EXPERIMENTAL STUDY

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Modified tension band wiring technique for olecranon fractures: where and how should the K-wires be inserted to avoid articular penetration?

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Objective: Articular penetration of K-wires is a possible complication of the modified tension band wiring technique. However, there is no clear information or evidence regarding the entry point or introduction angle for K-wires to avoid this complication. The aim of this experimental study was to evaluate the effect of varying K-wire insertion points and angles on the risk for articular penetration during modified tension band wiring for olecranon fractures.

Methods: All anatomical measurements were made on 50 cadaveric ulnas, and all other measurements were performed on exact foam replications of the 50 cadaveric ulnas. Morphometric measurements, including olecranon height and heights of the central, radial and ulnar facets of the semilunar notch, were taken. In the sagittal plane, articular angle and tubercle angle were measured. Two 1.6-mm parallel K-wires were inserted from 0, 5 and 8 mm anterior to the dorsal cortex of the olecranon process at angles of 20° and 30°. K-wire articular penetration was evaluated both visually and radiographically.

Results: The mean central, radial and ulnar heights of the semilunar notch were 17.3 mm (14.7–20.0), 16.2 mm (12.0–21.0) and 15.8 mm (13.30–20.5), respectively. We observed no articular penetration at the 0-mm level at 20° and 30° (0 mm 20° and 0 mm 30°, respectively) or at 5 mm 20°. At 8 mm 30° wire introduction, more than 64% articular penetration was observed on either facet. The sequence from least to most likely to cause articular penetration was: 0 mm = 5 mm 20° > 5 mm 30° = 8 mm 20° > 8 mm 30°. The radial height of the semilunar notch was negatively correlated to the risk of articular penetration, when the wire was introduced at 8 mm 30°, 8 mm 20° and 5 mm 30° (all $p<0.047$). There were poor correlations between radiological and direct observational assessments, particularly for 8 mm 20°and 5 mm 30°. The frequency of intra-articular positioning for those observed to be radiologically extra-articular was 4/28 (14.3%) for 8 mm 30°, 4/7 (57.1%) for 8 mm 20° and 5/6 (83.3%) for 5 mm 30°.

Conclusion: When applying the modified tension band wiring technique to prevent articular penetration, K-wires should be inserted in the first 5 mm from dorsal cortex of the olecranon process at a maximum angle of 20°. Moreover, if the wires are required to be inserted more anteriorly because of the anatomical configuration of the fracture, they should be inserted at a shallow angle in the sagittal plane in relation to the proximal cortex of the ulna.

Keywords: Articular penetration; complications; olecranon fractures; tension-band wiring.

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Olecranon fractures are common injuries of the elbow that constitute approximately 10% of all elbow fractures.[1] Weber and Vasey described 'tension band osteosynthesis' for the treatment of olecranon fractures. This technique was considered successful, but complications such as the backing out of K-wires, causing soft tissue problems and fracture displacement, limited its use.[2] In order to overcome these problems, the AO group developed a 'modified tension band wiring' technique based on inserting the K-wires from the olecranon tip directed to the anterior ulnar cortex, which enabled a bicortical grip.[3] This technique is one of the most commonly used techniques for the treatment of non-comminuted transverse olecranon fractures, with good long-term results.[16] Numerous studies revealed that this technique reduced backing out of K-wires, skin problems and the need for hardware removal.[4,5] Placing the K-wires closer to the ulna's articular surface and engaging the anterior ulna cortex reportedly produce better biomechanical results.[6] However, it comes with a number of complications.

In this technique, K-wires pass closer to the joint surface in order to engage anterior ulna cortex and introduce the risk of articular penetration. The anatomy of the proximal ulnar articular surface and semilunar notch is unique. The articular surface has both ulnar and radial facets and is triangular in shape in the coronal plane. The radial and ulnar facets are located more posterior and deeper to the articular line in the sagittal plane. We hypothesized that K-wires crossing the facets may actually be intra-articular despite appearing extra-articular on lateral X-ray views.

