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Internal joint stabilizer covered by an anconeus flap for elbow instability: surgical technique and preliminary results

Angelo De Crescenzo, MD[a,*], Raffaele Garofalo, MD[a], Andrea Celli, MD[b]

[a]Department of Orthopaedic and Traumatology Surgery, Shoulder and Elbow Unit, Ente Ecclesiastico Ospedale "F. Miulli", Acquaviva delle Fonti, Bari, Italy
[b]Department of Orthopaedic Surgery, Shoulder and Elbow Unit, Hesperia Hospital, Modena, Italy

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The highly congruent joint surfaces coupled with the collateral ligaments are essential for the elbow joint stability and motion afterward.[23,30] These can be severely damaged after acute lesions, and residual instability can be detected at the end of the surgery. In these scenarios, increased joint stability is thereby mandatory to prevent unsatisfactory results.[12] Similarly, the elbow stability may not be warranted when an extensive soft tissue release or excision is required for the treatment of chronic elbow instability, elbow contracture, or heterotopic ossification.[24]

The residual instability can be addressed with static methods of additional stabilization like static external fixators, transarticular pinning, or bridge plate.[23] These methods effectively maintain the concentric joint reduction, but motion is precluded, and severe complications may occur, like articular surface damage or pin track problems.[23] To promote both stability and early motion, hinged external fixators have been used with reasonable results.[5,20] However, the complication rate associated with the hinged external fixators is significant, with the most relevant represented by the pin-track problems such as infection and mobilization.[5,20] The malalignment to the axis of rotation can lead to abnormal tracking, restricting rather than promoting joint motion. As a result, recurrent instability has been found in as many as 30% of cases.[20]

To address these significant limitations of the hinged external fixator, the internal joint stabilizer (IJS) was developed by an idea of Orbay, who first described the results achieved with an internal hinge crafted by a Steinmann pin.[19] The IJS is a completely internal device designed to stabilize the joint, allow early motion, and protect bone and ligamentous healing. Reducing the distance of the device to the joint and its lever arm, the IJS allows a more accurate recreation of the axis of motion and helps to avoid the severe pin-site complications associated with hinged external fixation.[5,20] Moreover, an internal device is less cumbersome and heavy for the patient. Since its approval by the Food and Drug Administration in 2016, the IJS has demonstrated consistent and successful results, with similar recovery of motion, decreased rates of complications, and recurrent instability when compared to the hinged external fixators.[19,20]

The aim of this manuscript is to describe an alternative surgical approach to reduce the risk of symptomatic hardware when an IJS is required for additional joint stabilization. To improve local comfort, an anconeus flap raised for the surgical approach can, at the end of the procedure, be used to completely cover the device. The anatomical relationship with proximal ulna and lateral elbow remains unchanged. In addition, the article shows the safety and reliability of the removal procedure and the preliminary results obtained with this technique.

Methods

All patients and outcomes were collected prospectively in January 2022. We reviewed all the patients managed with an IJS (Skeletal Dynamics, Miami, FL, USA) as a temporary and additional

Institutional review board approval was not required for this technical note.

*Corresponding author: Angelo De Crescenzo, MD, Department of Orthopaedic and Traumatology Surgery, Shoulder and Elbow Unit, Ente Ecclesiastico Ospedale "F. Miulli", Strada Prov. 127 Acquaviva-Santeramo Km 4, 70021, Acquaviva delle Fonti, Bari, Italy.

E-mail address: dr.angelodecrescenzo@gmail.com (A. De Crescenzo).

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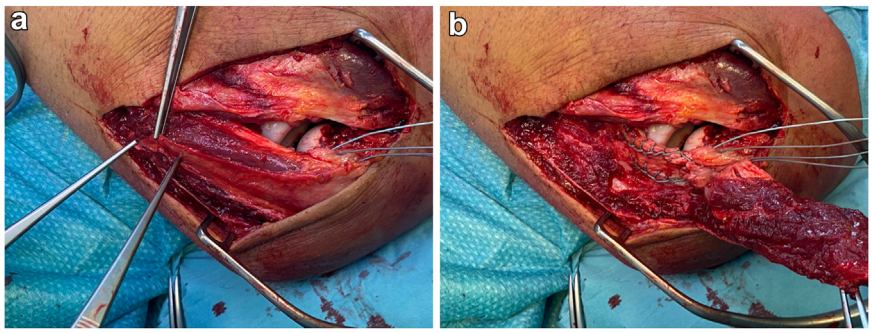

Figure 1 The anconeus flap preparation. (**a**) The intraoperative pictures show the deep dissection of the surgical approach creating the anconeus flap, and (**b**) after its elevation, the lateral collateral ligament complex, which is whipstitched.

stabilization for residual elbow instability and covered by an anconeus flap. The inclusion criteria were patients with adequate bone stock to position the internal device and residual instability after surgical fixation for acute fracture dislocations or its sequelae, patients willing to maintain the device for the needed time, and patients willing to cooperate with the study design and rehabilitation program. Patients with severe soft tissue and skin lesions, active infection, and sensitivity to titanium and chrome cobalt were excluded. The definitive indication for additional stability with IJS was deemed intraoperative, even though preoperative surgical plan gives a relatively high degree of suspicion for potential residual elbow instability. The persistent instability was defined as ulnohumeral gapping or recurrent radiocapitellar or ulnohumeral subluxation on lateral fluoroscopic views at flexion angles greater than 30 degrees.

The elbow injury was always preoperatively analyzed with both X-rays and CT scans; thereafter, each patient was routinely followed up with a radiographic and clinical evaluation at approximately 2 and 6 weeks and then 3, 6, and 12 months postoperatively. Radiographic analysis consisted of simple antero-posterior and lateral x-rays to check for ongoing concentric joint reduction and heterotopic ossification.

