THE MEDICAL BULLETIN OF
SISLI ETFAL HOSPITAL

DOI: 10.14744/SEMB.2023.87528
Med Bull Sisli Etfal Hosp 2023;57(4):495–499

Original Research

Is Lateral Onset Cross Pin Technique Strong Enough? A Biomechanical Study

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Abstract

Objectives: It is aimed to compare biomechanically the 3 different pin techniques and the lateral onset cross-pinning (LXP) technique in supracondylar humeral fractures.

Methods: Biomechanical testing was performed on 52 synthetic humeri Four pin configurations techniques were tested: crossed pins (XP), 2 lateral pins (2LP), 3 lateral pins (3LP), and LXP technique. Biomechanical testing was performed on Shimadzu Autograph measuring machine. Each pin configuration was tested in a total of 13 humeri: 4 in varus bending, 4 in valgus bending, and 5 in flexion bending. Displacement (mm), and load (N) data were sampled at 10 Hz during each test.

Results: Varus values were statistically lower in 2 LP group comparing to XP, 3 LP, LXP groups (p=0.01, p=0.02, p=0.012, consequently). Flexion load values statistically lower in 2 LP group comparing to XP, 3 LP, LXP groups (p=0.03, p=0.001, p=0,031, consequently). There was no difference between the groups in terms of valgus values (p>0.05).

Conclusion: LXP technique is biomechanically similar to the traditional XP technique. In situations where orthopedic surgeons choose to use medial pins in addition to lateral pins such as distal humerus fractures with medial-sided defects.

Keywords: Closed reduction, pediatric saw bone, percutaneous pinning, supracondylar humerus fracture

Please cite this article as "Oztermeli A, Karahan N, Kaya M. Is Lateral Onset Cross Pin Technique Strong Enough? A Biomechanical Study. Med Bull Sisli Etfal Hosp 2023;57(4):495–499".

The supracondylar humerus is the most common pediatric elbow fracture, 7.5% of all pediatric fractures.[1,2] According to the Gartland classification, closed reduction with percutaneous fixation is the method of choice in the treatment of type 2, type 3, and flexion-type fractures.[3] Depending on the insufficiency of the fixation, loss of reduction rates are still high, and related problems such as malunion and loss of elbow function can be seen.[4,5]

Distal cross pins (XPs), two lateral pins (2LPs), and three lateral pins (3LPs) are frequently used configurations in supracondylar humerus fracture surgery. The choice of the best pin configuration is controversial in the literature. Using one of these configurations depends on the type of fracture and the surgeon's preferences. Distal XP configuration is frequently used in the literature; however, ulnar nerve damage risk is 3–8% in this technique during medial k-wire application.[6] To prevent ulnar nerve injury, 2 or 3 lateral k wires can be applied, but these configurations have been found to be biomechanically weaker than XP in some studies.[7] The lateral onset XP (LXP) technique can be

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Submitted Date: May 19, 2023 **Accepted Date:** July 11, 2023 **Available Online Date:** December 29, 2023

used as an alternative to the distal XP technique to reduce the risk of ulnar nerve injury.[8,9] Although clinical studies do not show any difference between the two LXP techniques and the two distal XP techniques, there is no biomechanical study to compare these 2 techniques.[8,9]

Although there are biomechanical studies to evaluate crossed pins (XPs), 2LPs and 3LPs, LXP technique is not evaluated biomechanically before. This study aims to compare biomechanically the 3 different pin techniques and the LXP technique in supracondylar humeral fractures.

Methods

Biomechanical testing was performed on 52 synthetic humeri (Sawbones Model #1052, Pacific Research Laboratories, Vashon Island, WA). Four pin configurations techniques were tested: XPs, 2LPs, 3LP, and LXP techniques. Thirteen fracture models were tested for each pin configuration. Pin stabilization was performed with 1.6-mm (0.062 inches) smooth K-wires (Three Straight K-wires, 1.6 mm diameter; TST Medical, Istanbul, Turkey). The fracture patterns and pin configurations were standardized using a customized resin jig based on an intact model in which predetermined fracture simulation and pin placement could be consistently performed.

