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Original Article

Long-term results of olecranon fractures treated using the XS nail® system

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ABSTRACT

Purpose: Olecranon fractures are particularly vulnerable to distraction and subsequent fracture dislocation due to the high tensile forces. Surgical treatment aims at reducing the fracture and restoring the anatomical joint surface condition, as well as neutralizing the strain inhibiting fracture healing. The XS nail® (Intercus GmbH, Bad Blankenberg, Germany), an intramedullary implant exerting compression across the entire fracture surface, unlike plates, leaves a minimal extra-cortical profile, and can be secured with threaded locking wires, thereby retaining the anatomical reduction without displacement or steps within the articular surface, which was often found in tension band wiring. After encouraging initial results, the long-term outcome was assessed.

Methods: This retrospective study evaluated the long-term outcome of patients surgically treated at our trauma center between January 2002 and December 2005 using the XS nail®. Patients over the age of 18 years eligible for the study must have undergone surgery for isolated, recent (less than 14 days) traumatic olecranon fractures, without concomitant injuries to the ipsilateral elbow and forearm. Further exclusion criteria were pseudarthrosis, re-fractures and osteotomy for distal humerus surgery, as well as polytraumatized patients unable to aid in their own recovery. Data were retrospectively gathered by standardised questionnaire and patient records, as well as surgery and anesthesiology reports. Data analysis was performed using Microsoft Office Excel® 2016.

Results: There were 32 patients, 13 males (mean age 49.0 years) and 19 females (mean age 68.9 years) with 11 Schatzkers type D, 7 each type A and C, 5 type B and 2 type E at an average of 55.2 months, all showing complete consolidation. Of them, 6 patients had a loss of range of motion with more than 10° in the sagittal plane, and only 1 patient exceeded 10° reduction of supination. Twenty-five patients reported being pain-free under all circumstances, and all but 2 patients (93.75%) had returned to their previous activity level. The average disabilities of the arm, shoulder and hand score was 21.15 (range 0–88.3), and the overall Mayo elbow performance index was 91.87, without complications, such as wound infection, neurovascular impairment or premature hardware removal.

Conclusion: Using the XS nail® system, all fracture types can be successfully treated and the rate of complications was lower than that treated by standard methods published in current literature. An excellent functional outcome, high range of motion as well as good retention of reduction without soft tissue irritation makes this a very suitable implant for fractures subject to tension.

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Introduction

The treatment of fractures subject to muscle or ligament tension presents a unique set of challenges, as the traditional approach of reduction and retention is complicated by the continued strain placed on the fracture site. Tensile forces acting on the fragments may cause distraction, dislocation and subsequent mal- or non-

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union of the injured bone.[1] Olecranon fractures, accounting for some 10% of upper extremity fractures,[1–5] are particularly vulnerable to this condition. The most common technique of open reduction and internal fixation is using K-wires and tension band wiring (TBW).[2] However for comminuted fractures, K-wires or cannulated screws may not allow for a precise reduction and sufficient stabilization of the injury site, which usually leads to prolonged recovery, longer immobilization and post-traumatic arthrosis or delayed union.[3]

Another group of patients often sustaining olecranon fractures are elderly women with osteoporotic bone stock, and the likelihood of K-wire or tension band dislocation is consequently increased.[4] Gallucci et al.[5] suggested that non-surgical treatment through immobilization and subsequent functional therapy should be reserved for elderly patients, who were not suitable for surgery, as nearly 80% of their 28 investigated patients developed non-unions.

The development of the intramedullary locking compression XS nail® system for olecranon fractures, first described by Gehr et al.[6] addresses most of the adversities such as distraction, tissue irritation and implant migration. Here, unlike plates or TBW, the intramedullary device allows for compression across the entire fracture surface while leaving a minimal extra-cortical profile. Using threaded locking wires, multiple fragments may be addressed and maintain anatomical reduction without displacement within the articular surface, known to cause post-traumatic arthrosis.[3,6] With this novel implant, it seems possible to reduce the rate of fracture and implant dislocation, avoid soft tissue problems associated with other implants, and improve the functional outcome.[6] Furthermore, an Allen screw, allowing for high compression at the fracture site along the tension bearing axis, is a part of the implant design.

We retrospectively evaluated the long-term outcome of patients treated with the XS nail® system between January 2002 and December 2005, hypothesizing that this implant can be used to successfully treat all types of olecranon fractures and achieve a good long-term clinical outcome.

