RESEARCH

A BIOMECHANICAL STUDY COMPARING CROSSED K-WIRES AND INTRAMEDULLARY HEADLESS SCREW FIXATION OF UNSTABLE METACARPAL NECK FRACTURES

Siddharth Trivedi[1], Lalit Kumar[2], Anil Singh[3]

[1]Post Graduate Resident, Department of Orthopaedics, Muzaffarnagar Medical College, Muzaffarnagar, Uttar Pradesh, India.
[2]Professor, Department of Orthopaedics, Muzaffarnagar Medical College, Muzaffarnagar, Uttar Pradesh, India.
[3]Associate Professor, Department of Orthopaedics, Muzaffarnagar Medical College, Muzaffarnagar, Uttar Pradesh, India.

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Corresponding Author:
Dr. Anil Singh,
Email: anilsingh2062@ymail.com
ORCID: 0000-0001-5216-5649

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Abstract

Background: To evaluate the biomechanical efficiency of Intramedullary headless screw fixation in comparision to the standard crossed K-wire method. **Materials and Methods:** A metacarpal neck fracture model was developed using 23 human cadaveric metacarpals. Based on the fixation method, the specimens were split into two groups: Group 1- 3 mm intramedullary headless screw, and Group 2- 1.14mm crossed K-wires. The load-to-failure (LTF), maximum displacement, energy absorption, and stiffness were evaluated using a cantilever bending model. **Result:** For Intramedullary headless screw fixation, the mean load-to-failure was 70.6 ± 30.1 N, while for crossed K-wires, it was 97.5 ± 34.7 N. For Intramedullary headless screw fixation and crossed K-wires, the mean stiffness was 11.3 ± 3.4 N/mm and 17.7 ± 7.8 N/mm, respectively. For Intramedullary headless screw fixation, the mean maximum displacement was 20.2 ± 4.6 mm, whereas for crossed K-wires, it was 24.1 ± 3.7 mm. Additionally, the mean energy absorption for crossed K-wires and Intramedullary headless screw fixation was 1095.9 ± 454.4 Nmm and 778.3 ± 528.9 Nmm, respectively. Crossed K-wires outperformed Intramedullary headless screw fixation in terms of stiffness and maximum displacement by a substantial margin (p 0.05). **Conclusion:** When loaded in bending, crossed K-wires provide more stability than Intramedullary headless screw fixation of unstable metacarpal neck fractures.

INTRODUCTION

Orthopaedists and hand surgeons frequently treat metacarpal fractures as they account for 18% of all hand and forearm fractures, coming in third place after phalangeal fractures and radius/ulna fractures in terms of frequency.[1] A combination of splinting, casting, buddy taping, and/or early mobility procedures can successfully cure most metacarpal fractures without the need for surgery. However, non-operative therapy has its limitations since it is challenging to preserve rotational stability and length with this method. This is especially important because research has shown that there will be a 7° extension lag for every 2 mm of shortening, which might result in the appearance of pseudoclawing.[2]
The literature contains a variety of operational indications for metacarpal neck fractures, but the majority use acceptable reduction parameters of no rotational deformity and angulations of 15° at the index finger, 20° at the middle, 30° at the ring, and 40° to 50° at the small, with published ranges of 20° to 70° for the small finger.[3]
Numerous open and closed operational approaches for managing unstable metacarpal fractures have been presented to treat those fractures susceptible to surgical intervention. Among them are open reduction with screws alone or plate/screw structures, as well as closed reduction with percutaneous pinning in a variety of configurations, locked or unlocked intramedullary nails, and intramedullary wires.[4,5,6] Each technique has its own set of side effects, including infections of the wire tract, hardware prominence, and extensor tendon irritation, and they are all connected to variable degrees of malunion, non-union, and infection.[7] Other hand fractures, carpal injuries, and radial head fractures have all been successfully treated using headless screws,[8,9,10] Both comminuted sub-capital fractures and metacarpal shaft fractures have been successfully treated with intramedullary headless screws.[4] In addition to

rigid fixation in the distal fragment and isthmus of the metacarpal, percutaneous, intramedullary headless screw fixation has the advantages of minimal soft tissue dissection, limited required immobilization time, and prevention of the stiffness that all too frequently develops in these injuries. However, there are few and contradictory mechanical evaluations of the headless screw approach in the literature.[11,12]

The purpose of the current study was to examine the biomechanical properties of crossed K-wires (CKW) and intramedullary headless screw (IMHS) fixation in metacarpal neck fractures.