There is hardly any information in the literature about the risk of K-wire articular penetration related to the modified tension band wiring technique, except for a brief mention by Mauffrey and Krikler[7] and a suggestion by Schatzker[8] that if the wires were angled too far anteriorly, they might penetrate the joint. Although many clinical and biomechanical studies have been performed on this method,[4,9-13] there is no data in the literature regarding the entrance points of these wires. Substantial variation exists in surgical textbooks regarding K-wire insertion angles and insertion points.[3,14] Moreover, Catalano et al. demonstrated that the insertion points of the K-wires varied with the same surgeon up to 8 mm from the corner of the olecranon.[15] We hypothesised that the entrance point and insertion angles have a direct influence on the intra-articular placement and subsequent articular damage related to the K-wires.

The purpose of this experimental study was to evaluate the likelihood of articular penetration with K-wires inserted at different localizations (0, 5 and 8 mm anterior to the dorsal cortex of the olecranon process) and different angles (20° and 30°) on the olecranon tip. Moreover, we aimed to determine a relationship between intra-articular K-wire penetration and the anatomy of the semilunar notch.

Materials and methods

Fifty cadaveric ulnas (25 right and 25 left) were randomly selected from the bone collection of the anatomy department. No data on the cadavers were available (e.g. sex, age and body height of the deceased). Anatomical measurements were taken from the original cadaveric ulnas. All other study procedures were performed on two identical foam replications produced from each bone (i.e. a total of 100 models). Study protocol received prior approval from the local ethics committee.

Anatomical measurements (Fig. 1a)

All measurements were made with a validated calliper. The central height of the semilunar notch was measured between the dorsal surface of the ulna and the deepest portion of the ridge dividing the radial and ulnar parts of the notch. The radial height of the semilunar notch was measured between the dorsal surface of the olecranon and the deepest articular part of the radial facet

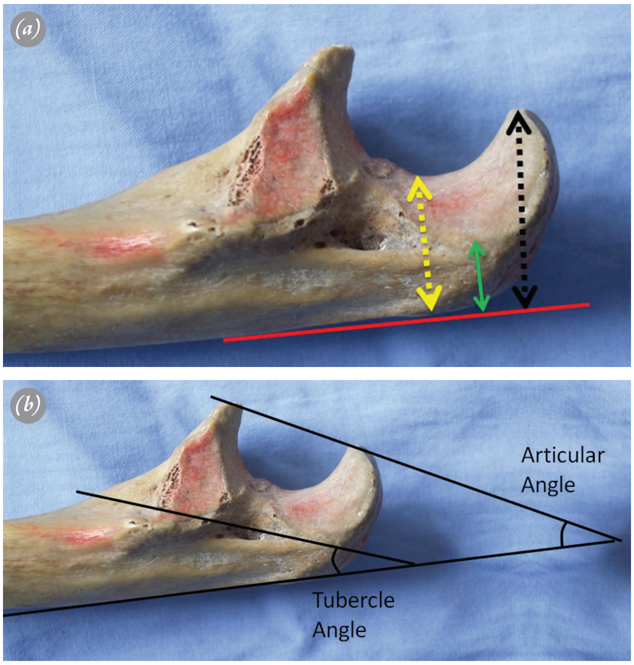


Fig. 1. **(a)** The central height (yellow arrow) and radial height (green arrow) of the semilunar notch and the olecranon height (black arrow) are seen. **(b)** Proximal ulna, radial side. Articular angle and tubercle angle measurements are seen. [Color figures can be viewed in the online issue, which is available at www.aott.org.tr]

of the semilunar notch in the sagittal plane. Similarly, the ulnar height of the semilunar notch was measured between the dorsal surface of the olecranon and the deepest articular part of the ulnar facet of the semilunar notch. The olecranon height was measured between the dorsal surface of the olecranon and the highest portion of the most proximal part of the olecranon process in the sagittal plane.