Methods

Between January 2002 and December 2005, by reviewing hospital files for this retrospective study, patients with olecranon fractures were identified with complete records and operated using the XS nail® system. Patients, over 18 years eligible for the study must have received recent (less than 14 days) isolated traumatic olecranon fractures surgery, and have no accompanying injuries to the ipsilateral elbow and forearm. Further exclusion criteria were pseudarthrosis, re-fractures and osteotomy for distal humerus surgery, as well as polytraumatized patients unable to aid in their own recovery. Only patients, who met the inclusion and exclusion criteria and were willing and able to participate in the study after obtaining full and detailed informed consent, were included in the study. Data were retrospectively gathered by standardised questionnaire and patient records, as well as surgery and anesthesiology reports. Data analysis was performed using Microsoft Office Excel® 2016.

Surgical technique

The operation is performed in the prone position. After skin incision and dissection to the olecranon, the ulnar nerve is presented. After marking and securing the ulnar nerve and reducing the fracture, a stab incision is made at the olecranon tip. A guide wire is placed intramedullary, which circumvents the risk to the volar neurovascular structures. Under the close radiographic survey, the medullary canal is drilled and an appropriate-length nail is inserted. Using the aiming jig, angular stable threaded wires secure the fracture and address any comminuted fragments. The implant allows for fixation of multiple fragments in 9 mm increments across the whole width of the bone. As the nail iss located very close to the articular surface, most fragments are held directly, while smaller fragments are reduced and secured with pins either before main fracture reduction, or fixed with metal or fibre wire encircling bands over the ends of the locking threaded wires. By tightening the Allen bolt, pressure is applied to the most proximal wire, thereby compressing the fracture site. After skin closure, splint free early mobilization is initiated on the first post-operative day (Figs. 1 and 2).[6]

Evaluation/follow-up

Patients were evaluated using a standardised questionnaire regarding their pre- and post-operative activities, which were then calculated based on the Tenger Activity Index.[7] Examination of the contralateral joint had been performed on the first post-operative day and quantified based on the neutral – zero method allowing for a more objective reference of the previous state of the operated elbow. X-rays in 2 planes pre- and post-operatively, as well as recent radiographic examination at the time of follow-up were attained, which were used for the classification and assessment of the reduction and retention.

At follow-up, patients were subject to thorough clinical and radiological examination and assessment using disabilities of the arm, shoulder and hand (DASH) score[8] and Mayo elbow performance index (MEPI).[9] Patients either provided recent radiographic films, or underwent X-rays at follow-up as part of their regular aftercare. Moreover, the data such as wound healing, range of

Fig. 1. Anterior-posterior radiograph after osteosynthesis shows the intramedullary position of the implant, as well as the compression screw.

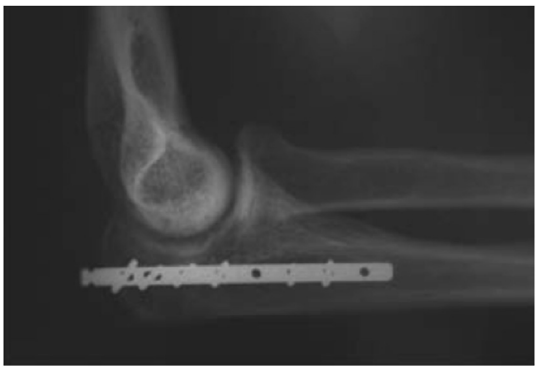

Fig. 2. Lateral radiograph after osteosynthesis shows the intramedullary position of the implant, as well as the compression screw (left on lateral view).

motion (ROM) and sensibility irritation were examined and documented.

Ethical approval

This study was conducted with the approval of the relevant ethics committee. All data were collected and evaluated retrospectively, archived anonymously and processed in accordance with patient's informed consent.

Results

For this study, of 32 patients, 13 males (40.6%) and 19 females (59.3%) were subsequently available for a mean follow-up of 4.6 (range 2.8–6.8) years. At the time of injury, male patients were 49.0 years old and females were 68.9 years old. The mean age in the investigated group was 58.9 years (Fig. 3). Of the 17 patients who did not participate in the study, 5 patients declined a follow-up visit, 5 were in feeble health and could not participate, 3 had died, 3 could not be reached by telephone or mail, and 1 had relocated over 250 km away.

According to the preoperative radiographic studies and the classification of Schatzker,[10] the fractures were categorized. Based