All the holes were predrilled with undersized holes (1.5 mm) using a drill press and fixtures to ensure consistent pin placement between specimens. An osteotomy was then created using a 2 mm hand saw at the level of the epicondyles (crossing the olecranon fossa), which was located 31 mm proximal to the most distal edge of the trochlea in the composite humeri.[7]

In the LXP technique, the distal pin was sent in a retrograde (ascending) direction from the lateral condyle to the fracture line and the pin was advanced until the contralateral cortex was passed by 1 or 2 mm. The distal pin orientation was extraarticular. The proximal pin was inserted 1.5 cm above the lateral epicondyle in an antegrade (descending) direction, starting from the posteriorolateral of the fracture line and through the anterior part of the medial condyle along the fracture site until the contralateral cortex was perforated 1 or 2 mm.[8,10,11]

In 2LP technique, the first pin was sent in the retrograde direction (ascending), starting from the capitellum, passing the fracture site, and advancing until it perforated the contralateral cortex 1 or 2 mm. The second pin was distal and extraarticular. The distal pin was divergently sent to the first pin in the retrograde direction (ascending). After the fracture site was passed, it was advanced until the contralateral cortex was passed 1 or 2 mm. In the third lateral pin application (3LP), the third pin was sent from the midpoint of the starting points of both pins laterally to the midpoint of the endpoints of these 2LPs in the medial cortex.[12]

In the XP technique, the lateral pin was sent in a retrograde direction (ascending) starting from the lateral epicondyle, and the fracture site was passed. It was advanced until the contralateral cortex was passed 1 or 2 mm. The medial pin was inserted in a retrograde direction (ascending) starting from the medial epicondyle. The fracture site was crossed and advanced until the contralateral cortex was passed 1 or 2 mm[13] (Fig. 1).

Biomechanical Testing

Biomechanical testing was performed on Shimadzu Autograph measuring machine. Each pin configuration was tested in a total of 13 humeri: 4 in varus bending, 4 in valgus bending, and 5 in flexion bending. The humerus was transected 18 cm from the joint line and potted proximally with a custom-designed cylindrical potting cup filled with bismuth alloy. Each humerus was mounted both proximally and distally in custom-made, 2-part epoxy resin molds (proprietary polyester resin 20124 with 100–42–5 styrene monomer composed of methyl ethyl ketone peroxide) designed to rigidly hold the fragments. After confirming that there was no movement in all connection points and the system was rigid, the evaluation was started.

For extension, varus, and valgus tastings the humeri were mounted horizontally with the mold holding the proximal end attached to the actuator of the machine. Each model was loaded onto the trochlea such that the longitudinal line descending from the middle of the humeral shaft was 2–3 mm proximal to the distal humerus. A 3.5 mm machine screw was used to apply compression to the appropriate spot only. The machine was programmed to apply load translationally across the distal fragment at a rate of 0.5 mm/s up to 5 mm. Force and displacement were recorded continuously at a rate of 10 Hz.[14] Displacement (mm), and load (N) data were sampled at 10 Hz during each test.

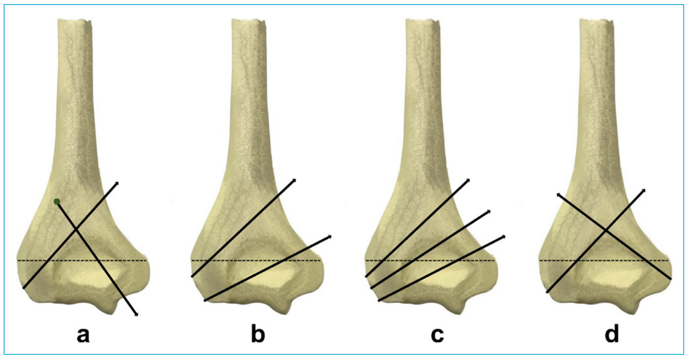

Figure 1. The diagram showing different pinning techniques. **(a)** lateral onset cross-pin technique, **(b)** 2 lateral pin technique, **(c)** 3 lateral pin technique, **(d)** cross pin technique.

Statistical Analysis

NCSS (number cruncher statistical system) 2007 (Kaysville, Utah, USA) program was used for statistical analysis. Kruskal Wallis test was used to compare the torsional, varus-valgus bending, and extension stiffness of the 4-pin configurations. Mann–Whitney U test was used to identify the group that caused the difference. Mann Whitney U-test was used to compare Kruskal–Wallis test and discriminant groups when comparing the descriptive statistical methods. Significance was evaluated at p<0.01 and p<0.05 levels.