In the sagittal plane, the angle between the line tangent to the dorsal surface of the proximal part of the olecranon process and the line connecting the highest portion of the proximal part of the olecranon and the coronoid process was measured and designated as the articular angle (Fig. 1b). The articular angle was used in the study as the insertion angle of one group of K-wires with an angle parallel to the joint angle. Again in the sagittal plane, the angle between the line tangent to the dorsal surface of the proximal part of the olecranon process and the line connecting the tip of the olecranon process and the brachial tubercle was measured and designated as the tubercle angle. This tubercle angle was measured to mimic the entrance point of the K-wires at the olecranon tip and exit point at the brachial tubercle.

Fracture generation and fixation

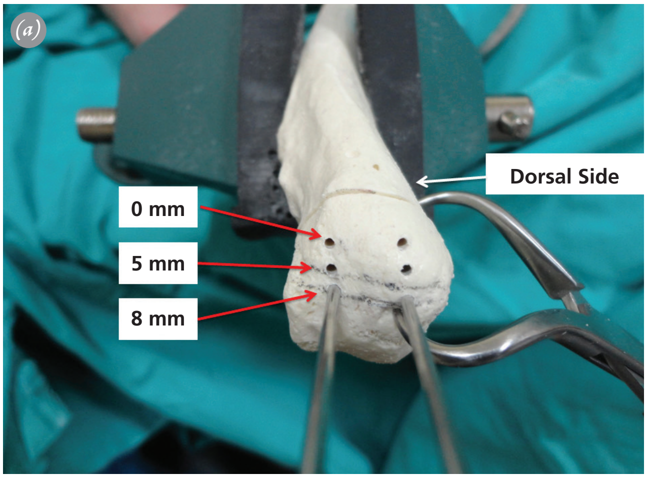
In order to eliminate potential performance bias, all fixations were performed by one surgeon (MHO). An AO 21-B1 type transverse, non-comminuted, intra-articular fracture pattern was generated on each model using an oscillating saw. The level of the fracture was at the midpoint of the semilunar notch in sagittal plane. The foam models were attached to the table with a clamp with the articular surface facing downwards. This allowed a blinded application (without visualization of the articular side) of the K-wires. The fracture was reduced anatomically and held with a pointed reduction clamp (Fig. 2a).

K-wires were introduced using three different insertion points (0 mm, 5 mm and 8 mm anterior from the angle of the olecranon) (Fig. 2a). The 8 mm insertion point was calculated as one-third of the mean olecranon height. From every insertion point, two parallel 1.6 mm K-wires were inserted at two different insertion angles (20° and 30°) in relation to the proximal ulna. The 30° insertion angle was used on one ulna model and a 20° angle was used on the other identical model. Selection methods for the insertion points and angles are described in the 'Results' section. Insertion angles were kept constant using a metal goniometer. Two parallel K-wires were inserted from each insertion point using a triple drill guide (Synthes AG, Switzerland). Using this guide allowed the wires to be inserted parallel to each other with a constant 1cm distance between (Fig. 2b).

After insertion of each pair of K-wires, articular penetration was checked visually on the radial and ulnar facets separately and recorded. Articular penetration was classified into four groups: 'total intra-articular' if the wire was completely in the articular side; 'partial intra-articular' if more than half the wire was in the articular side; 'subchondral' if the wire traumatized the articular side but most of it was in the bony side and 'total extra-articular' if no portion of the wire was inside the articular side (Fig. 2b).

Radiological analysis

After insertion of the K-wires, lateral radiographs were taken of every model. A consultant radiologist (AO)