The patients were analyzed and asked for any symptoms or discomfort. Each complication or further surgical intervention was regularly collected. During the follow-up period, range of motion (ROM) with a goniometer, pain score (visual analog scale rated from 0 to 10), and functional scores (the Disabilities of the Arm, Shoulder and Hand score, and Mayo Elbow Performance Score, respectively) were recorded as well.[10,18]

In the present study, as in the previous reports,[7,11,15,20,21,25,28] secondary surgery for device removal was not considered a "revision" unless performed for a complication directly caused by the device, such as implant breakage, motion impingement, or symptomatic hardware.

Surgical technique

The patient is placed in supine position with the arm over the chest or on a supporting table. Temporary ischemia is achieved with a sterile tourniquet applied to the upper arm. The skin incision is closely dependent on the bony and ligamentous fixation planned. Care is taken to elevate cutaneous skin flaps deep to the fascia surface. Injuries to the cutaneous nerves are thereby minimized. As the anconeus is exposed, the Kocher interval between the anconeus and the extensor carpi radialis is identified and opened. Then, a subperiosteal dissection is performed from distal to proximal along the radial border of the ulnar crest. The surgical approach can involve an anconeus flap or, if required, an anconeus triceps lateral flap extending proximally from the dissection.[3,2] If necessary, a midline split is made through the triceps muscle and the proper tendon unit down to the tip of the olecranon, preserving the proper medial tendon insertion area in the olecranon footprint.[3] The anconeus is raised as a single flap unit and reflected proximally, carefully preserving the ulnar insertion of the lateral collateral ligament (LCL) (Fig. 1 *a* and *b*).

In the setting of acute trauma, any fractures are initially addressed, and then ligaments are repaired. Capsular and osseous release combined with bone and ligamentous reconstructions are performed in patients with chronic elbow disease. At the end of the procedures, joint stability is assessed carefully throughout full ROM. If residual instability is detected, additional joint stabilization with the IJS is considered. As a matter of fact, the likely need for the IJS is generally considered at the beginning of surgery, as the center of rotation on the lateral capitellum should be left free for the axis pin rather than for an anchor for the lateral ulnar collateral ligament repair. For these reasons, a K-wire is placed in the axis of rotation of the distal humerus when an IJS is supposed to be used. The correct axis of rotation is easily reached with a specific aiming guide. The guide allows the connection of the isometric point on the lateral epicondyle, defined visually and with the help of a centering guide, to another medial point achieved by positioning the axis guide in the trochlear notch. For the most accurate axis recreation, the axis guide must engage as much as possible in the medial trochlear expansion with the largest-sized guide that is suitable for the patient. Varus stress and sometimes extension of proximal release can be necessary to open the joint, creating access for the guide. A fluoroscopy is suggested to confirm the proper K-wire position.

Once the bony elements and the lateral ligamentous have been addressed and residual instability has been observed, the K-wire is measured and drilled with the use of the 2.7-mm cannulated drill. The K-wire is thereafter removed, and the axial pin is inserted. In the presented cases, the LCL is repaired with a transosseous technique or with an all-suture anchor placed immediately posteriorly and proximally to the axial pin. In this position, a wider healing surface for the collateral ligament is provided. However, a recent biomechanical study has shown that as the anterior and inferior to the axial pin is the only anchor's position that do not interfere with joint motion.[17] The limbs of both sutures are whipstitched through the ligament but are tied down only once the IJS placement is completed to avoid overtensioning.

Once positioned the axial pin, proximal ulna is approached. The dorsal ulnar bone surface is cleared, and the ulnar head of the flexor carpi ulnaris is slightly raised to facilitate plate coverage at the end of the procedure. The baseplate is temporarily positioned and fixed with the first screw placed through the oblong hole, aiming distally

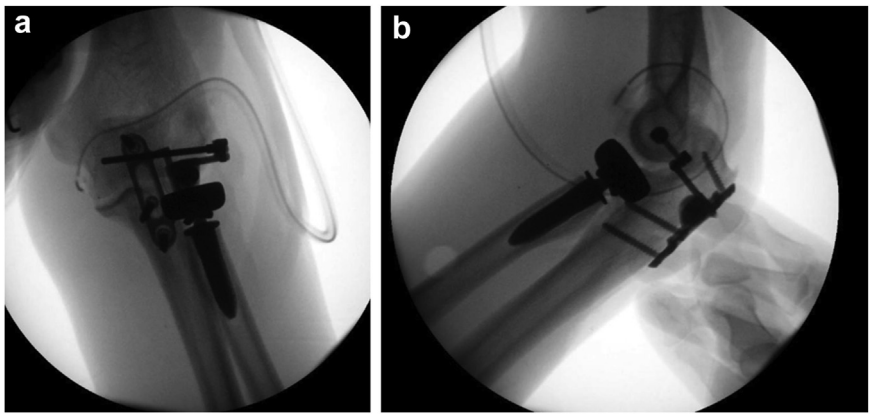

Figure 2 Intraoperative fluoroscopic IJS evaluation. The intraoperative fluoroscopic images show the final radiographic evaluation of IJS implantation in (**a**) an anteroposterior view and (**b**) lateral view. *IJS*, internal joint stabilizer.

toward the coronoid process. Application of first screw through the center-sliding slot makes a correction to plate position still possible before definitive fixation. After image intensifier assessment, the proximal and distal screws are positioned, taking care to avoid both the ulnohumeral and proximal radioulnar joints. At this stage, the axis pin is tightened to the connecting rod, and proximal and distal screws on connecting rod are secured after concentric reduction is confirmed. Full ROM is checked to detect any potential bony impingement of the connecting arm with the lateral epicondyle. In that case, bone excision and flattening are warranted. The stability is again confirmed, and the excessive length of connecting bar is trimmed (Fig. 2 *a* and *b* and Fig. 3). At this point, stitches on LCL are tied down. The anconeus can now be effortlessly reattached, covering the internal device completely (Fig. 4 *a* and *b*). At the end of the procedure, accurate hemostasis is performed, drains are routinely employed, and the skin is closed.