Results

Varus bending load values were 33.81±2.49 in XP group, 29.41±2.34 in 2 LP group, 36.9±3.71 3 LP group and 32.3±1.07 in the LXP group. Valgus bending load values were 24.28±3.68 in XP group, 20.90±1.63 in 2 LP group, 23.68±4.71 3 LP group, and 20.83±2.35 in LXP group. Flexion bending load values were 11.95±1.58 in XP group, 8.93±1.31 in 2 LP group, 10.90±0.95 3 LP group, and 11.19±0.70 in LXP group (Table 1).

Varus values were statistically lower in 2 LP group compared to XP, 3 LP, LXP groups (p=0.01, p=0.02, p=0.012, consequently). Flexion load values statistically lower in 2 LP group compared to XP, 3 LP, LXP groups (p=0.03, p=0.001, p=0.031, consequently). There was no statistically significant difference between XP, LXP, and 3LP groups in terms of varus, valgus, and flexion load values (p>0.05). There was no statistically significant difference between all the groups in terms of valgus values (p>0.05) (Table 2).

Discussion

The most important finding in our study is that LXP group showed similar biomechanical properties with classic XP and 3LP configurations in terms of flexion bending, varus bending, and valgus bending. Therefore, LXP could be used for fractures with the necessity of medial pin placement without the risk of ulnar nerve damage.

The gold standard for supracondylar humeral fracture is closed reduction and percutaneous pinning.[15] But which configuration to choose is controversial. In a cadaveric study, distal XPs were shown to be torsionally more stable than lateral pins.[6] However, ulnar nerve damage can be seen in medial pin percutaneous applications in distal XPs.[5,13] Although various techniques have been described to avoid iatrogenic ulnar nerve damage during medial pin application when applying the XP technique, these techniques do not preclude completely iatrogenic ulnar nerve damage.[16] Lateral pin application is recommended to avoid iatrogenic ulnar nerve injuries in literature.[17,18] Although there are studies evaluating the LXP technique to avoid ulnar nerve damage,[8,10,11] there is not a biomechanical study to compare this technique with other common techniques. In our study, LXP technique which has no risk of ulnar nerve injury is found to be strong as XP technique biomechanically.

In the lateral entry XP technique, after the pin has been thrown from the lateral condyle, the proximal pin must be penetrated the medial condyle, advancing the cortex 1–2 mm. The exact starting point of distal pin has not been described in the literature.[8,10,11] In our study, it was preferred to center the lateral condyle. Since the proximal

Table 1. Stiffness data for construct and direction of mechanical loading

Loading condition	Lateral onset cross pin (mean±SD)	Cross pin (mean±SD)	2 lateral pins (mean±SD)	3 lateral pins (mean±SD)
Flexion load (N/mm)	11.19±0.70	11.95±1.58	8.93±1.31	10.90±0.95
Varus (N/mm)	32.3± 1.07	33.81±2.49	29.41±2.34	36.9±3.71
Valgus (N/mm)	20.83±2.35	24.28±3.68	20.90±1.63	23.68±4.71

Table 2. The comparison of stiffness data of four groups

Loading condition	[a]p	Binary comparisons; [b]p					
		LXP-XP	LXP-2LP	LXP-3LP	XP-2LP	XP-3LP	2LP-3LP
Flexion Load (N/mm)	0.012*	0.95	0.012*	0.998	0.01*	0.823	0.02*
Varus (N/mm)	0.02*	0.850	0,031*	0.256*	0.03*	0.664	0.001*
Valgus (N/mm)	0.333	0.646	1	0.881	0.518	1	0.846

[a]Kruskal–Wallis Test; [b]Mann–Whitney U Test *p<0,05. LXP: Lateral onset cross pin; XP: Cross pin; 2LP: 2 lateral pins; 3LP: 3 lateral pins.

pin may cause radial nerve damage in percutaneous application, anatomical tracing of the radial nerve according to age is important. In the cadaveric study, posterolateral pinning with the starting point 1–2 cm proximal to the lateral epicondyle is recommended for the proximal pin to avoid radial nerve injury.[11] In our study, the proximal XP was applied posterolateral with starting point 1.5 cm above the lateral epicondyle, as suggested in the literature. On the other hand, In the LXP technique, the endpoint emerges from the anterior of the medial condyle as the starting point is more posterior. Thus, the wire travels a long distance through the olecranon fossa, not inside the bone. Although this suggests that LXP could have less biomechanical strength than XP, we found no difference between LXP and XP techniques biomechanically.