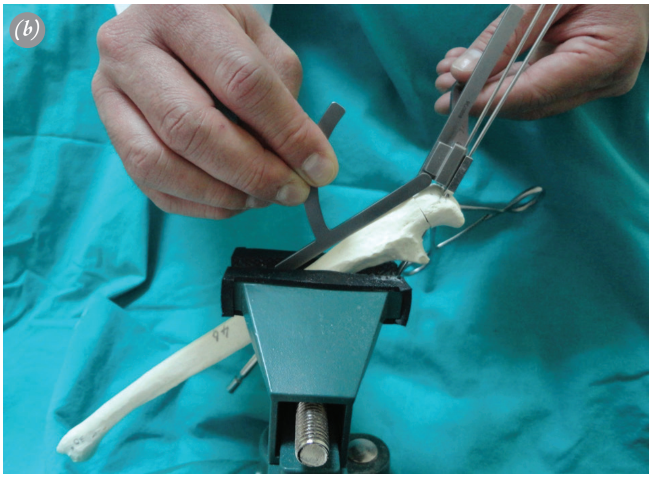


Fig. 2. **(a)** Three insertion points (0, 5 and 8 mm) are seen. **(b)** Two parallel K-wires were inserted using a metal goniometer and triple drill guide (Synthes AG, Switzerland). [Color figures can be viewed in the online issue, which is available at www.aott.org.tr]

with expertise in musculoskeletal radiology analysed the radiographs. Based on this analysis, K-wires were classified as 'intra-articular', 'probably intra-articular' or 'extra-articular'.

Differences between the related measurements were evaluated by Friedman's test. When a significant p-value from the Friedman test was found, Bonferroni-corrected Wilcoxon signed rank test was applied to determine stepwise differences. The Kendall's Tau rank correlation test was used to assess the correlation between the radiological and direct observational evaluations. Statistical Package for the Social Sciences (version 11.5.0; SPSS Inc, Chicago, IL) was used for statistical analyses, and p-values less than 0.05 were considered significant.

Results

The mean articular angle was 28.2° (±1.8), and the mean tubercle angle was 20.3° (±1.8). Therefore, the nearest whole numbers of 30° and 20° were selected as the wire insertion angles. The mean olecranon height was 24.6 mm (±2.6 mm). One-third of the olecranon height, 8 mm, was selected as the third wire insertion point after 0 mm and 5 mm insertion points.

The mean central, radial and ulnar height of the semilunar notch was 17.3 mm (±1.3 mm), 16.2 mm (±1.8 mm) and 15.8 mm (±1.7 mm), respectively. There was a significant positive correlation between the three heights (all p<0.0001). Moreover, total olecranon height was also correlated with central and radial heights of the semilunar notch (all p=0.012).

No articular penetration was observed at the 0-mm level using insertion angles of either 20° or 30°. At the 5 mm level, no articular penetration was observed at 20° (Table 1). However, with insertion at 5 mm and an angle of 30° (5 mm 30°), total articular penetration was observed in 28% of procedures on the radial side and in 22% on the ulnar side. At 8 mm 20° wire introduction, total articular penetration was overserved in 16% of the procedures on both the radial and ulnar sides. With an 8 mm 30° wire introduction, total articular penetration was observed in 68% of procedures on the radial side and in 64% on the ulnar side.

There was a significant difference in articular penetration between the different insertion points and angles (p<0.0001). Articular penetration was least likely using the 0-mm insertion point (p<0.0001) and the 5 mm 20° insertion (p<0.001). Conversely, articular penetration was most likely using the 8 mm 30° insertion. In pair-wise comparisons, all comparisons were statistically significant (all p<0.003) except for wire insertions of 8 mm 20° and 5 mm 30° (p=0.527). The sequence from least to most likely to cause articular penetration was: 0 mm = 5 mm 20° > 5 mm 30° = 8 mm 20° > 8 mm 30°.

Detailed analyses of the articular penetration data revealed that, when using 8 mm 30° wire insertion, not only was the articular penetration rate high, but the severity of the injury was also greater than in the other insertion models (Table 2). There was no significant difference between the 8 mm 20° and 5 mm 30° wire insertion models in terms of injury severity status.

There was a negative correlation between the radial height of the semilunar notch and the risk of articular penetration when the wire was introduced at 8 mm 30° (r=−0.356, p=0.011), 8 mm 20° (r=−0.298, p=0.036) and 5 mm 30° (r=−0.282, p=0.047). Moreover, there was a negative correlation between the ulnar height of the semilunar notch and ulnar inserted K-wires in terms of joint penetration when using the 5 mm 30° insertion position (r=-0.30, p=0.046).

