

# Hammering K-wires is Superior to Drilling with Irrigation

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**Abstract** Cooling during drilling Kirschner wires is not always effective in preventing thermal related damage. In this study, we used a human in vitro model and compared temperature elevation, insertion time, and extraction force between three Kirschner wire insertion methods—drilling with and without irrigation and pneumatic hammering. Forty five Kirschner wires were inserted into 15 fresh human cadaver metacarpals. All three insertion methods were applied in each metacarpal. Drilling without irrigation resulted in a temperature elevation of  $67.25 \pm 5.4^\circ\text{C}$  with significantly lower values for drilling with irrigation ( $4.15 \pm 0.6^\circ\text{C}$ ) and pneumatic hammering ( $31.52 \pm 3.4^\circ\text{C}$ ). The insertion time for pneumatic hammering ( $47.63 \pm 8.8$  s) was significantly lower compared to drilling without irrigation ( $263.16 \pm 36.5$  s) and drilling with irrigation ( $196.10 \pm 28.5$  s). Extraction forces after drilling without irrigation, drilling with irrigation, and pneumatic hammering were  $39.85 \pm 4.1$  N,  $57.81 \pm 6.5$  N, and  $62.23 \pm 6.7$  N, respectively. Pneumatic hammering is superior to drilling without irrigation, especially when irrigation is not possible.

**Keywords** Drilling · Metacarpal · Pneumatic hammer · Irrigation · K-wire

## Introduction

Kirschner wires (K-wires) are often used in hand surgery because it is a quick and simple method for stabilization of fractures [19]. Multiple passes, type of K-wire configuration, quality of soft tissues, and accuracy of placement are important issues in K-wire fixation. The drilling technique itself may play an important role in the occurrence of frictional-heat-related complications like necrotic bone around the wires [8, 12]. This predisposes to pin-track infections and loosening of K-wires which can result in early removal or even osteomyelitis [3, 16]. Thermal necrosis is a product of time [4, 6] temperature [2, 7], drill speed [4, 21], insertion force [1, 20], K-wire characteristics [13, 18], and the factor irrigation [14, 24].

The influence of heat generation on bone has long been recognized. Hippocrates (500 BC) even recommended that the trepanning tool must be cooled during bone removal to avoid injury to the surrounding bone [17]. Temperature elevation during drilling into bone is nowadays kept to a minimum by external or more effectively by internal irrigating [15, 24]. Internal irrigation however is not useful when drilling K-wires, because it is not possible to let the cooling agent passing down the center of the K-wire [14]. Therefore, the external irrigation technique must be used. This technique is effective when a constant flow is provided at the point of insertion. In areas of limited access, however, this can not be realized and therefore will result in less or no cooling effect at all [15, 22, 24]. Also, constant external irrigation at the opposite cortex or during percutaneous drilling is usually impossible, resulting in a very low or absent cooling effect [9].

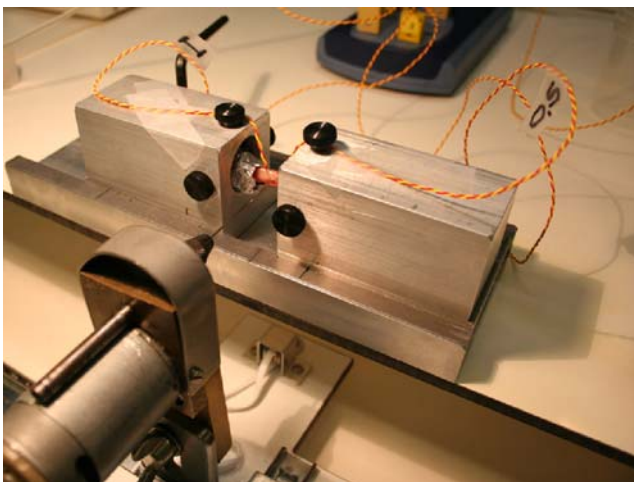
The ultimate K-wire insertion method would be a technique without the necessity of irrigation but with the advantages of drilling and without thermal related compli-

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cations. K-wire insertion by hammering using a pneumatic hammer could prove to be effective in reaching this goal [11, 23, 25]. It has been shown that hammering of K-wires results in lower heat generation, shorter insertion time, less thermal damage and equal or even better initial fixation compared to drilling without irrigation. All together, this suggests that hammering is a good alternative for drilling. These experiments, however, have one major drawback as they used in vivo or in vitro animal models. Eriksson showed that temperatures measured in animal models are not applicable to the clinical situation [9]. Furthermore, these experiments did not compare drilling with irrigation versus hammering. We therefore designed a study to determine the insertion time, extraction force, and maximum bone temperature while inserting K-wires into human cadaver metacarpals using a pneumatic hammer and comparing these data to conventional drilling with and drilling without irrigation.