Postoperative program

Postoperatively, the patients are immobilized in splints for 6 weeks, and supervised physiotherapy is started on the first day after surgery. Pain is controlled with a brachial plexus block catheter, followed by oral medication. The drains are usually removed after two to three days to benefit from initial joint mobilization. The patients are patiently instructed on self-exercises to perform when not supervised by a physiotherapist. After the hospital discharge, each patient is routinely checked at approximately 15 days after surgery, where the skin staples are removed according to the condition of the skin and soft tissues. Then, the subsequent follow-up visits are organized after 6 weeks, 3, and 6 months with x-rays.

IJS removal

As for the index surgery, the patient is placed in a supine position with the arm over the chest, and a temporary ischemia is achieved with a sterile tourniquet. The skin incision is performed over that of the previous surgery. The two flaps with cutaneous and subcutaneous layers are carefully raised, and exposition to the posterolateral elbow is gained. If the anconeus flap covered the whole internal device, the hardware is not clearly visible at this point of the procedure (Fig. 5). However, the hardware removal needs two small windows to be opened (Fig. 6). These include one smaller on the lateral epicondyle to expose the axial pin and one larger on the ulnar plate. As a matter of fact, these two windows can be created from skin incisions as well. The anconeus belly is

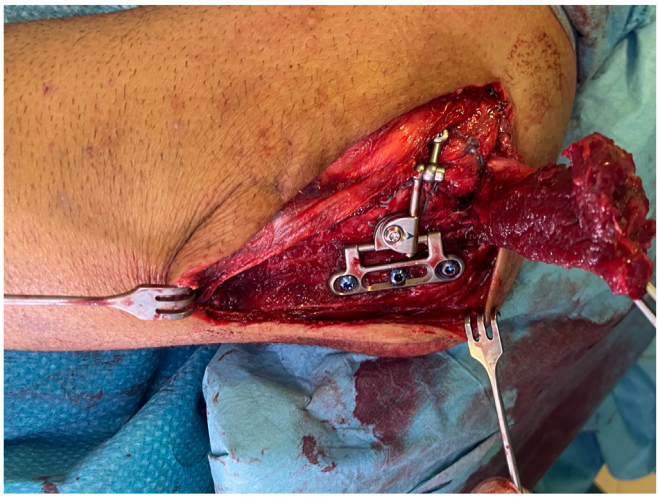

Figure 3 Intraoperative clinical IJS evaluation with an anconeus flap. The intraoperative picture shows the definitive IJS implantation with the anconeus flap raised. *IJS*, internal joint stabilizer.

minimally raised to gain access to the base plate, whereas the remaining portion remains untouched (Fig. 7). The first element to be unlocked is the connection between the axial pin and the lateral connecting arm, followed by the proximal and distal locking screws. The axial pin and the connecting arm can now be removed by pulling them out of the small window at the lateral epicondyle (Fig. 8). If the small window does not allow easy access to the proximal locking screw, turning the connecting arm 180° can make its removal possible. The ulnar base plate is now approached, and the three screws and the plate are sequentially removed (Fig. 9). As any hardware is removed, the joint is thoughtfully evaluated in ROM and stability. The surgical field is then copiously irrigated, and accurate hemostasis is performed after tourniquet release. The anconeus is carefully evaluated for tissue quality (Fig. 10) and the two windows are closed (Fig. 11). The skin flaps are closed, and some additional stitches are often used between the superficial flaps and the deep layers. These stitches aim to reduce the dead space that can promote seroma development. For the wide scar tissues, the risk of observing seroma in the postoperative phase is remarkable. For this purpose, the joint immobilization is usually maintained for about 7 days since the rate of stiffness is theoretically low being the removal procedure extra-articular.

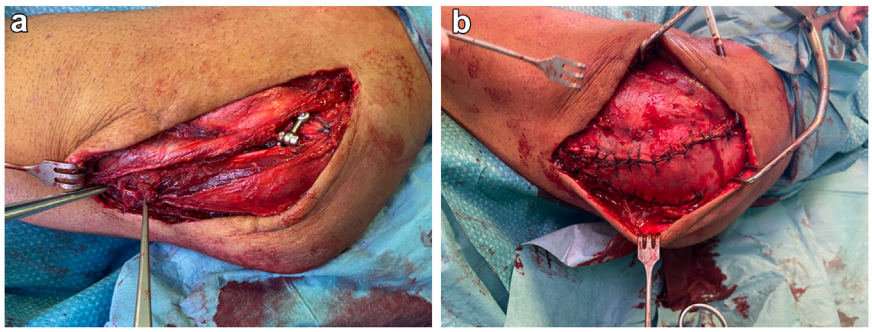

Figure 4 IJS coverage and anconeus flap reattachment. (**a**) The anconeus flap can, at the end of the procedure, completely cover the internal device and (**b**) effortlessly be reattached to its original position. *IJS*, internal joint stabilizer.

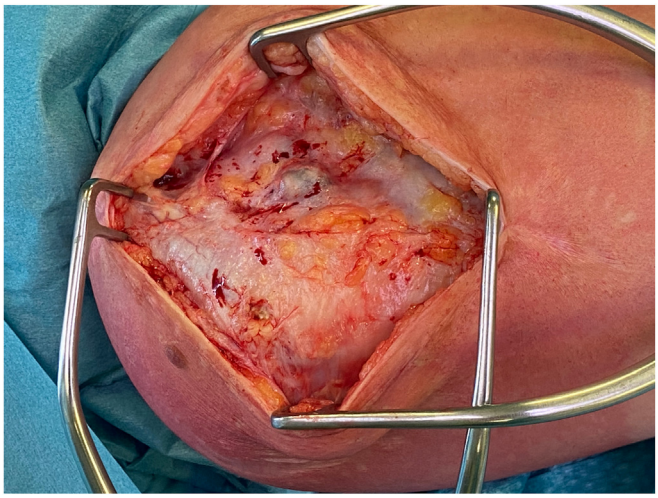

Figure 5 Superficial dissection at IJS removal. At the time of device removal, the superficial dissection displays how the IJS is completely covered by the anconeus muscle belly. *IJS*, internal joint stabilizer.