Radiological analyses indicated that in 8 mm 20° insertion, 62% of the samples were reported to be extra-articular, 13% probably intra-articular and 15% intra-articular. In the 5 mm 30° insertion, these values were 61%, 15% and 14%, respectively. Finally, in the 8 mm 30° inser-

Table 1. Total articular injury related to wire insertion points and insertion angles.

Articular penetration status	Total intra-articular	Partial intra-articular	Subchondral	Total extra-articular	Total injury (%)
Insertion point and angle					
5 mm, 20 degrees, radial	0	0	0	50	0
5 mm, 20 degrees, ulnar	0	0	0	50	0
5 mm, 30 degrees, radial	0	3	11	36	28
5 mm, 30 degrees, ulnar	0	3	8	39	22
8 mm, 20 degrees, radial	1	4	3	42	16
8 mm, 20 degrees, ulnar	2	2	4	42	16
8 mm, 30 degrees, radial	15	11	8	16	68
8 mm, 30 degrees, ulnar	17	8	7	18	64

Table 2. Injury severity details based on visual analysis.

Articular injury severity	Total intra-articular (%)	Partial intra-articular (%)	Subchondral (%)	Extra-articular (%)
8 mm 30° radial	30	22	16	32
8 mm 30° ulnar	34	16	14	36
8 mm 20° radial	2	6	6	86
8 mm 20° ulnar	4	4	8	84
5 mm 30° radial	0	6	22	72
5 mm 30° ulnar	0	6	16	78

tion, these values were 26%, 18% and 56%, respectively.

Kendall's Tau analysis demonstrated poor correlation between the radiological and direct visual observational assessments, particularly for 8 mm 20° and 5 mm 30°. The rank correlations observed were 0.43 for 8 mm 30°, 0.30 for 8 mm 20° and 0.12 for 5 mm 30° ($p<0.001$, 0.058 and 0.38 respectively).

The frequency of discordance between radiological and observational results was 34% for 8 mm 30°, 36% for 8 mm 20° and 74% for 5 mm 30°. The frequency of intra-articular positioning for those observed to be radiologically extra-articular was 4/28 (14.3%) for 8 mm 30°, 4/7 (57.1%) for 8 mm 20° and 5/6 (83.3%) for 5 mm 30°.

Discussion

Ours is the first study highlighting the importance of insertion points and angles in modified tension wiring of olecranon fractures. To the best of our knowledge, our idea of articular injury related to K-wires is novel and has not been proposed previously, despite the use of this procedure for over a decade.

Extension loss after tension band wiring is a common complication. Romens et al. reported that in patients treated with modified tension band wiring, 49% demonstrated extension deficits of greater than 10°.[12] Similarly, ven der Linden et al. reported a loss of elbow extension which generally recovered after implant removal.[10] We hypothesize that one of the reasons for this problem may be the intra-articular positioning of the K-wires and/or related articular injury, which we believe is an unrecognized issue.

The proximal ulna has unique anatomy. The semilunar notch has radial and ulnar facets located posterior to the joint line. K-wires passing through these facets may be seen as extra-articular in lateral radiographs. In addition, intra-operative fluoroscopic evaluation of K-wires is always more difficult than post-operative radiographs because of the low radiation doses in fluoroscopy. Supporting this hypothesis, we found no statistical correlation between radiological assessments and direct observational assessments in our study.

Our results revealed that the insertion point and insertion angle influence the intra-articular placement of the K-wires. Wires placed further from the dorsal cortex (i.e. close to the joint line) have higher risk of articular penetration, particularly when they are introduced at steeper insertion angles. The most striking example is when the wires were placed 8 mm anterior to the dorsal cortex at a 30° insertion angle, which was associated with a more than 60% risk of articular penetration. The risk of articular penetration rate decreased with K-wire insertion points being closer to the dorsal cortex and performed at shallower insertion angles. However, there was still an unacceptable risk (more than 22%) when a higher insertion angle (30°) was used with an insertion point 5 mm anterior to the dorsal cortex. Therefore, we conclude that articular penetration is unlikely when introducing the K-wires within the first 5 mm of olecranon from the dorsal cortex with maximum insertion angle of 20°.