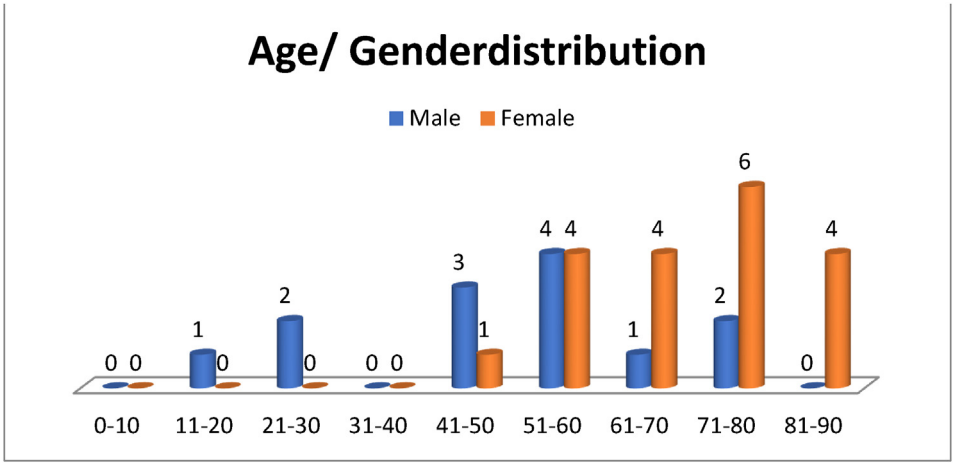

Fig. 3. The age/gender distribution.

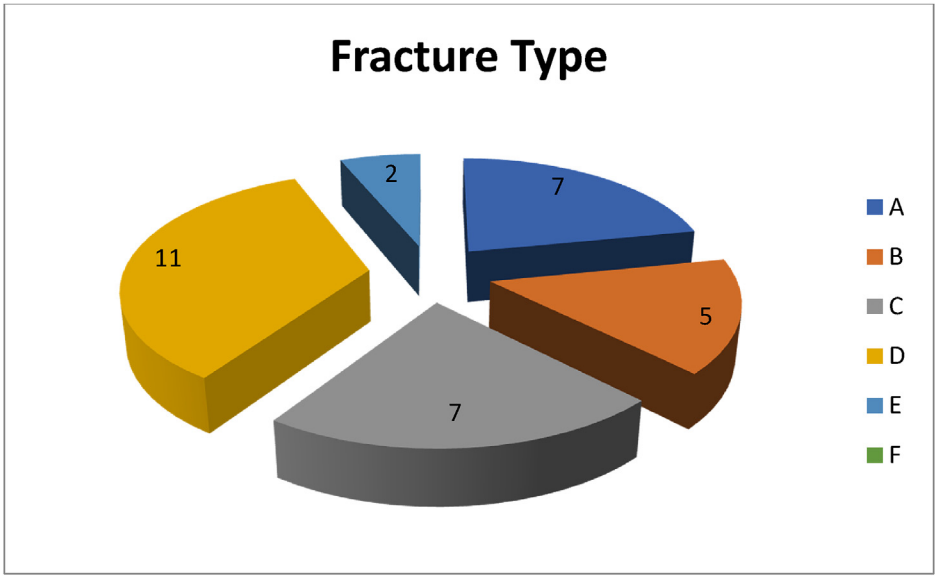

Fig. 4. The distribution of fracture types.

Fig. 5. Radiographs at initial presentation, lateral view.

on its pattern, Schatzker classifies the fractures as transverse (type A), transverse-impacted (type B), oblique (type C), comminuted (type D), oblique-distal (type E) and fracture-dislocation (type F).[10] The most common fracture types were multi-fragmentary and comminuted fractures (type D) with 11 patients (34.3%). The type A and type C fractures, both in 7 patients (21.8%), were followed by type B (5 patients, 15.6%) and type E (2 patients, 6.25%). There were no fracture-dislocation injuries of type F (Fig. 4).

Complications and X-rays

At follow-up, a thorough and extensive patient history was taken, and complications were recorded. Of the 32 eligible patients, only 1 patient had to undergo revision surgery due to a post-operative fragment dislocation. Twenty-six patients showed an anatomical injury reduction without measurable displacement in the post-operative X-rays, while 4 patients had a cortical step of less than 1 mm, and 1 patient sustained a displacement of 1–2 mm. The radiographs at follow-up displayed complete bony consolidation in all 32 patients, elective implant removal occurred in half,

Fig. 6. Radiographs at initial presentation, anterior-posterior view.

Fig. 7. Radiographs post-operatively after treatment with XS nail®, lateral view.

and no hardware irritation or soft tissue complications were reported (Figs. 5–8).

Clinical examination

All examined patients exhibited anatomical elbow joint articulation, and all but 1 patient with known chronic polyarthritis

Fig. 8. Radiographs post-operatively after treatment with XS nail®, anterior-posterior view.

