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Kirschner wire fixation for scaphoid fractures: an experimental study in synthetic bones

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Abstract
We have studied the biomechanical stability in vitro of three different Kirschner (K) wire configurations in three types of simulated scaphoid waist fractures. The fractures were created with a saw in Sawbones models. There were three fracture patterns: perpendicular to the long axis of the scaphoid model; and 30° and 20° oblique to that. Two 1.2 mm. K-wires were used in each scaphoid. The three configurations were: parallel; 20° oblique; and crossing. The oblique or crossing configurations of K-wires were the most stable depending on the fracture pattern.

Keywords
Scaphoid, bone, Kirschner wires, fixation

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Introduction

Although several types of screws are available for stabilization of acute scaphoid fractures, Kirschner (K) wires are still used. K-wires are easier to insert and are more flexible than screws (Chan and McAdams, 2004; Ezquerro et al., 2007; Gunal et al., 2002). In addition, K-wires can be inserted with minimal dissection and reduce the unwanted shearing and longitudinal moment during insertion (Chan and McAdams, 2004). Sometimes following failure of other fixation methods, K-wires may be the only option (Gunal et al., 2002).

The optimum configuration and the number of K-wires to achieve scaphoid stability is not known. We conducted a study to test the stability of different configurations of K-wires inserted into three different patterns of scaphoid waist fractures.

Materials and methods

We used 72 synthetic scaphoids (Sawbones®, Sweden). A waist fracture was created with a saw (blade width 0.5 mm). Three types of fractures were created as described by Bohler et al. (2003): a 'transverse' fracture perpendicular to the long axis of scaphoid (Group A, Fig. 1A); a 'dorsal oblique' fracture cut at 30° to the perpendicular from dorsal proximal to volar distal (Group B, Fig. 1B); and a 'volar oblique' fracture cut at 20° to the perpendicular volar proximal to dorsal distal (Group C, Fig. 1C). There were 24 scaphoids in each group.

Each fracture was fixed with a pair of 1.2 mm K-wires under direct vision. Three configurations of K-wires were inserted: parallel to the long axis of the scaphoid (Group P, Fig. 2A); 25° oblique (Group O, Fig. 2B); and crossed at an angle of 20° at the proximal fragment (Group X, Fig. 2C). These were chosen as they are common forms of K-wire configuration (Ezquerro et al., 2007; Panchal et al., 2007).There were nine subgroups (AP, AO, AX, BP, BO, BX, CP, CO, CX) with eight 'scaphoids' in each group.

After the position of the K-wires were checked radiologically, the protruding wire ends were cut off. Specimens with improper position were excluded from the study and replaced with a new one. The scaphoids were positioned 45° in the dorsopalmar plane and 0° in the ulnoradial plane (Fig. 3) and placed in the testing machine (Autograph®, Shimadzu Co., Kyoto, Japan) (Fig. 4) using acrylic cement (Imicryl®, Enta Co., Turkey). Then a force was applied vertically to the distal pole of each scaphoid with loading at 0.5 mm/second up to the beginning of deformation as assessed visually. All tests were

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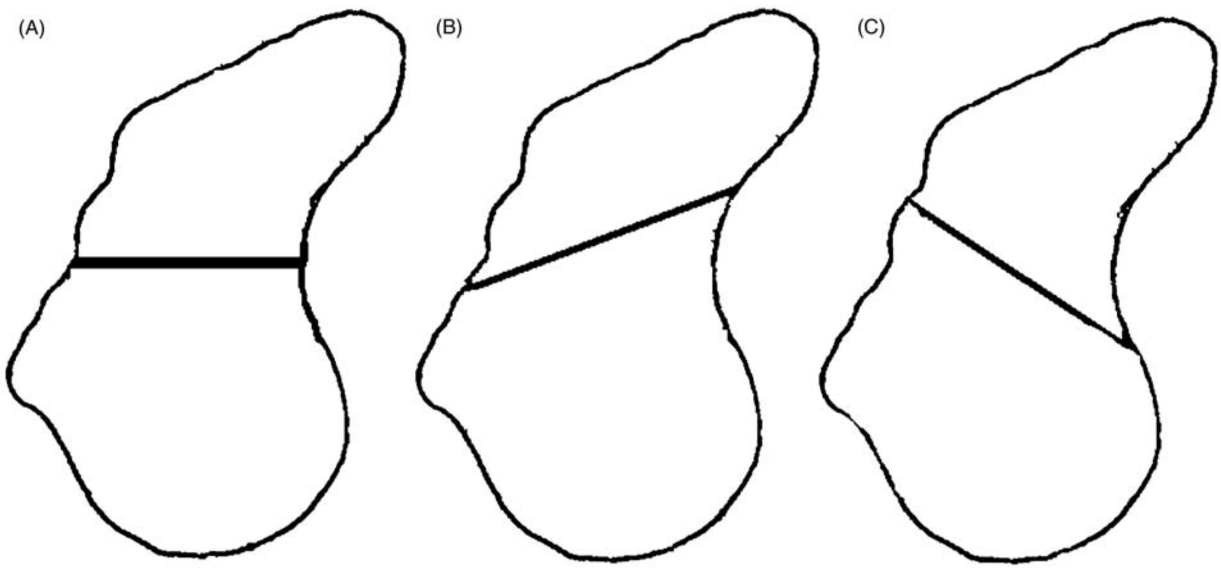

