrigation, where the temperature rose dramatically and momentarily when the continuous flow in the saw blade was interrupted.

Discussion

While cutting bone during osteotomies or, particularly, during arthroplasty, avoiding heat damage of the bone is a reasonable objective. All the temperatures recorded in this study during bone cutting were below the level for impaired bone regeneration, which was indicated by Eriksson (1984) to be in the range of 44–47 °C, and the margin to the critical temperature was safe.

Earlier in vivo studies have shown that the mean maximum temperature in the conventional oscillating saw blade was 68 °C, with a range from 44 °C to more than 100 °C during preparation of the tibia component during knee prosthetic surgery. External irrigation with squirt cooling with saline did not lower the temperature (Toksvig-Larsen and Ryd 1989). Previous tests have also shown that alterations in the saw-blade geometry (Toksvig-Larsen et al. 1991) did not lower the cutting temperature to a desired level. External cooling was sometimes satisfactory under laboratory conditions, but the amount of saline in the operating area was profuse and not suitable for clinical practice. The internally cooled blade consistently lowered the cutting temperature to low, subcritical temperatures. A flow of 20 mL/min was sufficient to avoid critical temperatures, but flow below 30–40 mL/min was associated with some plugging of the canals in the saw blade. Even 80 mL/min was not inconvenient when the liquid continually was removed by a suction pipe.

The case where the measurement in the saw blade was excluded illustrated well the effect of internal irrigation, where the temperature rose dramatically and momentarily because there was not a continual flow in the saw blade.

Lavelle and Wedgwood (1980) obtained a clear effect of liquid cooling and showed that internal irrigation appeared effective regardless of penetration depth in contrast to the external cooling. When drilling straight through the canine femur from the lateral to the medial side, a 9 °C higher temperature was measured in the remote, medial cortex compared with that recorded in the lateral one when cooling was applied externally (Eriksson et al. 1984). Internal cooling is effective because the cooling agent is led to the saw teeth to cool the specific cutting area, and secondly, the saw chips are cleared away from the kerf. Heat accumulation in the chips, which in metal cutting comprises 60–70 percent of the total heat generation (Schmidt 1950), is thus avoided. Also, such chips would otherwise tend to be pushed into the uncut bone at the front of the teeth, resulting in a milling process instead of real cutting.

A spin-off effect in the double saw blade is a considerable stability with less tendency for bending ("skyving") during the working process. Thus, an optimally flat surface, giving a closer contact between bone and prosthesis, which is a prerequisite for osseointegration, may be achieved (Carlson et al. 1988).

Acknowledgements

This investigation was supported by the Alfred Österlunds Stiftelse, Lund Hospital Foundation, Lund University Foundation, Greta and Johan Kocks Stiftelse, and Malmöhus Läns Landsting.

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