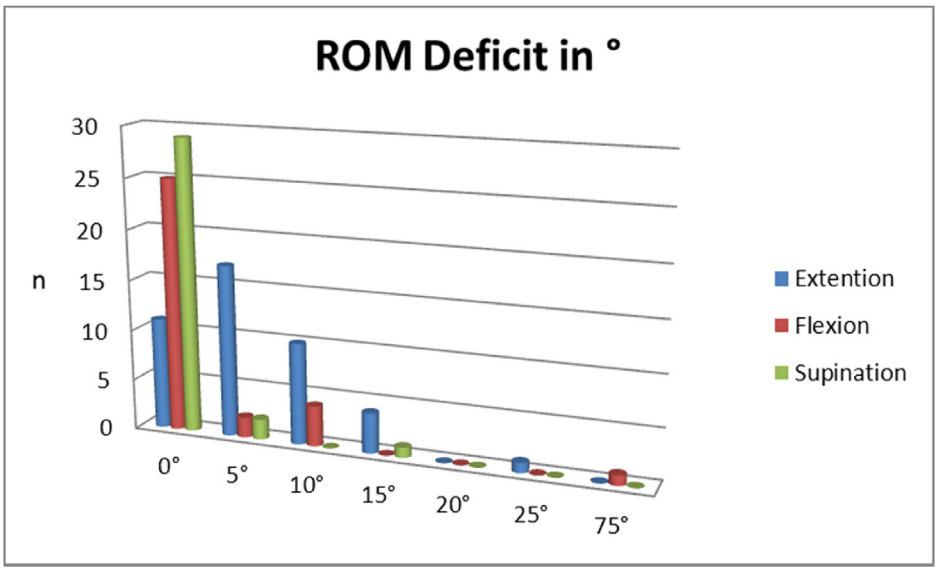

Fig. 9. The range of motion in degrees.

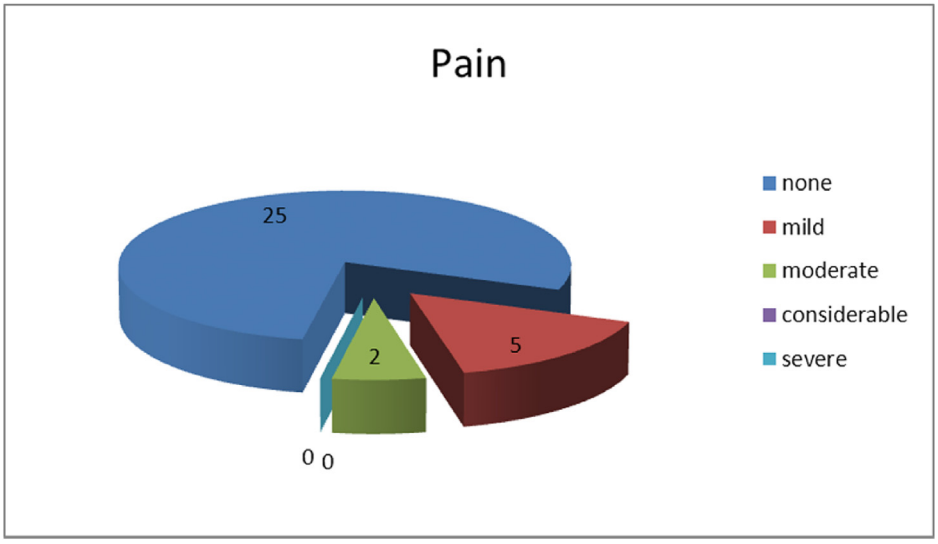

Fig. 10. The distribution of pain level.

showed regular scar tissue without swelling or irritation. Four patients complained of hyposensibility around the scar tissue.

When comparing the ROM for both elbows and using 0° (full extension) consistent with the neutral – zero method as a baseline, 17 patients (53%) had a deficit of 5° or less, and 10 patients (31%) exhibited an insufficiency of 10° extension. The ROM for only 5 patients (16%) was reduced more than 10°.

Twenty-five patients had identical bilateral range of flexion, while 2 patients with initial type E fractures showed a decrease of 5°. Four patients including 2 with type D fractures, 1 with type B and 1 with type C incurred a deficit of 10°. The remaining patient had a type D fracture, and due to postoperative joint fibrosis, the restriction of extension was 25° and the flexion was reduced by 75°. In 29 patients (90.62%), the supination was uninhibited, the mobility decreased by 5° in 2 patients, and the supination decreased by 15° in 1 patient (Fig. 9).

Level of pain

Twenty-five (78.12%) patients reported no pain at any time, while 5 (15.61%) patients mentioned mild pain during extreme sports. One patient complained of occasional moderate pain, while 1 patient had chronic polyarthritis with persistent chronic pain. Overall, only 2 patients reported a reduction of their activity, while 30 (93.75%) reported no change in their physical activity, based on the Tenger Activity Index (Fig. 10).

