

Drilling efficiency and temperature elevation of three types of Kirschner-wire point

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An innovative Kirschner (K-) wire point was developed and compared in fresh pig femora in terms of drilling efficiency and temperature elevation with the trochar and diamond points currently used in clinical practice. The tips of thermal couples were machined to the defined geometry and the temperature measured during drilling. Using the same drill speed (rev/min) and feed rate, the new K-wire point produced the lowest thrust force and torque as measured by a Kistler dynamometer. Drill point temperatures were highest with the trochar geometry ($129 \pm 6^\circ\text{C}$), followed by the diamond ($98 \pm 7^\circ\text{C}$). The lowest temperatures were recorded with the Medin K-wire ($66 \pm 2^\circ\text{C}$). On repeated drilling it could be used for up to 30 holes before reaching the less satisfactory drill performance of the diamond tip. The new K-wire provides a better alternative as it requires less effort for insertion, generates less heat and may be re-used.

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Kirschner (K-) wires are commonly used in orthopaedics for percutaneous fixation of fractures and circular external fixation. Insertion of these wires involves drilling, a process which may generate heat and cause necrosis of bone. Our aim was to evaluate a new design of K-wire point and to compare it with the trochar and diamond points which are commonly used in terms of drilling efficiency and thermal effects.

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Materials and Methods

Three different wire points were tested (Fig. 1). The trochar point had three facets ground to a point with a rake angle of -28° and clearance angle of $+6^\circ$. Figure 2 shows the rake and clearance angles. The diamond point had two opposing flat facets ground to a pair of cutting edges with rake angles of 12° and clearance angles of $+60^\circ$. The new point design (Medin K-wire; Medin AC, Nove Mesto na Morave, Czech Republic) had two steep flutes for removal of bone fragments during drilling and was ground with a rake angle of $+20^\circ$ and a clearance angle of $+30^\circ$. All the wires tested were manufactured by the same manufacturer (Medin AC) using implant steel (ISO 5832-1E).

We obtained the femora of six-month-old pigs from a local butcher within six hours of slaughter. The soft tissues were removed and the bone was cut transversely into blocks. In order to make consistent measurements, wires were inserted in areas where the cortical thickness was 2.5 to 3 mm. All tests were performed at room temperature (22 to 24°C).

Drilling efficiency was characterised by the thrust force and torque under the same drilling conditions (rotation velocity $n = 280$ rev/min and feed rate $f = 0.1$ mm/rev). We used a Kistler 9272 dynamometer (Kistler Instrumente AG, Winterthur, Switzerland) to measure the thrust force and torque which were sampled at a frequency of 8kHz. The listed drill speed and feed of a round-column drilling machine were calibrated to 5%. Wires of 2.5 mm in diameter were used. For each type of point, three wires were used and each was tested six times. In order to reduce the effect of noise in the digitised data on the results, 100 data points each were selected which included the maximum thrust force and torque moment during drilling and their means calculated for each test giving 18 (3×6) mean forces and 18 torque moments for each type of wire. One-way analysis of variance (ANOVA) and the Scheffé multiple range test (confidence level = 95%) were then performed on the pooled data on the three types of wire using Statgraphics v.7 (STSC Inc, Manugistics Group Inc and Statistical Graphics Corporation, Maryland).

The tool life of the Medin K-wire point was also measured since reinsertion is often necessary in clinical practice. Three new wires of each type were inserted repeatedly through a single cortex while the thrust force and torque

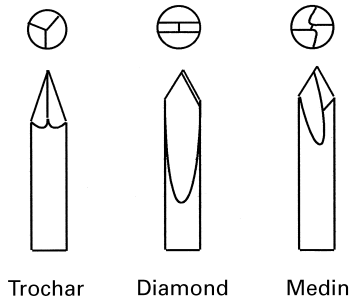


Fig. 1

Diagram showing the K-wire tip configurations.

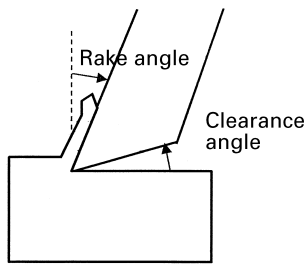


Fig. 2

Diagram showing the rake angle and clearance angles of a cutting edge.

were measured. Wear of the drill point was measured at the end according to the ISO 3685 standard.

Temperature elevation during drilling was measured using fast-response coaxial Medtherm thermocouples (Medtherm Corporation, USA, Huntsville, Alabama) with their points being shaped into the defined geometry (Fig. 1). These were calibrated against laboratory mercury thermometers to an accuracy of 1°C. Each thermocouple was fastened to the tool head of a computer numerical

control lathe and inserted into the specimen of bone which was clamped onto a special template. Thermocouple output was sampled at 50Hz and recorded during drilling of the first cortex. Each wire point was tested three times. For each test we selected data for eight seconds which included the highest temperatures for each type of wire. ANOVA and the Scheffé multiple range test (confidence level 95%) were then performed on the pooled files.