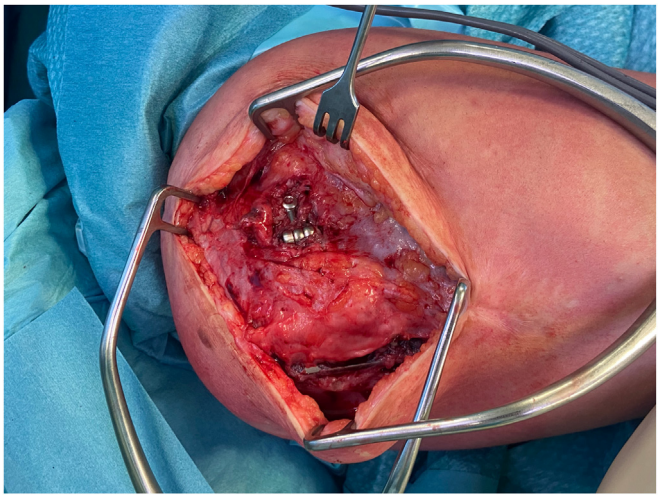

Figure 6 Deep dissection at IJS removal. Two deep windows are created to gain access to the lateral pin (small and lateral window) and the base plate (big and posterior window). *IJS*, internal joint stabilizer.

Results

Our series consisted of 10 consecutive patients (4 males and 6 females) with an average age of 42.6 years at presentation (range: 27-54, Table I). Eight patients had an acute injury (5 terrible triad, 1 simple dislocation, and 2 anteromedial coronoid fractures with a varus posteromedial rotatory instability), while two of the cases had a delayed presentation with a malunion of their coronoid fracture and subluxation of their ulnohumeral joint in one patient and a severe contracture and heterotopic ossification in the other patient (Table I). In detail, the patients with terrible triad injuries were managed with open reduction and internal fixation (ORIF) of radial head fractures and LCL repair in two cases, ORIF of radial head fracture, coronoid fracture suture fixation, and LCL repair in one patient, and radial head arthroplasty and LCL repair in one patient. The patient with a simple elbow dislocation was managed with the repair of both anterior bundle of medial collateral ligament and LCL. The two cases of varus posteromedial rotatory instability were treated with ORIF of the coronoid and LCL repair in one patient and with only LCL repair in the other patient. In one patient with chronic presentation, the malunion of coronoid fracture was judged not significant; thus, after an adequate soft tissue release and once the joint congruency was regained, the collateral ligaments were repaired and protected with the internal device. In conclusion, a similar procedure was performed on the other patient suffering from a chronic condition of elbow stiffness with severe contracture and heterotopic ossification. The device was removed at an average of 5.5 months (range from 3 to 7.5) from index surgery, and the mean follow-up was 13.5 months (range from 11 to 17.5, Table I). No patient was lost to the follow-up.

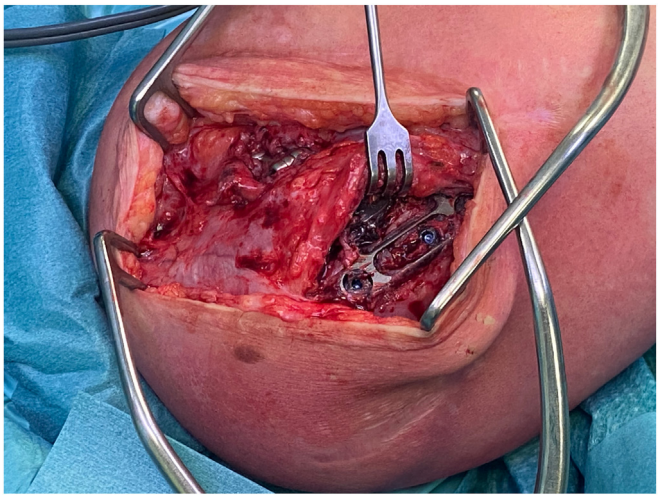

Figure 7 Anconeus flap elevation. The anconeus muscle is minimally raised to expose the base and the distal locking screw.

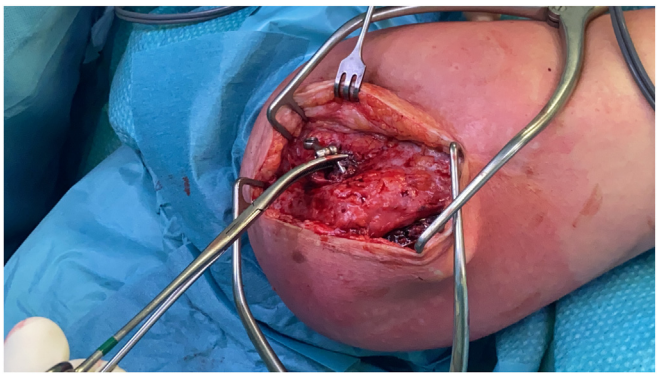

Figure 8 Connecting arm removal. The connecting arm can be easily removed from the small lateral window without any further dissection.