MATERIALS AND METHODS

The study included 23 cadaveric metacarpal samples that were age matched. Metacarpals two (index), three (middle), four (ring), and five (small) in particular were used. A transverse osteotomy was made at the metacarpal neck of each specimen using a fine-blade oscillating saw in order to create a repeatable fracture. In order to overcome the difficulties of replicating the same interdigitating pattern over several osteotomies, a smooth osteotomy cut was developed. The fixation by one of two different structures was then randomly allocated to each of the metacarpal specimens. Twelve of the specimens received CKW pinning, while 11 were given the IMHS fixing treatment. 3 mm CCS Speed tip screws were the IMHS implants that were utilized the guide wire was positioned in the dorsal, central half of the metacarpal in line with the intramedullary canal to a depth of approximately 1 mm below the level of the articular surface after the metacarpal head had been over drilled with a cannulated drill bit. The screws were then inserted retrogradely. CKW implants were implanted retrogradely at a starting point at the collateral recess and non-threaded wires 1 mm in diameter, taking care to contact the distant cortex with the wire.

Each specimen was put to the test by being loaded to failure at the distal fragment using a bending force supplied by a servo-hydraulic testing apparatus. The load was steadily raised until the fixation construct failed due to implant deformity, loss of reduction, or metacarpal fracture. Failure was determined as a clear shift in the load-displacement curve. Stiffness (slope of the linear component of the stress/strain curve, N/mm), load-to-failure (N), maximum displacement (displacement at failure, mm), and energy absorption were mechanical characteristics that were estimated and reported (area under the curve, Nmm).

Mean and standard deviation (SD) are used to show the data. For statistical analysis, the Kolmogorov-Smirnov test was used to first determine if the distributions of the groups were normal, then an unpaired student t-test was used to compare them. A nonparametric Mann-Whitney U Test was used for variables that failed the normality test. All statistical analyses were performed using R-project statistical software. A p-value of 0.05 or less was regarded as significant.

RESULTS

In [Table 1], the biomechanical characteristics of the IMHS and CKW structures are shown. In comparison to the other fixation structures, CKW showed to be stiffer (17.7 N/mm) than IMHS (11.3 N/mm). (p = 0.02) The difference was statistically significant.

The load-to-failure underwent additional study. Similar to stiffness characteristics, CKW exhibited a greater load-to-failure (97.5 N) than IMHS did (70.6 N). However, this discovery merely approached statistical significance (p = 0.06) but fell short of achieving it. Additionally assessed was the displacement at the moment of failure. CKW had a higher maximum displacement (24.1 mm) than IMHS, (20.2 mm), Statistics showed that this difference was significant (p = 0.04). Additionally, compared to IMHS(778.3 Nmm), CKW's energy absorption was around 40% greater (1,095.9 Nmm). However, this difference was not statistically significant (p = 0.14), similar to the load-to-failure study.

Table 1: Biomechanical characteristics of both fixation constructs

	IMHS		CKW		
Parameter	**Mean(SD)**	**Range**	**Mean(SD)**	**Range**	**P-value**
Stiffness(N/mm)	11.3(3.4)	5.8-16.2	17.7(7.8)	5.9-30.1	0.02
Load to failure(N)	70.6(30.1)	32.8-123.8	97.5(34.7)	41.8-157.5	0.06
Maximum Displacement(mm)	20.2(4.6)	11.5-26.4	24.1(3.7)	19-30	0.04
Energy Absorption (Nmm)	778.3(528.9)	272.9-1790.5	1095.9(454.4)	397.8-1933.3	0.14