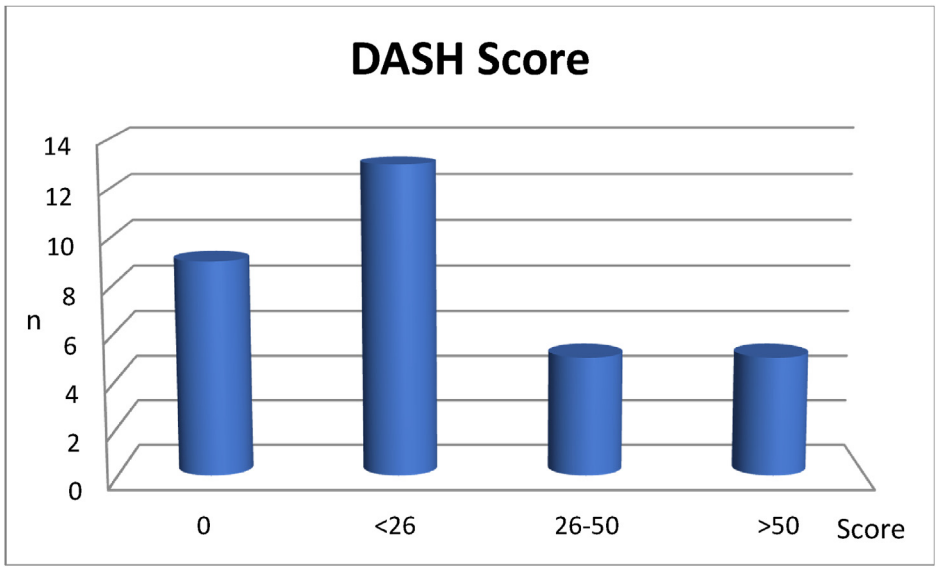

Fig. 11. The disabilities of the arm, shoulder and hand score.

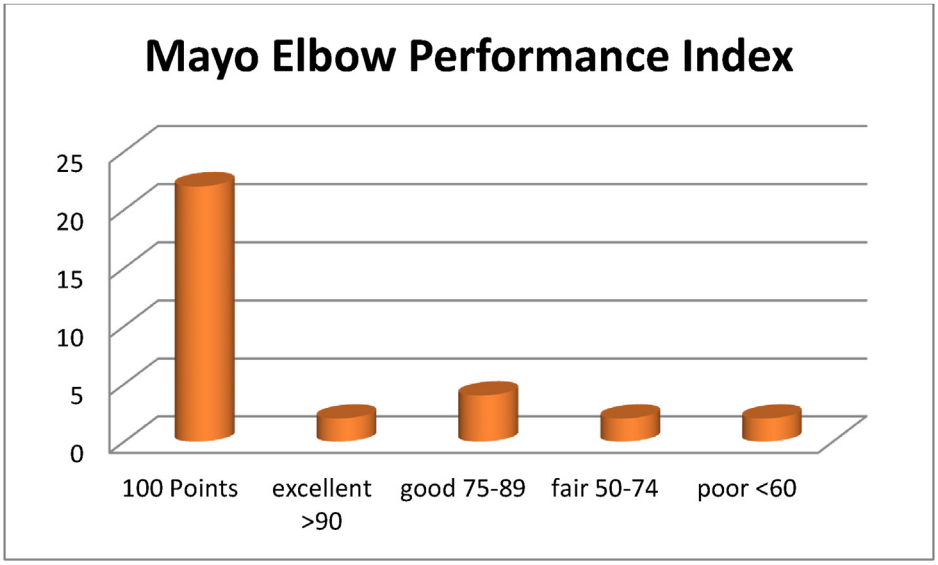

Fig. 12. Mayo elbow performance index.

DASH score

Lower DASH score indicates less disability of the extremity. In our group, the average score of follow-up was 21.15 (range 0–88.3). Nine patients reported no disability, 13 patients showed up to 25% disability, and 5 patients showed 26%–50% and 51%–88.3% disability, respectively. Four patients had poor DASH scores due to omarthrosis (Fig. 11).

MEPI

According to MEPI, considering the aspects of pain, motion, stability and function, 24 patients scored an excellent result. Four achieved good results, 2 fair results and 2 poor results, respectively. The overall average score was 91.87 and 22 patients had a perfect score (Fig. 12).

When illustrating MEPI according to fracture types, only 4 patients scored below “good”. Each patient had sustained a fracture