However, biomechanical problems may result when the insertion point more closely approximates the dorsal cortex (e.g. the 0 mm insertion point in our study) due to the problem of fixing less bone in the proximal fragment. Therefore, if more bone purchase in the proximal fragment is desired in an effort to increase the fixation quality of the proximal fragment of the olecranon fracture, a more anterior insertion point can be used (5 mm in our study). However, to decrease the articular penetration risk, wires should be placed at shallower insertion angles (i.e. 20°) to the ulnar shaft in the sagittal plane.

The correlation between the dimensions of the proximal ulna and articular injury risk indicates that articular injury related to the K-wires may be riskier in smaller patients with smaller proximal ulnas. Therefore, one should exercise caution when selecting an insertion point for the K-wires in smaller patients.

The discordance between radiological and observational results in terms of articular injury highlights the importance of safe wire insertion points and angles. Given the special anatomy of the olecranon, it is not always possible to be certain about the position of the wires based on lateral radiographs or fluoroscopic images.

When using the modified tension band wiring technique, a number of complications have been identified, including impaired forearm rotation, anterior interosseus nerve injury, median nerve palsy, proximal radio-ulnar synostosis, ulnar artery pseudo-aneurysm, ischemia of the hand and Volkmann contracture. These conditions may complicate the treatment process and necessitate removal of the hardware.[15,17-22] All of these complications are related to the K-wires exiting from the anterior ulnar cortex. New methods have been described in an effort to decrease complications related to the modified tension band technique.[11,13] We now add another complication of articular penetration related to the K-wires, which we have demonstrated as being related with the insertion point and insertion angle. Schatzker recommended against anterior cortical perforation of the K-wires for fear of injuring nearby vital neurovascular structures.[8] In view of the many and relatively severe complications, we too believe that the use of this technique should be questioned.

A major limitation of our study was the use of foam models. However, by using exact replications of the cadaveric bones, we had the advantage of working on models with unique and actual anatomical differences, which are important in determining the efficacy of any procedure. The other limitation is that this is the first study to test the hypothesis of articular injury related to K-wires, and as such, its clinical validation is required before drawing a definitive conclusion. Iatrogenic intra-articular penetration of the K-wires is a new issue, and its effect on clinical results is not known. Although this study gives some key points with respect to K-wire insertion for the tension band technique, it must be correlated with clinical studies for functional results. Another limitation is that we did not have data about the ages, genders and the sizes of the cadavers from which the ulnas belonged. Furthermore, only depth and angle of the K-wires were evaluated. K-wires were always introduced 10 mm distance from one another in a parallel manner. The wire spread distance might affect the results in relation to the triangle shaped anatomy of the articular surface of semilunar notch in the coronal plane.

In conclusion, our study demonstrated that when performing the modified tension band wiring technique, K-wires should be inserted in the first 5 mm to the dorsal cortex of the olecranon process with maximum angle of 20°. Moreover, when the wires need to be inserted more anteriorly because of the anatomical configuration of the fracture, they should be inserted at a shallower angle (max. 20°) in the sagittal plane in relation to the dorsal proximal cortex of the ulna.

Conflics of Interest: No conflicts declared.