## Materials and Methods

Fifteen fresh human cadaver metacarpals were used. They were collected from two male human cadavers who had no reported history of disorders or diseases related to bone which was verified by X-ray examination. Their ages at death were 75 and 77 years. The metacarpals were denuded of all soft tissue and were measured at two places at the diaphysis resulting in an average diameter of 10.3 mm (SD=2.1 mm). The experiment was conducted at room temperature (21.6°C, SD=1.12°C) with the bones rigidly fixed (Fig. 1). The fixator was placed on the operation device as described before [11, 12]. A weight of 0.5 kg was used for forwards movement of the drill and pneumatic hammer. Three stainless steel trocar-tip K-wires (1.0 mm ×



**Fig. 1** Experimental setup. Drilling Kirschner wire into bone. Two thermocouples are placed at a distance of 0.5 and 1.0 mm from the periphery of the K-wire insertion place.

150 mm, Synthes, Zeist, The Netherlands) were inserted, by hammering, drilling without irrigation and drilling with irrigation (10 ml/s, 21.1°C (SD=1.16°C)) in the diaphysis of each metacarpal. Each metacarpal has a proximal, mid, and a distal location for K-wire placement. The three techniques were alternated between these locations, which resulted in five times K-wire insertion for each technique per location. The temperature was measured with two 4.0-millimeter-diameter Type K chromel–alumel thermocouples placed into the cortex of the metacarpals at a depth of 1.0 mm at a distance of 0.5 and 1.0 mm from the periphery of the insertion site at 180° to each other. The thermocouples were attached to a Pico USB TC-08 8-channel thermocouple data logger with a measuring range of –270 till 1,370°C (accuracy±0.5°C). The temperature was recorded at 1-s intervals. Canals for the thermocouples, 0.5 mm in diameter, were predrilled by a Rosa XY-table (Milan, Italy) with a drill speed of 3,000 rpm. Friction between the thermocouples and the walls of the predrilled canals was sufficient to hold them in place. K-wires were drilled with a speed of 1,200 rpm (Fig. 1) [11].

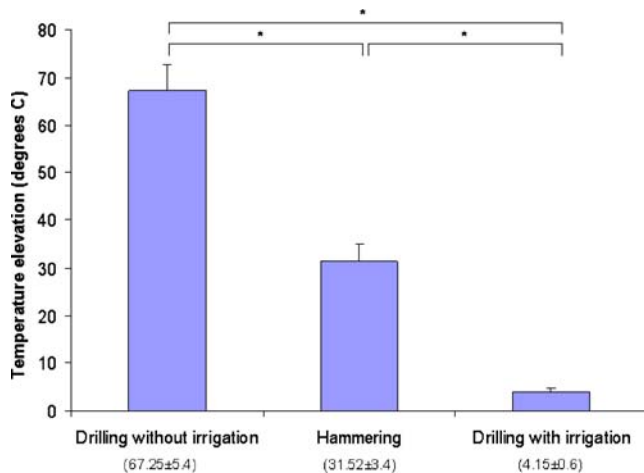
For hammering K-wires, an adapted Micro-Aire 1500 (Micro-Aire Surgical Instruments Inc., Valencia, California, USA) was used. This is from an origin air-powered osteotome apparatus which we used as pneumatic hammer. The hammering frequency (maximum of 10,000 pulses/min) depends on the air pressure in the hammer and has an inlet pressure varying between 80 and 100 psi (5–7 kg/cm<sup>2</sup>).

Trocar tip K-wires were cut to a length of 60 mm to prevent side bending. The duration of each experiment was counted from the beginning of insertion until the K-wire had penetrated both cortices.