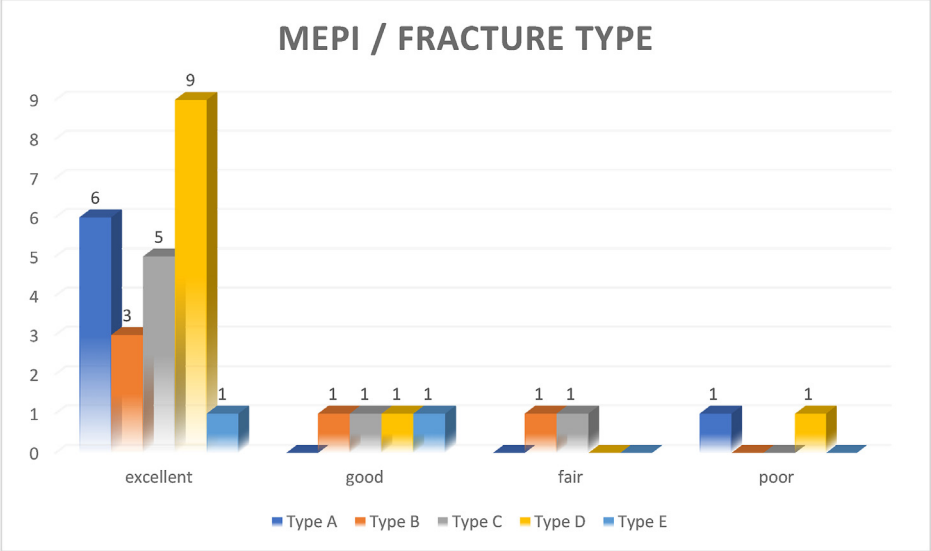

Fig. 13. Mayo elbow performance index according to the fracture types.

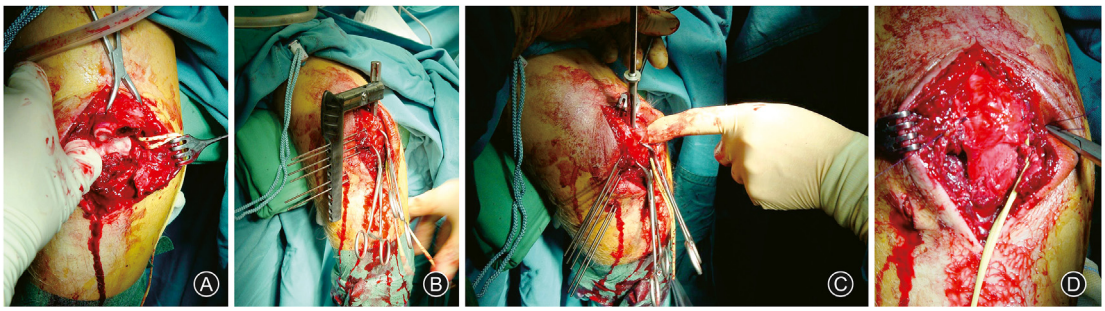

Fig. 14. Intraoperative presentation of important surgical steps: (A) Presentation of the fracture; (B) Insertion of the XS nail; (C) Compression of the fracture and (D) Intraoperative soft tissue coverage and soft tissue protection.

type A through D, respectively. Both comminuted fractures and simple fractures achieved "good" or better results, with 2 exceptions each. (Fig. 13).

Discussion

In this study, we evaluated the long-term outcome of patients treated by the XS nail® system in acute, isolated olecranon fractures of all types according to the Schatzkers[10] classification. By their nature and anatomy, all olecranon fractures are intraarticular[1], so the ultimate objective is to restore joint function. Surgical fracture reduction, retention and early mobilization is recommended as the current standard of care for virtually all olecranon fractures, and has yielded the best outcome.[2,3,5]

The current most frequently used technique for open reduction and internal fixation is to employ K-wires and TBW, which was first described by Weber & Vasey in 1963.[3] This surgical treatment option for olecranon fractures has been extensively studied, and a wide array of different arrangements with K-wires, tension bands and sutures in various configurations have been described over the last 50 years.[2–4] However, TBW only results in dorsal compression, whereas articular surface compression is thought to be induced by elbow flexion. These alternating loads not only cause fatigue failure of the tension band wires, but continuous compression provides a more stable system.[11,12] Compared with a mere lateral arrangement, the centrally located implant also distributes the compression force more symmetrically over the entire fracture plane.[3,4] Moreover, for comminuted fractures, TBW alone may not allow for accurate reduction and sufficient stabilization of the injury site.[3]

Recently, Brink et al.[11] questioned the general underlying principle of converting tension into compression forces while sustaining reduction by K-wires, and described a general loss of compression at the fracture site. In a cadaver model, active extension resulted in only minimal (0.37 MPa − 0.51 MPa) compression at the medial surface when comparing with active flexion (0.2 MPa) and no compression forces were recorded at the posterior column. The XS nail, by contrast produces the compression force centrally, which is then distributed uniformly on the articular and the dorsal part of the bone.

Chapleau et al.[13] noted the importance of the proximal ulna dorsal angulation, which contributed to loss of ROM and malunion. In addition, many biomechanical studies have reported the loss of compression immediately after applying the tension band system, and the interposing soft tissues further reduces the potential tightness.[11,14,15]

Locking plates do allow for multidirectional screw placement and even fixation of complex fractures while providing protection from tension, but only few implants apply additional compression.[3,6,15] However, the implants are often removed due to the risk of local irritation, infection and discomfort, as well as the increased extra-osseous profile.[2,3] Herein there is another advantage of the XS

nail®. Due to the fully recessed nature of the implant, the very thin soft tissue covering at the olecranon is less likely to be irritated (Fig. 14).