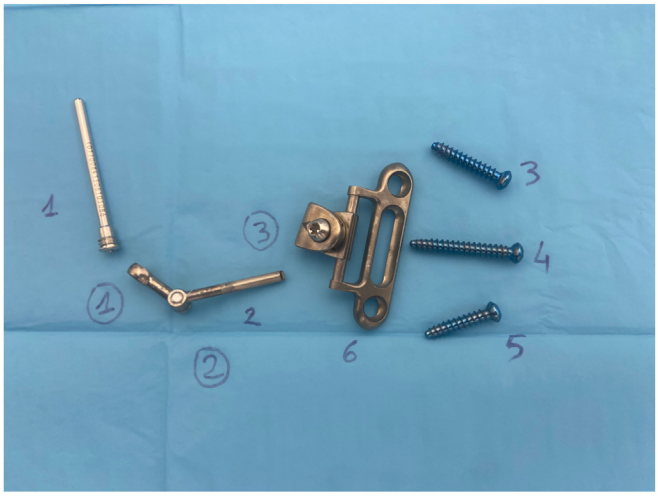

Figure 9 IJS removal steps summary. The steps for the device removal are summarized; the first steps aim to unlock the axial pin to the connecting arm, then the two locking screws (circled numbers), and then the sequential components' removal is suggested (numbers not circled). *IJS*, internal joint stabilizer.

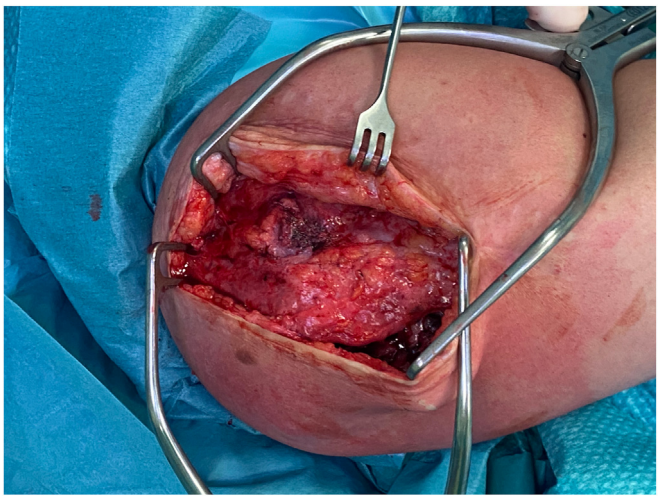

Figure 10 Anconeus muscle condition after IJS removal. The intraoperative picture shows the anconeus tissue quality after the IJS removal. *IJS*, internal joint stabilizer.

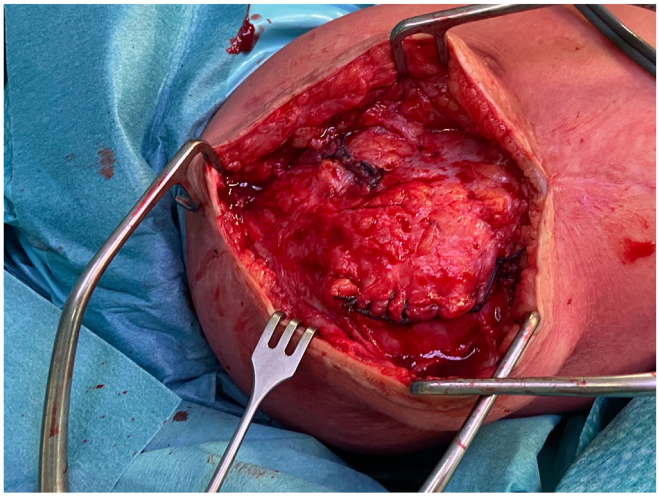

Figure 11 Final window closure and anconeus status. The two windows needed for device removal are closed and a final anconeus with good tissue quality is finally assessed.

At the last follow-up, the mean arc of flexion-extension was 118° (90°-150°) and the mean pronation-supination arc was 155° (110°-170°, Table II). The average Mayo Elbow Performance Score was 90.5 ± 8.1 and the average Disabilities of the Arm, Shoulder, and Hand score was 12.5 ± 11.3 (Table II). The mean visual analog scale pain score was 1.2 ± 0.4. There were no patients with recurrent elbow instability.

Overall complications occurred in five patients (50%, five out of 10 patients), with only one patient requiring an additional procedure (Table III). This was a 45-year-old man who was operated on for a terrible triad and suffered from ulnar neuropathy after the index surgery. At the time of device removal, performed 3 months after the index surgery, the ulnar nerve was released and transposed anteriorly in the subcutaneous layer. Even though performed during the removal surgery, it was considered a patient requiring a reoperation. Then, a patient had a seroma that resolved in a few days without any treatment, and two patients had heterotopic ossification without any interference with the joint motion (Table III).

Considering the complications directly related to the internal device, two patients developed some issues (20%, 2 out of 10 patients). A patient had loosening of the axial pin from the connecting arm (Fig. 12) and another patient had radiolucent lines around the axial pin of no more than 2 mm (Table III). The latter patient is also one of the two patients with non-symptomatic heterotopic ossification. Both patients with device problems did not require any additional surgery beyond the removal procedures, which were performed at 3 and 3.5 months, respectively. The IJS was generally well tolerated without any complaints or tenderness on the posterior and lateral side of the elbow observed.

Discussion

The present study shows the viability of an alternative surgical approach for the IJS application proposed to reduce local tenderness and symptomatic hardware related to the IJS. Covering the internal device with the anconeus muscle flap, this technique makes the device submuscular rather than subcutaneous. The preliminary reports show no complaints about local discomfort or adverse events directly related to the surgical approach. The implant removal does not represent a drawback since the

Table I
Patient characteristics.

Variable	Value
Number of patients	10
Gender, n (%)	
Female	4 (40%)
Male	6 (60%)
Age at operation (yr)	
Mean	42.6
Minimim age	27
Maximum age	54
Injury pattern, No. (%)	
Terrible triad	5
Simple elbow dislocation	1
Posteromedial rotatory instability (PMRI)	2
Chronic elbow dislocation >3 weeks	2
Removal surgery, months	
Mean	5.5
Minimim	3
Maximum	7.5
Follow-up, months	
Mean	13.5
Minimum	11
Maximum	17.5

Table II
Clinical and radiographic results.