Figure 1. Fracture types. A. 'Transverse' fracture perpendicular to the long axis of scaphoid. B. 'Dorsal oblique' fracture cut at 30° to the perpendicular from dorsal proximal to volar distal. C. 'Volar oblique' fracture cut at 20° to the perpendicular volar proximal to dorsal distal.

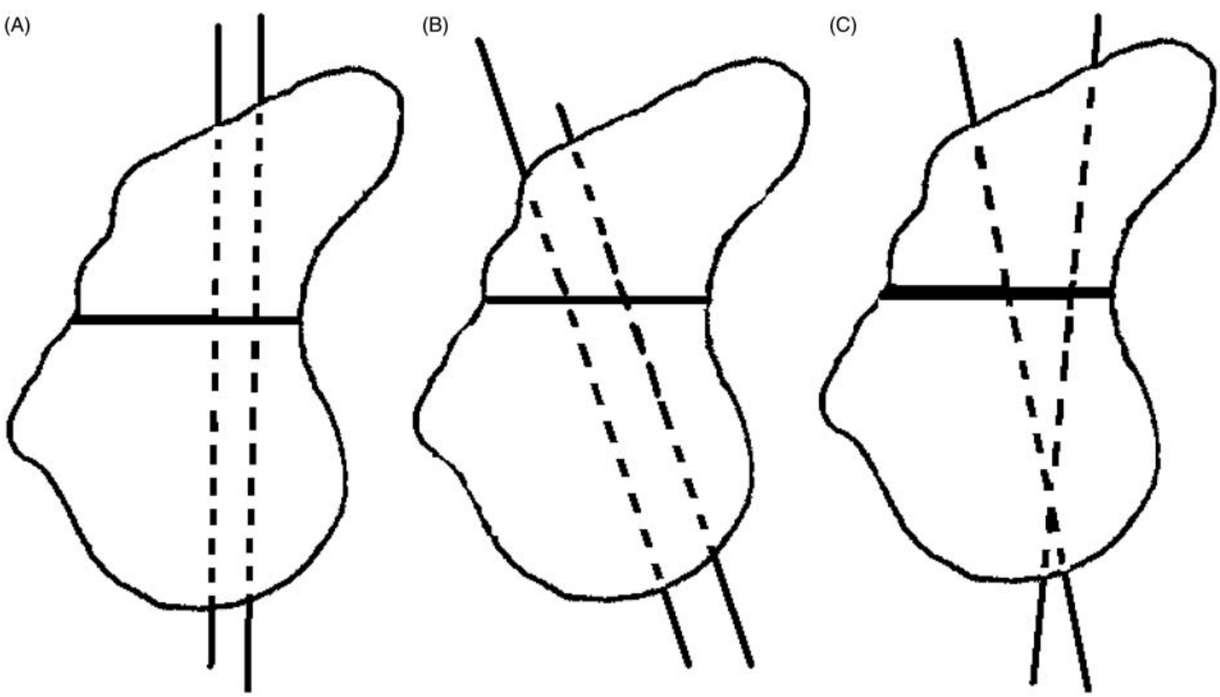

Figure 2. Fixation types. A. Two K-wires parallel to the long axis of the scaphoid. B. Two K-wires 25° of oblique. C. Crossed K-wires at angle of 20°.

repeated three times with half an hour resting period between the experiments.

Statistical calculations were performed using the Mann–Whitney *U* test with an alpha value of significance of less than 0.05.

Results

The maximum loading (Newtons) for deformation, the time (seconds) for maximum loading and the amount of displacement (mm) are displayed in Table 1. Mean values of the groups are also given in Table 2.