DISCUSSION

The most typical metacarpal fracture damage pattern, especially in younger, more active individuals, is a metacarpal neck fracture. The amount of dorsal angulation and the existence of a rotational deformity are the main determinants of surgical indications, with the more radial digits tolerating less deformity due to their more rapid decline in grip strength with increasing angulation compared to the ulnar digits. There does not appear to be a definite agreement on the best stabilization procedure for metacarpal neck fractures, with surgical complication rates as high as 36%.[13]

Our findings show that CKW is biomechanically better than IMHS in the management of metacarpal neck fractures. The substantially greater stiffness and maximum displacement necessary to cause build failure with CKW attachment served as proof for this. Notably, this tendency was supported by the finding that CKW structures had greater load-to-failure values and energy absorption, despite the fact that these two factors were not statistically significant. These results suggest that CKW confers a more stable construct than IMHS overall. Among contrast, there are just two studies that look at the mechanics of IMHS in the scant amount of research that is currently available. Jones et al. compared the mechanical properties of locking plate fixation, CKW fixation, and IMHS fixation for the treatment of metacarpal neck fractures in 30 cases.[12] They discovered no differences in the load to failure across the designs, which is similar to the current investigation. In contrast to the current experiment, they showed similar maximum displacement for both and greater stiffness with IMHS compared to CKW. These variations might be explained by their usage of composite Sawbones rather than cadaveric specimens. Finally, Jones et al came to the conclusion that the mechanical fixing qualities offered by both techniques are equivalent.

Avery et al. also evaluated the biomechanics of intramedullary K wire fixation against IMHS for the treatment of cadaveric metacarpal neck fractures.[11] In terms of 3-point bending, axial loading, and load-to-failure, they discovered that IMHS was better. However, the present study did a more thorough examination using four parameters, whereas their analysis only comprised a mechanical evaluation of stiffness and load-to-failure. Additionally, as was already mentioned, Avery et al. compared IMHS to longitudinally-oriented intramedullary K-wires, a K-wire design that is fundamentally different from CKW. Similar biomechanical patterns have been shown for different fixation techniques for metacarpal neck fractures.[14,15,16]

While the results of this study suggest that the more conventional CKW fixation method produces higher mechanical stability, more recent clinical trials looking at IMHS have generated interest in this more modern approach. A mean return to work was seen at six weeks, and radiographic healing was complete at 49 days, in a small series assessing the short-term (average of 36 weeks) outcomes of metacarpal neck and shaft fractures treated with IMHS, according to Doarn et al.[17] Due to the advantages of early motion without immobilization and comparable technological simplicity, they endorsed the use of IMHS for these injuries. In a different, bigger series, 39 patients who had had IMHS with a 3-month follow-up were assessed.[18] By three weeks, extensor delays had disappeared in all patients, and by six weeks, grip strength had fully returned and the radiographic union had been achieved. The need of damaging the metacarpal's articular surface with the drill and the implant raises questions about the utility of IMHS fixation.

It was discovered that the CKW technique's biomechanical characteristics were better to those of IMHS. This makes CKW a favoured procedure, along with the fact that they are less expensive than the implants used in other fixation systems (such IMHS and plate constructions).

However, it is unknown how much force is necessary for sustained fixation in a clinical environment.

Thus, IMHS or other structures with poor biomechanics may be viable for fixing and should be tailored to the specific fracture. This means that IMHS should still be included in the surgeon's toolkit for the treatment of metacarpal neck fractures, along with the relatively simple insertion of the IMHS implants, the avoidance of postoperative immobilization, and the clinical outcomes as reported in the previously cited studies.

CONCLUSION

When loaded in bending, crossed K-wires provide more stability than IMHS fixation of unstable metacarpal neck fractures.

Clinical Relevance

Crossed K-wires provide better stability for the treatment of metacarpal neck fractures, which has clinical relevance. These findings show that IMHS fixation is less advantageous biomechanically and that it should be carefully chosen in terms of fracture stability.

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