Variable	Value
Range of motion	
Flexion/extension arc, mean (min-max)	118° (90°-150°)
Pronation/supination arc, mean (min-max)	155° (110°-170°)
VAS score (0-10) (mean ± SD)	1.2 ± 0.4
MEPS (mean ± SD)	90.5 ± 8.1
DASH (mean ± SD)	12.5 ± 11.3
Concentric reduction, n (%)	10 (100%)

SD, standard deviation; *VAS*, visual analog scale; *MEPS*, Mayo Elbow Performance Score; *DASH*, Disabilities of the Arm Shoulder and Hand.

Table III
Number and type of postoperative complications.

Overall complication rate, n (%)	5 (50%)
Complications not related to the IJS, n (%)	
Total	4 (40%)
Ulnar neuropathy	1 (10%)
Heterotopic ossification	2 (20%)
Seroma	1 (10%)
Complications related to the IJS, n (%)	
Total	2 (20%)
Loosening of axial pin from the connecting arm	1 (10%)
Radiolucent lines around the axial pin (<2 mm)	1 (10%)

IJS, internal joint stabilizer.

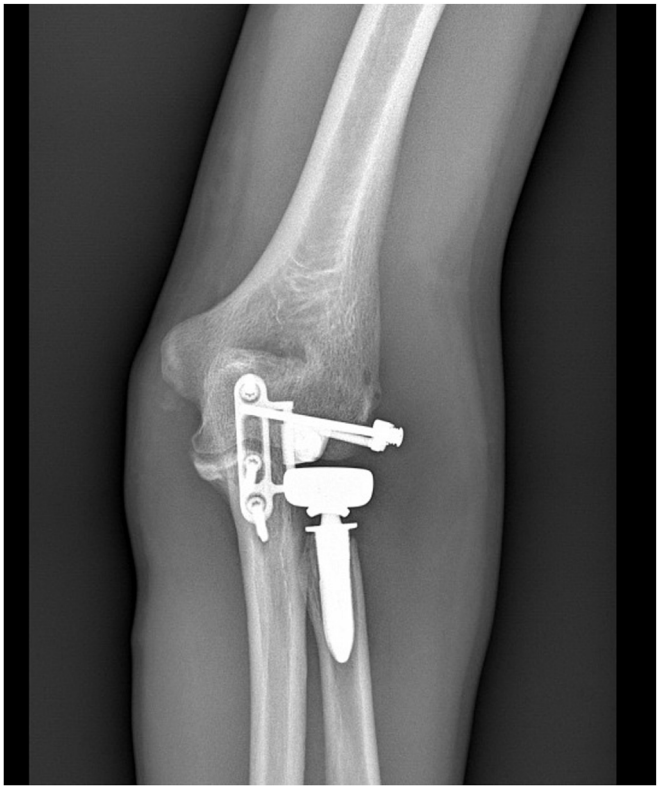

Figure 12 IJS disassembly. The x-ray shows a patient with a disassembly of axial pin from lateral connecting arm after three months of index surgery. *IJS*, internal joint stabilizer.

dissection required is not significantly wider and only a partial anconeus elevation is needed.

The elbow is a joint particularly prone to instability likely due to the small joint surfaces, the short working length of stabilizing structures, and the long moment arms to which it is subjected.[30] An adequate stability must then be sought intraoperatively to prevent detrimental immobilization and poor outcomes.[4] To date, joint immobilization is associated to cartilage necrosis, poor soft tissue healing properties, and joint stiffness. Accordingly, supplemental stabilization is suggested when residual instability or a tenuous soft tissue and bony fixation discourage from an early mobilization.

Among the different and available methods, simple immobilization in flexion with a cast may fail to maintain a concentric reduction, whereas transarticular pinning or static external fixators are associated with severe complications such as articular surface damage or pin track problems.[20,23] However, the immobilization required leads to rehabilitation delay, elbow stiffness, and remarkable consequences for functional outcomes. The hinged external fixator provides increased joint stability while allowing early motion, but it is clumsy, and complication rates could be as high as 67% including nerve injury, fractures, and pin track problems.[5,9] With the largest series of 100 consecutive patients undergoing hinged external fixation, Cheung et al reported 18% of pin site complications in the form of infection, loosening or fracture.[5] Similar complication rates were achieved by McKee et al, who reported a pin tract infection rate of 12.5% and a broken pin rate of 6.3% after the use of hinged external fixators.[16] In addition, the long lever arms and the subsequent implant flexibility can aggravate defects in recreation of the axis of rotation, resulting in up to 30% of recurrent instability.[20]

The IJS provides an alternative stabilizer that is easier to perform and potentially more efficient.[7,11,15,19,20,21,25,28] The IJS overcomes the consistent biomechanical drawbacks of a hinged external fixation.[20] The shorter lever arm coupled with an easy recreation of the axis of rotation provides more efficient joint stabilization and, at the same time, motion.[5,19,22,29]

Since the first description by Orbay in 2014,[19] different studies have shown favorable and consistent results with the IJS.[7,11,15,19,20,21,25,28] To date, IJS shows a remarkable high rate of maintained concentric reduction and functional ROM.[11] Sheth et al have compared the function, ROM, and complications in patients with elbow fracture-dislocations treated with (30 patients) and without (34 patients) an IJS.[27] At a mean follow-up of 16 ± 17 months, there were no differences in flexion-extension arc, complications, and functional scores between cohorts.[27]

Figure 13 Hardware prominence. The IJS can be remarkably prominent when classically positioned above the anconeus and within a subcutaneous layer, predisposing to discomfort and symptomatic hardware. *IJS*, internal joint stabilizer.