Figure 3. Specimen fixed in acrylic cement.

Figure 4. Specimen placed in testing machine.

When fracture types were compared, group B was the most stable whereas group C was the least ($p < 0.05$, Table 2). Additionally, the most stable fixation was crossed K-wires for groups A and C and oblique fixation for group B ($p < 0.05$, Table 1). The time for the start of deformation in group B was greater than the other configurations (Table 2).

Discussion

Although sophisticated screws specifically designed for scaphoid fractures are available, K-wires are recognized both for primary fixation and for salvage following a previous failure (Gunal et al., 2002).

In this study we found that K-wires crossed in the proximal part of the scaphoid was the most stable configuration for simulated fractures perpendicular to the long axis of the scaphoid (Group A, Fig. 1A) and similar 'volar oblique' fractures (group C, Fig. 1C). The most stable fixation for 'dorsal oblique' fractures was oblique fixation (Fig. 1B). These results

Table 2. Mean (SD) values according to fracture types

	Group A	Group B**	Group C*
Maximum loading (Newtons)	206 (28)	231 (62)	185 (49)
Time (seconds)	582 (131)	648(61)	455 (112)
Displacements (mm)	1.4 (0.4)	1.2 (0.4)	1.3 (0.4)

Fracture types: A. 'Transverse' fracture perpendicular to the long axis of scaphoid. B. 'Dorsal oblique' fracture cut at 30° to the perpendicular from dorsal proximal to volar distal. C. 'Volar oblique' fracture cut at 20° to the perpendicular from volar proximal to dorsal distal.
**The most and *the least stable fracture patterns ($p < 0.005$).

Table 1. Mean (SD) results obtained in each group

	Group A			Group B			Group C		
	P	O	X*	P	O*	X	P	O	X*
Maximum loading (Newtons)	206 (23)	205 (41)	208 (16)	169 (26)	279 (73)	249 (26)	190 (44)	154 (45)	211 (59)
Time (seconds)	582 (158)	536 (132)	629 (10)	560 (106)	626 (175)	790 (113)	516 (97)	326 (120)	521 (118)
Displacements (mm)	1.1 (0.4)	0.9 (0.3)	1.4 (0.6)	1.0 (0.4)	0.7 (0.4)	2.0 (0.4)	1.5 (0.5)	1.0 (0.5)	1.3 (0.2)

Fracture types: A. 'Transverse' fracture perpendicular to the long axis of scaphoid. B. 'Dorsal oblique' fracture cut at 30° to the perpendicular from dorsal proximal to volar distal. C. 'Volar oblique' fracture cut at 20° to the perpendicular from volar proximal to dorsal distal.
Fixation types: P. Two K-wires parallel to the long axis of the scaphoid. O. Two K-wires 25° of oblique. X. Crossed K-wires at angle of 20°.
*$p < 0.05$. Crossed wires bears statistically significant loads without deformation in 'transverse' and 'volar oblique' fractures and two K-wires 25° of oblique in 'dorsal oblique' fractures.

were in accordance with the results of Ezquerro et al. (2007) that more stable fixation was achieved by crossing the K-wires.

A review of the literature revealed only one previous biomechanical study comparing K-wires and Acutrak® screws (Panchal et al., 2007). In this study, the authors found no statistically significant difference between mini-Acutrak® screws and two parallel 0.045 inch (1.1 mm) K-wires in load and stiffness when 4 mm displacement occurred. (Panchal et al., 2007). On the other hand standard Acutrak® screws were stiffer and stronger than parallel K-wires when either 2 or 4 mm displacement occurred (Panchal et al., 2007). However, the authors tested the screws against the configuration of K-wires that was weakest in this study (Table 1).

The main limitations of our study are first that the specimens were not real bones. We used synthetic bones (Sawbones®) that have been used in previous studies (Schüller et al., 2009). Other materials such as polyurethane foam (Hausmann et al., 2007; Marshall et al., 1993; Rankin et al., 1992), polistein (Shaw, 1987) or ash-wood (Sukul et al., 1990) have been used in biomechanical studies and have been shown to have mechanical properties similar to those of human bone (DeCoster et al., 1990). Secondly and perhaps more importantly the role of other carpal bones and their attachments in vivo were not simulated (Seber et al., 2008). These may resist some or all of the forces least well resisted by the K-wires in vitro. Thus in vivo the results may be completely different. Nonetheless this study gives an indication of the stability of different patterns of K-wire fixation for simple scaphoid fractures.

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Conflict of interests

None declared.

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