The effect of the position of the pin on stability is still controversial. In some biomechanical studies, divergence lateral pinning was found more stable in varus, valgus loading than parallel lateral pinning.[7,19] On the other hand, Wallace et al.[20] found no difference between divergence lateral pin and parallel pin in a biomechanical study. It has been proven biomechanically that the stability increases with the increase of pin thickness.[20,21] The thickness and the position of the pin may influence the biomechanical strength of the construct; therefore, pins with the same thickness and position were preferred for distal lateral pinning. Two separate configurations have been described for isolated lateral pin techniques. In Hamdi technique, lateral pins are sent directly via lateral epicondyle as extra-articular. In capitellar technique, lateral pins are sent starting from capitellum as intraarticular.[14,22] Capitellar onset lateral pins were found better torsional resistance than extra-articular lateral pins.[12] Thus, in our study, capitellar onset lateral pins were applied in 2 LP and 3 LP groups.

There are lots of biomechanical studies evaluating isolated lateral pin configurations with XP techniques and they have various results. In some biomechanical studies, XPs were found to be torsionally more rigid compared to lateral pins.[13,6] However, Marsland and Belkoff's cadaveric study showed no difference between the XP and double-lateral pins regarding internal rotation loads.[23] In addition, Chen et al.'s[24] biomechanical study showed no difference between 2LPs and XPs but in humerus distal fractures with medial sided defect they found 2LPs are insufficient. In other biomechanical studies, 3-lateral pinning was found to be more rigid in varus and extension loading than XP, on the other hand, XP was found to be more rigid in valgus loading than 3-lateral pinning.[13,14,25] There are studies showing no difference in internal rotation varus and extension loads between 2LPs and 3LPs.[12,14,19,25] In our study, we found no difference between LXP, XP, and 3 LP in terms of varus, valgus, and flexion bending but 2 LP was inferior to these constructs in varus and flexion loads. Moreover, 2LPs technique gave similar results in valgus loads compared to other groups. This technique may have provided sufficient resistance to valgus loading as a result of the pins being on the lateral side.

This study has a few limitations. First, the pediatric synthetic humerus was used in our study. It has been used frequently in similar biomechanical studies; it is preferred because it is easily accessible, cheap and there are few variations among specimens. Pediatric sawbone humerus was preferred due to an insufficient number of pediatric humerus distal end cadavers and adult cadaver specimens which were generally osteoporotic and lacked epiphysial cartilage and did not resemble biomechanically.[26,27] The absence of periosteum and other soft tissues around the pediatric sawbones could affect the results. All patients are given a cast or splint following fixation, which adds to the mechanical stability of such a construct and prevents exertion of mechanical forces.[21] Second, the supracondylar humerus fractures may be at different levels and in different configurations (proximal, distal, oblique, or segmented fractures); the lack of biomechanical comparisons in these configurations is one of the limitations of the study.[28] Another limitation is that we evaluated the constructs in terms of varus, valgus, and flexion bending, no rotational evaluations were made. Last, in literature XP techniques are suggested in distal humerus fractures with medial side defects, but we did not include this type of model in our study.

Conclusion

LXP technique is biomechanically similar to the traditional XP technique. In situations where orthopedic surgeons choose to use medial pins in addition to lateral pins, such as distal humerus fractures with medial-sided defects, this technique is a good and safe option without the risk of ulnar nerve injury. We also found that 3LP technique is biomechanically similar to XP techniques. However, other biomechanical studies evaluating the torsional loads are needed to support our findings.

Disclosures

Ethics Committee Approval: This study has obtained approval from the Marmara University Non-Interventional Clinical Studies Ethics Committee with protocol number 02, dated January 28, 2023.

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

Authorship Contributions: Concept – N.K.; Design – M.K., N.K.; Supervision – N.K.; Materials – N.K., M.K.; Data collection – A.O.; Analysis – A.O.; Literature search – A.O., N.K.; Writing – A.O., N.K.; Critical review – A.O.

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