References

1. Van Der Horst CM, Keeman JN. Treatment Of Olecranon Fractures. Neth J Surg 1983;35:27–9.
2. Weber Bg, Vasey H. Osteosynthesıs In Olecranon Fractures. [Article in German] Z Unfallmed Berufskr 1963;56:90–6. [Abstract]
3. Mueller ME, Allgoewer W, Sneider R, Willengner R. In Manual of internal fixation. Techniques recomended by the AO-Group. New York: Springer; 1991. p. 460–461.
4. Mullett JH, Shannon F, Noel J, Lawlor G, Lee TC, O'Rourke SK. K-wire position in tension band wiring of the olecranon - a comparison of two techniques. Injury 2000;31:427–31. CrossRef
5. Prayson MJ, Williams JL, Marshall MP, Scilaris TA, Lingenfelter EJ. Biomechanical comparison of fixation methods in transverse olecranon fractures: a cadaveric study. J Orthop Trauma 1997;11:565–72. CrossRef
6. Prayson MJ, Iossi MF, Buchalter D, Vogt M, Towers J. Safe zone for anterior cortical perforation of the ulna during tension-band wire fixation: a magnetic resonance imaging analysis. J Shoulder Elbow Surg 2008;17:121–5. CrossRef
7. Mauffrey CP, Krikler S. Surgical techniques: how I do it? Open reduction and tension band wiring of olecranon fractures. Injury 2009;40:461–5. CrossRef
8. Shatzker J. In The rationale of operative fracture care. Edited by Shatzker J, Tile M. Berlin: Springer-Verlag; 2005. pp. 123–30. CrossRef
9. Donegan RP, Bell JE. Olecranon fractures. Operative techniques in orthopaedics. 2010;20:17–23. CrossRef
10. van der Linden SC, van Kampen A, Jaarsma RL. K-wire position in tension-band wiring technique affects stability of wires and long-term outcome in surgical treatment of olecranon fractures. J Shoulder Elbow Surg 2012;21:405–11.
11. Huang TW, Wu CC, Fan KF, Tseng IC, Lee PC, Chou YC. Tension band wiring for olecranon fractures: relative stability of Kirschner wires in various configurations. J Trauma 2010;68:173–6. CrossRef
12. Rommens PM, Küchle R, Schneider RU, Reuter M. Olecranon fractures in adults: factors influencing outcome. Injury 2004;35:1149–57. CrossRef
13. Sadri H, Stern R, Singh M, Linke B, Hoffmeyer P, Schwieger K. Transverse fractures of the olecranon: a biomechanical comparison of three fixation techniques. Arch Orthop Trauma Surg 2011;131:131–8. CrossRef
14. Rüedi TP, Murphy WM. AO principles of fracture management. 2000. p. 327–45.
15. Catalano LW 3rd, Crivello K, Lafer MP, Chia B, Barron

OA, Glickel SZ. Potential dangers of tension band wiring of olecranon fractures: an anatomic study. J Hand Surg Am 2011;36:1659–62. CrossRef
16. Chalidis BE, Sachinis NC, Samoladas EP, Dimitriou CG, Pournaras JD. Is tension band wiring technique the "gold standard" for the treatment of olecranon fractures? A long term functional outcome study. J Orthop Surg Res 2008;3:9. CrossRef
17. Candal-Couto JJ, Williams JR, Sanderson PL. Impaired forearm rotation after tension-band-wiring fixation of olecranon fractures: evaluation of the transcortical K-wire technique. J Orthop Trauma 2005;19:480–2. CrossRef
18. De Carli P, Gallucci GL, Donndorff AG, Boretto JG, Alfie VA. Proximal radio-ulnar synostosis and nonunion after olecranon fracture tension-band wiring: a case report. J Shoulder Elbow Surg 2009;18:40–4. CrossRef
19. Lee SH, Han SB, Jeong WK, Park JH, Park SY, Patil S. Ulnar artery pseudoaneurysm after tension band wiring of an olecranon fracture resulting in Volkmann's ischemic contracture: a case report. J Shoulder Elbow Surg 2010;19:6–8. CrossRef
20. Parker JR, Conroy J, Campbell DA. Anterior interosseus nerve injury following tension band wiring of the olecranon. Injury 2005;36:1252–3. CrossRef
21. Rompen JC, Vos GA, Verheyen CC. Acute ischemia of the hand seven months after tension-band wiring of the olecranon. J Shoulder Elbow Surg 2010;19:9–11. CrossRef
22. Thumroj E, Jianmongkol S, Thammaroj J. Median nerve palsy after operative treatment of olecranon fracture. J Med Assoc Thai 2005;88:1434–7.