Argintar et al.[16] compared plates and intramedullary nails in a biomechanical study, finding that nails sustained significantly higher loads (65.5%) and withstood more cycles (32.6%) in a cadaver model. Novak et al.[15] conducted a biomechanical study, comparing nails to TBW and locking plates, respectively. They concluded that in both cases, the nails showed better stability and less fracture gap, which disbanded the theory of compression through TBW. Brill and Hof had previously shown on a patella model, that the concept of static dorsal compression and dynamic compression by flexion at the articular column is not achievable, which may explain the high failure rate of TBW.[17]

Recently, only Flinterman et al.[18] had a longer follow-up interval, but their patients were operated on over the span of 20 years. Given the long follow-up time, being able to assess 32 patients constitutes a strong point of this study. Ren et al.[19] described 13 studies with similar or fewer patients included in their meta-analysis with an average follow-up time of only about 1 year.

Furthermore, this study included standardised scores such as Tenger, DASH, MEPI, radiographic findings, ROM analysis and detailed complication recording. Our results are consistent with reports of Flinterman et al.,[18] investigating TBW in simple fractures after 20 years. In their retrospective study, the mean patient age was 35 years, and while our study also included comminuted fractures, the average age was 59 years. Consequently, their published mean MEPI was 98, which compares well with our 91.9. However, our study showed slightly higher DASH scores of 21.15 compared with 10 of Flinterman et al.,[18] owing in part to an older population, where 4 patients suffered from severe omarthrosis.

Also, the ROM was comparable. One patient with arthrofibrosis had an overall deficit larger than 15°, which is similar to the 140° arc described by Flinterman et al.,[18] and close to the results by De Giacomo et al.[20] and Niglis et al.,[21] who used plates in their trials. An extension deficit of more than 10° was only found in 15.6% of patients, faring well when compared to 39% reported by De Giacomo,[20] and 31% described by Niglis,[21] while MEPI in our study was slightly lower than their published 94.8 and 96.6, respectively. In our study, only 1 patient had a loss of forearm rotation exceeding 5°, and suffered other limitations due to arthrofibrosis. Additionally, due to its predominantly intramedullary location, no cases of postoperative wound infection, soft tissue irritation or premature hardware removal of the XS nail® were observed in our long-term group, one of the major disadvantages of all extra-osseous implants.[3,6,19–21]

Tarallo et al.[3] compared TBW to plate fixation related to fracture type. In our study, all olecranon fractures were treated with a single implant, while Tarallo et al.[3] showed a slight advantage in TBW for simple fracture and plate fixation for more complex fracture types. The DASH, MEPI and ROM outcomes were similar to those presented in our single implant study. Schliemann et al.[22] agreed with those results, treating non-comminuted Mayo type IIA fractures with either plate fixation or TBW, but removed all but 1 plate occurred to hardware irritation. Here, the results of MEPI and DASH were also comparable to our findings, but no wound infection or postoperative soft tissue damage was found in our research.[22]

Although the retrospective nature of this study represents the most significant weakness, we found that XS nail® implant is suitable for all types of olecranon fractures, while TBW and plate osteosynthesis are limited by their indications, thus greatly reducing the comparability. In conclusion, all fracture types can be successfully treated using the XS nail® system, and the rate of complications was lower than using tension banding, compression screws or plating reported in current literature. Excellent functional outcome, wide range of movement and good retention of reduction without soft tissue irritation makes the XS nail® system a very suitable implant for fractures subject to tension forces.

Funding

Nil.

Ethical statement

This study was conducted with the approval of the relevant ethics committee. All data were collected and evaluated retrospectively, archived anonymously and handled consistent with patient's informed consent. Data analysis was performed using Microsoft Office Excel® 2016.

Declaration of competing interest

All authors declare that they have no conflict of interest or received any funding. Wilhelm Friedl is the inventor of the XS nail® and works as a development consultant for Intercus GmbH.

Author contributions

All authors declare that they have made a substantial contribution to the collection of data, the evaluation and the preparation of the manuscript.