After insertion, the K-wires were removed using a 1,000-N (±0.022%) Mecmesin Advanced Force Gauge, (Newton House, West Sussex, United Kingdom). Differences in temperature, insertion time and extraction force were analyzed by Bonferroni Multiple Comparisons. Statistical significance was determined based on  $p < 0.05$ . The data were analyzed using SPSS 12.0.1 for Microsoft Windows

## Results

In total, 45 K-wires were placed. The cortical temperatures recorded by the thermocouple positioned 0.5 mm from the drilling site were always higher than those recorded by the thermocouple located 1.0 mm from the drilling site. Therefore, temperature data presented below were recorded by the thermocouple located 0.5 mm from the K-wire insertion place. The elevation of the bone temperature during drilling with irrigation was significantly lower compared to hammering and drilling without irrigation. The temperature elevation during hammering however was

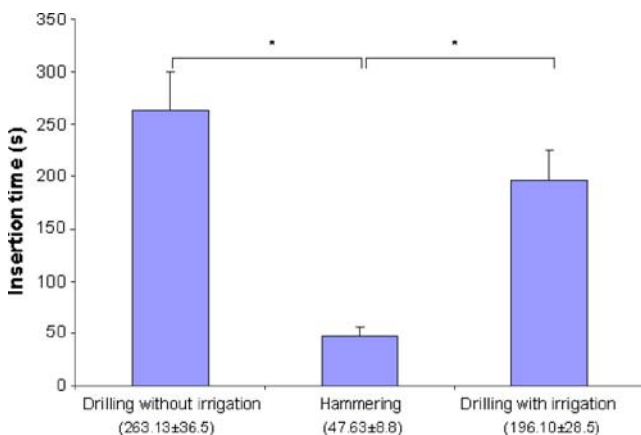


**Fig. 2** Temperature elevation during K-wire insertion at 0.5 mm from the K-wire insertion site. Mean value and standard error of mean of the temperature elevation during K-wire insertion. The asterisk (\*) indicates statistical significance,  $p < 0.01$  (Bonferroni Multiple Comparisons).

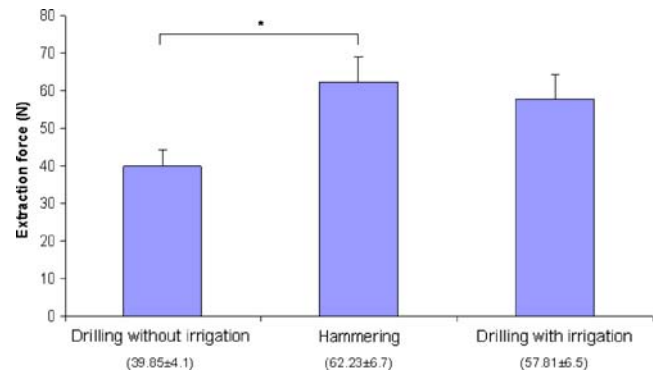
significantly lower compared to drilling without irrigation (Fig. 2).

Hammering further, resulted in a significantly shorter insertion time compared to drilling without irrigation and drilling with irrigation. There was, however, no significant difference between drilling with and drilling without irrigation (Fig. 3).

The extraction force of the K-wires inserted by pneumatic hammering and drilling with irrigation was not found to be significantly different. K-wires inserted without irrigation showed significant lower extraction force compared to hammering (Fig. 4). We had to exclude two measurements from the hammering group. The K-wires stuck in the anterior cortex, where after, it was not possible to hammer the K-wire through the posterior cortex.



**Fig. 3** K-wire insertion time. Mean value and standard error of mean of the Kirschner wire insertion time. The asterisk (\*) indicates statistical significance,  $p < 0.01$  (Bonferroni Multiple Comparisons).



**Fig. 4** Extraction force needed to remove the K-wire directly after insertion. Mean value and standard error of mean of the extraction force needed to remove the Kirschner wire. The asterisk (\*) indicates statistical significance,  $p < 0.05$  (Bonferroni Multiple Comparisons).