Results

The thrust force and torque showed typical ‘M’ shapes which corresponded to dual-cortex penetration with the higher values occurring during the penetration of the first cortex for nearly all specimens. The box-whisker plots for thrust force and torque moment are shown in Figures 3 and 4. There were significant differences ($p < 0.05$) in the mean thrust forces between each pair of wire types. The mean thrust force for the new Medin wire was 63% lower than the trochar and 39% lower than the diamond point. The trochar wires produced a significantly ($p < 0.05$) higher torque (more than 60%) than the other two. The actual wear of the drill points for the Medin wire was too low to measure according to the ISO 3685 standard. The increase in torque and thrust forces on subsequent passes is shown in Figure 5. With each pass a decrease in performance was noted, but the performance of the Medin wires did not approach that of the diamond point until approximately 30 holes had been drilled.

The changes in tool temperature during drilling are shown in Figure 6. Each wire had a plateau of maximum temperature elevation lasting approximately eight seconds. The highest mean maximum temperatures (SD) were $129 \pm 6^\circ C$ for the trochar point followed by $98 \pm 7^\circ C$ for the diamond. The lowest mean temperature of $66 \pm 2^\circ C$ was found with the Medin K-wire, which was significantly ($p < 0.05$) lower than the others.

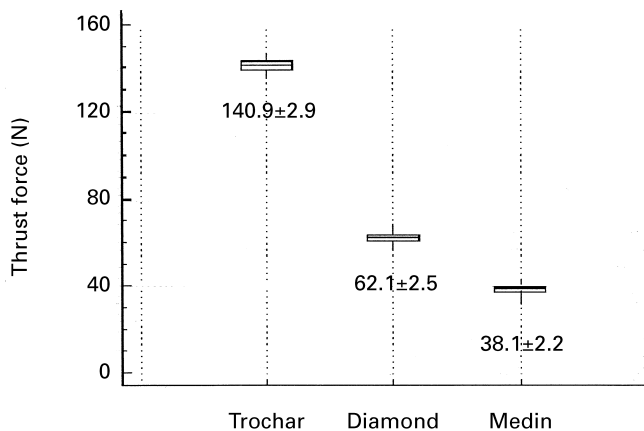


Fig. 3

Multiplex box-whisker plots and mean $\pm SD$ for the thrust forces. Drilling conditions: drill speed $n = 280$ rev/min, feed rate $f = 0.1$ mm/rev.

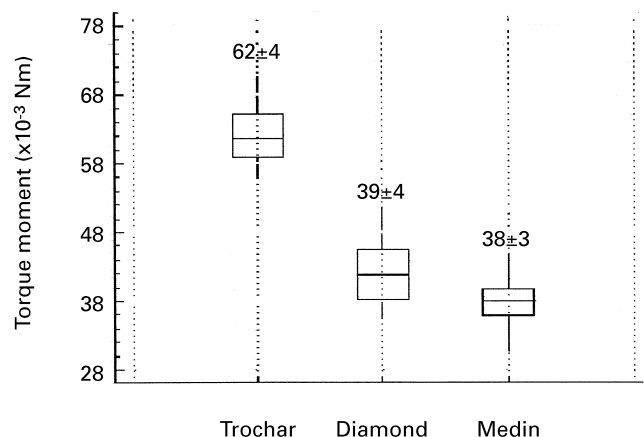


Fig. 4

Multiplex box-whisker plots and mean $\pm SD$ for the torque moments. Drilling conditions: drill speed $n = 280$ rev/min, feed rate $f = 0.1$ mm/rev.