Even though the rate of recurrent instability is very low and complications due to the hinged external fixators are avoided, the overall complication rate with IJS is consistent, ranging from 21% to 65.5%.[11,14,27]

The complications directly related to the internal device should be distinguished from the overall rate. Most of these are, in fact, represented by heterotopic ossification, ulnar neuropathy, joint contracture, and superficial infection.[14,20] The issues directly related to the internal device are usually less common.[5,28] The rates of radiolucent line around axial pin and hardware failure (base plate broken or connecting rod disassembly) range from 0% to 47% and 0% to 23%, respectively.[14,20,21,27,28] Sheth et al found four implants (23%, 4 out of 30 patients) disassembled at the connecting rod and nonprogressive radiolucencies of 1-2 mm in width around the axis pin in 8 patients (47%, 8 out of 30 patients).[27]

As an internal device, the IJS is less cumbersome than an external frame. Patients with severe associated diseases such as drug or tobacco abuse, brain injury, or psychiatric conditions can better tolerate an internal device.[25] However, the IJS can be prominent and provide some esthetic and clinical discomfort (Fig. 13). The thin and soft tissue envelope around the posterior aspect of the elbow can predispose to soft tissue irritation and symptomatic hardware. For this reason, an alternative surgical approach is proposed here to make the device less superficial and potentially less symptomatic. The IJS is usually positioned on the anconeus on the lateral side of the elbow, whereas the present study suggests an alternative approach exploiting the anconeus muscle, which is raised and reattached covering the internal device.

The anconeus muscle flap is a well-described technique to provide coverage for soft tissue defects about the posterior and lateral elbow.[26] As previously described, an anconeus flap can be raised in continuity with the lateral triceps to get a wider access to the elbow.[3,2] In the setting of elbow instability, this approach can provide wider access to the posterolateral elbow and the opportunity to cover the internal device. The preliminary results achieved in 10 patients at an average of 7.8 months follow-up from index surgery show similar results to those of previous studies in terms of ROM, clinical scores, and complication rate.[11,14,15,19,20,21,25,27,28] When analyzing the issues directly due to the internal device, a patient with loosening of the axial pin from the connecting arm and a patient with radiolucent lines no more than 2 mm (20%, 2 out of 10 patients) were observed, but no revision surgery was required. All patients underwent removal surgery at an average of 5.5 months without any local discomfort or complaints raised by the patients throughout the follow-up.

This surgical approach with an anconeus flap can be feasible for every injury, but some scenarios are more suitable. Firstly, the symptomatic hardware can be easier observed in thin patients, who are more prone to develop symptoms from thin tissue envelope around the elbow. This is a well-known issue even after an open reduction and internal reduction of proximal ulna with even potential wound breakdown.[8] Secondly, in patients with hypertrophic muscles, the bulky anconeus may move the device away preventing a close rapport of the internal device with the joint. In this way, the advantages of the IJS might be partly lost as its lever arm increases. Thirdly, this technique can be performed whenever the anconeus flap is performed for the treatment of elbow injury taking a further advantage from the surgical approach. If a Boyd approach is initially preferred, opening the Kocher's interval can easily provide the muscle flap necessary to cover the internal device.

The need for secondary surgery for implant removal remains the main drawback of the IJS. This is recommended by the author at approximately 6-8 weeks after index surgery,[20] which is considered adequate for fracture and soft tissue healing to maintain concentric elbow reduction and avoid implant failure or bone damage over time. However, a growing experience reporting a safe and well-tolerated activity even for several months is driving most of the authors to delay the device removal at 3-4 months from index surgery.[25,28] At this time, complete tissue healing and a better definition of the injury's sequelae can be achieved. Moreover, the removal surgery can be exploited to perform adjunct procedures as needed, such as capsular release or heterotopic ossification excision.[28] The longer the period from index surgery to implant removal, the more lasting the recovered arc of motion can be assured, and soft tissue or bone constraints can be removed as well. In a recent report by Pasternack et al, four out of 10 patients (40%) required additional surgeries, which were performed at an average of 231 days after IJS implantation.[21] With these procedures performed after device removal (at an average of 68 days after index surgery), a delayed removal could avoid further surgeries.[21]

As a matter of fact, the device can be indefinitely left in selected patients without symptomatic hardware or radiographic complications, as argued by Sochol et al.[28] Similarly, reports on patients lost to follow-up suggest that the internal device may be well tolerated for a longer period. This scenario can be observed with complex patients, such as those with psychological disease, who are lost to follow-up or merely not willing to respect the follow-up schedule.[25] However, planned device removal remains the preferred option since device breakage or loosening can happen over time as well as bone loss around the axial pin if the center of rotation is not perfectly identified.

In the presented series, the device was removed at an average of 5.5 months from the index surgery.

In our experience, the removal of an internal device positioned underneath the anconeus is not more aggressive and damaging compared to the classic technique. The surgery can be performed, as described above, with a single or double skin incision. In the latter scenario, a small incision on the lateral epicondyle gives direct access to the axial pin and provides for the removal of the axial pin and connecting arm. When a single incision is preferred, a wider window is clearly needed. However, the anconeus is raised from its ulnar insertion as little as possible to gain access to the base plate and distal locking screw (Fig. 7).

At the time of device removal, the anconeus appeared to be of good quality and vitality in each patient analyzed. Several anatomic studies indicate that the anconeus muscle can be detached distally and reflected eventually in continuity with the lateral triceps muscle without injuring its vascular and nerve supply.[1,6,31] The muscle is supplied by three arterial pedicles: the recurrent posterior interosseous artery, the medial collateral artery, and the posterior branch of the radial collateral artery.[13] Even though the vascular supply from the distal recurrent posterior interosseus artery is interrupted by the surgical approach, the tissue quality seems not to have considerably changed (Figs. 10 and 11). This likely happens since this artery consistently anastomoses to the medial collateral artery, as described by Schmidt et al.[26] The neurological supply coming from a branch of radial nerve emitted in the humeral spiral groove between the lateral and medial heads and descending distally is not interfered by the surgical approach (Fig. 14).