## Discussion

Our experiment showed the lowest temperature rise during drilling with irrigation compared to drilling without irrigation and hammering. This can be explained because the denuded cortex was exposed directly to the constantly provided cooling agent at the point of penetration resulting in an optimal irrigation effect. The temperature increase with hammering was not as low as drilling with irrigation, but was significantly lower compared to the temperatures reached with drilling without irrigation. These results confirm the previously reported findings of Zegunis et al., who showed temperatures of 54°C for drilling and 34°C for hammering [25]. The significant lower maximum temperatures reached using the hammering technique can result in less thermal damage during K-wire insertion without the need for irrigation.

In our experiment, we standardized the insertion force for both techniques. Half a kilogram was found to be the optimal weight for forwards movement of the pneumatic hammer. This weight, however, was relatively low for the forward movement of the drill, resulting in relatively long insertion times. Although one would think that this also can lead to an increase in temperature, similar findings were seen in three previous experiments. Zegunis et al. showed a difference of 9 s, needing 41 and 50 s for hammering and drilling, respectively [25]. The measured temperatures were 34°C for hammering and 54°C for drilling. They did not mention standardizing the insertion force. Wassenaar et al. used a variable insertion force of 7 N and 16.9±4.9 N for hammering and drilling respectively, this resulted in insertion times of 18.4 s for hammering and 73.6 s for drilling [23]. Finally, our research group used weights of 1.0 and 1.5 kg for hammering and drilling, respectively. This resulted in insertion times of 13 s for hammering and 142 s for drilling [11]. In our present research using K-wires with

different tip shapes, similar differences were obtained. The short insertion time, seen in all experiments with different insertion forces, is an important characteristic of the hammering technique. Thermal-related osteonecrosis is a product of insertion time and the temperature reached. We further know that osteonecrosis will occur when bone is heated to a temperature of 50°C for 1 min [5]. Therefore, when using the hammering technique, the bone is exposed to lower temperatures during a shorter insertion time with the same insertion weight or with optimized weights for each method. Theoretically, this should result in less thermal damage resulting in better-fixed K-wires.

Our results suggest such a relation since the highest extraction forces were needed to remove the faster inserted hammered K-wires. These results confirm the experiments of Wassenaar et al. in which K-wires were hammered and drilled into ribs of pigs. Those K-wires needed 129.0 N and 57.4 N, respectively, to remove them [23]. Notwithstanding the fact that significant more extraction force was needed to remove the hammered K-wires in both, our and Wassenaar et al. [23] experiments, there is an absolute difference between the extraction forces needed in both experiments. This is probably due to the fact that Wassenaar et al. [23] drilled with 600 rpm, used a variable insertion force, pig ribs, and a different diameter K-wire. On the other hand, in one of our earlier in vivo experiments we showed no significant difference in the extraction forces [11]. We suggested that there was no significant difference due to the rabbit model we used. Based on these results, we conclude that hammering K-wires is a good alternative for drilling with irrigation and is superior when irrigation can not be properly applied using the drilling technique.

Despite our promising results concerning hammering K-wires, we have to keep in mind that we used a human cadaver model. Our experimental conditions differ from the clinical setting in several aspects. The metacarpals were stripped of soft tissue, were at room temperature instead of body temperature and there was no cortical blood flow. The function of this cortical blood flow, however, is debatable. It is possible that it may absorb heat generated in vital bone, but on the other hand, the cortical blood flow rate is normally very low and coagulation of small vessels occurs very rapidly when heated [10]. The relative differences, however, may still be significant and need further investigation.

In two cases, it was not possible to insert the K-wire through the opposite cortex using the pneumatic hammer. This is probably due to the maximum “hammer” power produced by the Micro-Aire 1500 we used. The apparatus which was originally designed for performing osteotomies was not powerful enough to penetrate the two K-wires which were stuck in the first cortex, through the opposite cortex. It is likely that this can be prevented in the near future by using a more powerful pneumatic hammer.

This experiment suggests that hammering can be superior to drilling without irrigation because it results in lower temperatures, higher extraction forces, and short insertion times. The latter was managed in this experiment by using similar insertion forces for both insertion techniques. This of course is not comparable with drilling in the clinical setting because K-wires are normally inserted much faster with unknown raise in bone temperature around the wire. The only advantage of drilling with irrigation compared to hammering is the lower mean maximum temperature, which is, however, difficult to realize in daily practice. We therefore conclude that hammering is a good alternative for drilling K-wires and is the preferable method when proper external irrigation is not possible.

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