References

1. Baecher N, Edwards S. Olecranon fractures. *J Hand Surg Am*. 2013;38:593–604. https://doi.org/10.1016/j.jhsa.2012.12.036.
2. Wilkerson JA, Rosenwasser MP. Surgical techniques of olecranon fractures. *J Hand Surg Am*. 2014;39:1606–1614. https://doi.org/10.1016/j.jhsa.2014.05.014.
3. Tarallo L, Mugnai R, Adani R, et al. Simple and comminuted displaced olecranon fractures: a clinical comparison between tension band wiring and plate fixation techniques. *Arch Orthop Trauma Surg*. 2014;134:1107–1114. https://doi.org/10.1007/s00402-014-2021-9.
4. Huang TW, Wu CC, Fan KF, et al. Tension band wiring for olecranon fractures: relative stability of Kirschner wires in various configurations. *J Trauma*. 2010;68:173–176. https://doi.org/10.1097/TA.0b013e3181ad554c.
5. Gallucci GL, Piuzzi NS, Slullitel PAI, et al. Non-surgical functional treatment for displaced olecranon fractures in the elderly. *Bone Joint Lett J*. 2014;96:530–534. https://doi.org/10.1302/0301-620X.96B4.33339.
6. Gehr J, Friedl W. Intramedullary locking compression nail for the treatment of an olecranon fracture. *Oper Orthop Traumatol*. 2006;18:199–213. https://doi.org/10.1007/s00064-006-1171-5.
7. Tegner Y, Lysholm J. Rating systems in the evaluation of knee ligament injuries. *Clin Orthop Relat Res*. 1985;198:43–49.
8. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The Upper Extremity Collaborative Group (UECG). *Am J Ind Med*. 1996;29:602–608, 10.1002/(SICI)1097-0274(199606)29:6<602::AID-AJIM4>3.0.CO;2-L.
9. The B, Reininga IHF, El Moumni M, et al. Elbow-specific clinical rating systems: extent of established validity, reliability, and responsiveness. *J Shoulder Elbow Surg*. 2013;22:1380–1394. https://doi.org/10.1016/j.jse.2013.04.013.
10. Schatzker J. Fractures of the olecranon. In: Schatzker J, Tile M, eds. *The Rationale of Operative Fracture Care*. New York, NY: Springer-Verlag; 1996:113–119.
11. Brink PRG, Windolf M, de Boer P, et al. Tension band wiring of the olecranon: is it really a dynamic principle of osteosynthesis? *Injury*. 2013;44:518–522. https://doi.org/10.1016/j.injury.2012.08.052.
12. Saeed ZM, Trickett RW, Yewlett AD, et al. Factors influencing K-wire migration in tension-band wiring of olecranon fractures. *J Shoulder Elbow Surg*. 2014;23:1181–1186. https://doi.org/10.1016/j.jse.2014.02.018.
13. Chapleau J, Balg F, Harvey EJ, et al. Impact of olecranon fracture malunion: study on the importance of PUDA. *Injury*. 2016;47:2520–2524. https://doi.org/10.1016/j.injury.2016.08.029.
14. Wilson J, Bajwa A, Kamath V, et al. Biomechanical comparison of interfragmentary compression in transverse fractures of the olecranon. *J Bone Joint Surg Br*. 2011;93:245–250. https://doi.org/10.1302/0301-620X.93B2.24613.
15. Nowak TE, Burkhart KJ, Andres T, et al. Locking-plate osteosynthesis versus intramedullary nailing for fixation of olecranon fractures: a biomechanical study. *Int Orthop*. 2013;37:899–903. https://doi.org/10.1007/s00264-013-1854-0.

16. Argintar E1, Martin BD, Singer A, et al. A biomechanical comparison of multidirectional nail and locking plate fixation in unstable olecranon fractures. *J Shoulder Elbow Surg*. 2012;21:1398–1405. https://doi.org/10.1016/j.jse.2011.08.068.
17. Brill W, Hopf T. Biomechanical study of various osteosynthesis procedures in transverse patella fractures. *Unfallchirurg*. 1987;90:162–172.
18. Flinterman HJA, Doornberg JN, Guitton TG, et al. Long-term outcome of displaced, transverse, noncomminuted olecranon fractures. *Clin Orthop Relat Res*. 2014;472:1955–1961. https://doi.org/10.1007/s11999-014-3481-5.
19. Ren YM, Qiao HY, Wei ZJ, et al. Efficacy and safety of tension band wiring versus plate fixation in olecranon fractures: a systematic review and meta-analysis. *J Orthop Surg Res*. 2016;11:137. https://doi.org/10.1186/s13018-016-0465-z.
20. De Giacomo AF, Tornetta 3rd P, Sinicrope BJ, et al. Outcomes after plating of olecranon fractures: a multicenter evaluation. *Injury*. 2016;47:1466–1471. https://doi.org/10.1016/j.injury.2016.04.015.
21. Niglis L, Bonnomet F, Schenck B, et al. Critical analysis of olecranon fracture management by pre-contoured locking plates. *Orthop Traumatol Surg Res*. 2015;101:201–207. https://doi.org/10.1016/j.otsr.2014.09.025.
22. Schliemann B, Raschke MJ, Groene P, et al. Comparison of tension band wiring and precontoured locking compression plate fixation in Mayo type IIA olecranon fractures. *Acta Orthop Belg*. 2014;80:106–111.