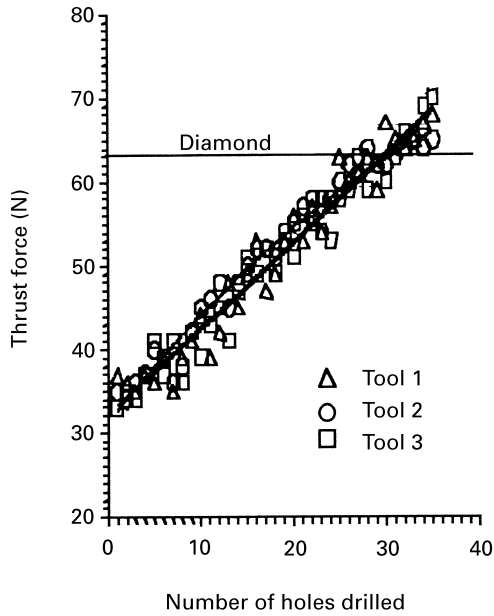


Fig. 5a

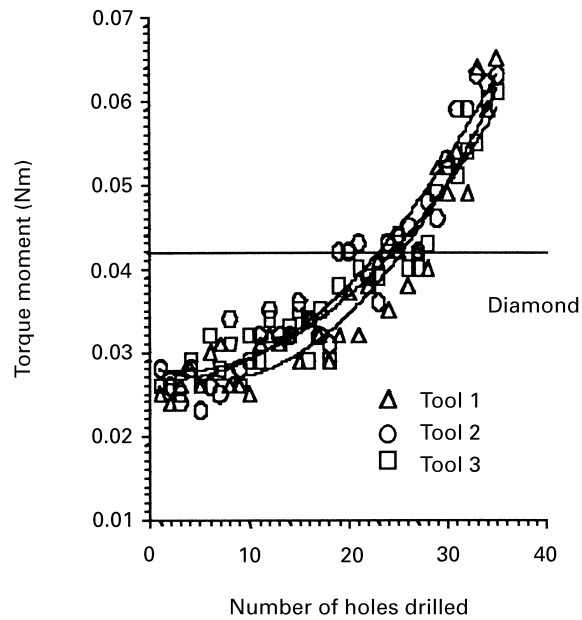


Fig. 5b

Graphs showing a) the thrust force and b) the torque moment during the tool life test of the Medin wires in pig cortical bone (drill speed $n = 280\text{rev/min}$, feed rate $f = 0.1\text{mm/rev}$). For comparison the mean thrust force and torque moment of the diamond tip are included.

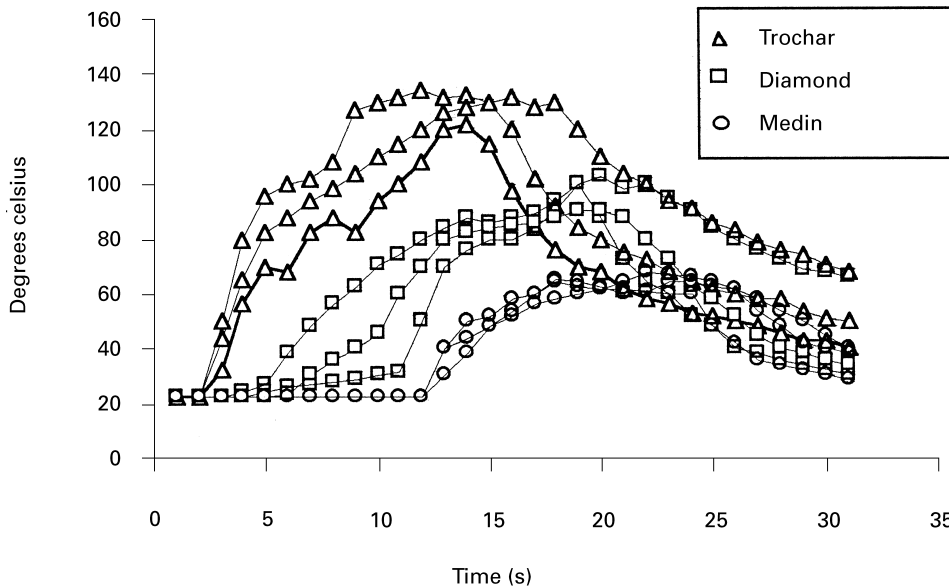


Fig. 6

Graph showing the temperature elevation for different K-wire tips when drilling into pig cortical bone over 35 seconds (drill speed $n = 280\text{ rev/min}$, feed rate $f = 0.1\text{ mm/rev}$).

Discussion

To our knowledge there has been no previous study documenting the temperature elevation of different thin K-wires (< 3 mm in diameter) during drilling. Zegunis, Toksvig-Larsen and Tikuisis¹ used 1.6 mm trochar and 2.0 mm diamond K-wires but reported only a combined mean maximum temperature of 54°C at a site 0.5 mm away

from the hole. Matthews, Green and Goldstein² used five different skeletal fixation pins of 3.9 mm in diameter and human cadaver bone to investigate the thermal effect of drilling. A mean maximum temperature of approximately 115°C for the trochar and 110°C for the diamond (spade) were reported at a site 0.5 mm from the pin. In our study we measured the wire point temperature in the two most commonly used K-wires and in a new design. We believed

that the higher tool temperature would result in a higher temperature in the surrounding bone but that this would be lower than the wire because of heat conduction and dissipation.

Our results showed that under the same drilling conditions, which may not be optimal, the new wire produced the lowest thrust force, torque and temperature elevation. This superior performance was attributed to its positive rake angles and the presence of flutes. A very low thrust force would not only require less effort on the part of a surgeon, but also produce less buckling of the wire and much easier control of the direction of drilling. Further advantages of the new design are its large point angle and very sharp point, which would anchor itself easily at the intended drilling site without slipping. Since surgeons often reinsert

wires to achieve the optimal position, those which blunt less easily would be preferred. We believe that the new design of tip provides a better alternative than the trochar and diamond points currently in popular use.

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