The implant prominence and the following complaints can be reduced by positioning the device underneath the anconeus muscle rather than above it. Taking care to conduct an accurate and sensible muscle dissection, the anconeus can be effortlessly reattached covering completely the internal hardware (Fig. 4 *a* and *b*). In this way, the hardware may be more comfortable, and symptoms related to skin friction may be reduced accordingly. The different relationship of the device with the anconeus could promote a closer position of the hardware to the bone surfaces. As a matter of fact, this does not happen in our opinion, as suggested by the lack of any impingement or other complications. In addition, ROM and, in specific, the pronation-supination arc do not seem hindered by the internal device, as argued by Sheth et al to explain their decreased pronation arc.[27]

In the setting of the device removal, a new and complete anconeus dissection is not required since the connecting arm can be pulled out from a small window performed over the lateral condyle. The other complications observed (heterotopic ossification, ulnar neuropathy, and seroma) are not directly a consequence of the internal device and its anatomical rapport with the anconeus as well.

The results assumed from the present study must be considered after the description of some limitations. Firstly, this is a prospective single-arm study without a control group and with a small cohort of patients analyzed. As observed in other reports, the rarity of elbow instability requiring an adjunct stabilizer makes the planning of larger and more controlled studies difficult. Then, the limited follow-up of the patients analyzed does not allow an accurate assessment of complications that may develop later such as arthrosis and neuropathy. The device tolerability that is the main aim to be addressed with this approach has been however adequately analyzed. In addition, the heterogeneity of the types of injuries analyzed, whether acute or chronic, may skew the final assumptions. Further research will be needed to compare the new technique with the conventional approach.

Conclusion

The IJS represents an effective and reliable option as a temporary stabilization for residual elbow instability. When performing a lateral approach with an anconeus flap, the internal device can be completely covered by the muscle belly at the end of the procedure. The preliminary results show an excellent tolerance and patients' satisfaction without any local discomfort or symptomatic hardware. The overall clinical outcomes, in terms of ROM and functional scores, and complication rates are similar to those achieved with the classic technique suggesting this surgical approach as an option to address the potential symptoms and complaints of subcutaneous hardware.

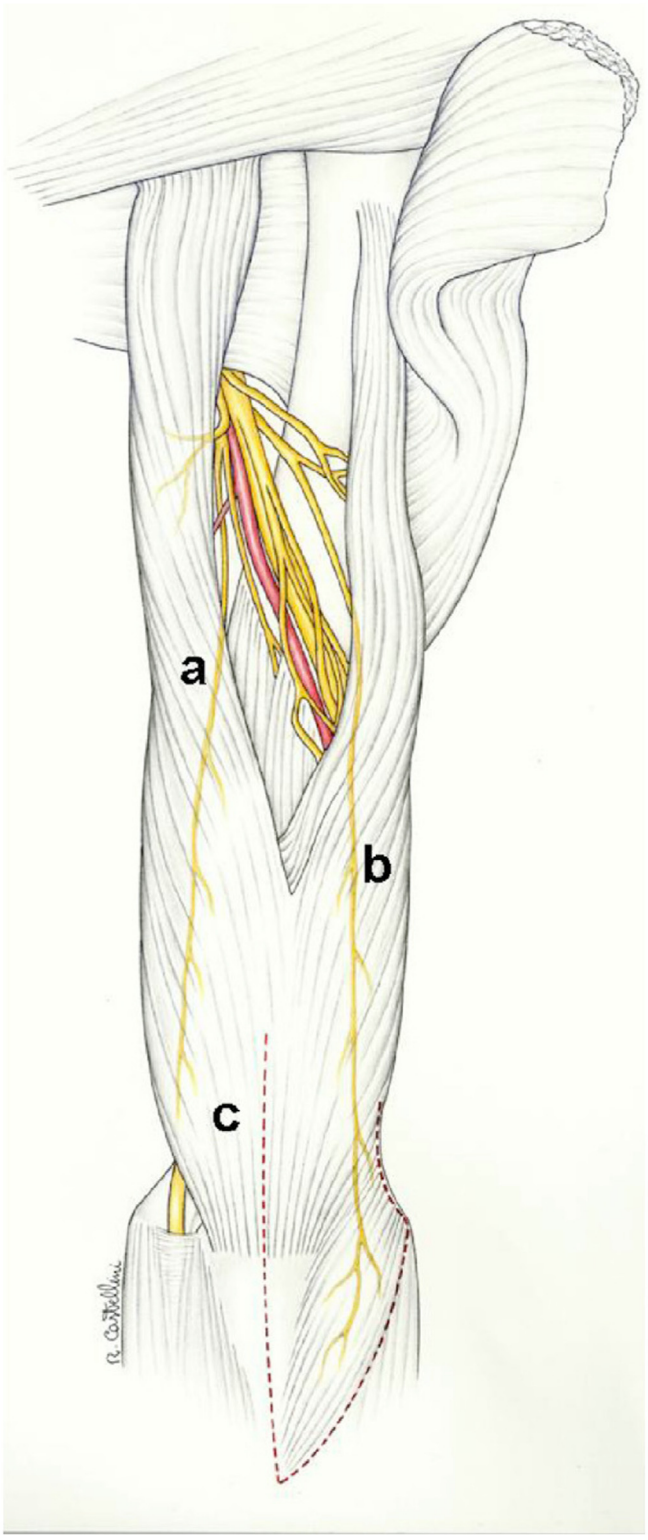

Figure 14 Anconeus innervation. (*a*) Ulnar collateral nerve of Krause; (*b*) the radial nerve emits a branch that descends distal to the lateral portion of the medial head, innervating several muscle branches before reaching the anconeus muscle; (*c*) the dashed lines depict the anconeus–lateral triceps flap approach (redrawn and modified from Cosentino[3,6]).

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