The management of residual elbow instability is challenging in both acute and chronic injuries. Among the available devices, the hinged external fixator provides an additional joint stabilization while allowing an early motion, but it is clumsy and associated to high rate of pin track complications. To address these issues, an internal joint stabilizer (IJS) has been recently developed. An easier recreation of the axis of rotation coupled to the reduced lever arm of the hinge is the root of the consistent and satisfactory results thus far observed. In addition, the device is more comfortable for the patients being an internal stabilizer. Nonetheless, a second surgery for the device removal is necessary, of which the timing is still not standardized. This current concepts paper describes literature regarding outcomes of the IJS focusing on the rate of maintained radiographic joint reduction, the resultant range of motion, and the associated complication profile.

Current concepts

- With a shorter-lever arm and an easier recreation of the axis of rotation, the internal joint stabiliser (IJS) overcomes the severe and consistent biomechanical drawbacks and following complications of a hinged external fixation.
- Even though as an internal device, it can be prominent, and a second removal surgery is required; the IJS is generally less cumbersome than an external frame.
- The rate of recurrent instability of 4.7% is almost comparable to that of transarticular fixation but remarkably lower than the hinged external fixators.

Future perspectives

- A good-quality randomised controlled trial comparing the IJS to the existing alternatives would provide a better understanding of the benefit and drawbacks of this relatively new device.
- Future studies are advocated to evaluate the most appropriate indication and minimize recurrent instability and complications.
- The proper timing for the device removal should be standardized to reduce potential and avoidable complications.
INTRODUCTION

The elbow is a joint with a high inherent stability assured by congruent articular surfaces and strong collateral ligaments. Nonetheless, the elbow is particularly prone to the instability due to the small joint surfaces, the short working length of stabilizing structures, and long moment arms, to which it is subjected [1]. After acute fracture-dislocations or in the setting of reconstructive surgery of chronic injuries, residual joint instability can be revealed. Despite fixation of osseous and soft-tissue constraints, concentric reduction may not be maintained within a reasonable range of motion, preventing an early motion recovery.

As a consequence, a prolonged immobilization with splints or orthosis is usually considered to achieve secondary stability. In more severe scenarios, static reduction needs additional stabilization with surgical procedures such as transarticular pins, bridging plates, or static external fixators [2–5]. In this way, the joint stability is pursued at the expense of motion leading to a progressive stiffness. To afford stability while allowing early motion, hinged external fixators have been used with inconsistent results [6]. Despite the successful range of motion regained, these are clumsy, and complication rates could be as high as 67%, including nerve injury, fractures, and pin-track problems (infection and mobilization) [4,6,7]. With the largest series in this regard being 100 consecutive patients undergoing hinged external fixators, Cheung et al. reported 18% of pin-site complications in the form of infection, loosening, or fracture [6]. Similar complication rates were achieved by McKee et al. reporting a pin-tract infection rate of 12.5% and broken pin rate of 6.3% after use of hinged external fixators [5,6,8]. These remarkable complications stem from intrinsic biomechanical drawbacks. Being an external frame, the long-lever arm makes the recreation of a correct axis of rotation extremely complex. In addition, a significant flexibility stemming from the distance of the hinge and the pins to the joint can magnify defects in the axis of rotation recreation [3]. As a result, recurrent instability can be found in up to 30% of cases [8,10].

To address these issues, the internal joint stabilizer (IJS) has been developed by Orbay who firstly proposed the first internal device achieved crafting intraoperatively a Steinman pin [11]. This device is intended to stabilize the joint while allowing early motion, but the lever arm is reduced making reproduction of axis of ulnohumeral rotation easier. In this way, the severe pin-site complications of hinged external fixation can be avoided. Moreover, an internal device is clearly less cumbersome and heavy for the patient. Since the Food and Drug Administration approval in 2016, different reports have been published showing consistent and successful results with IJS, which compared similarly and sometimes favourably to those achieved with a hinged external fixator [8,9,11–13].

The purpose of this study was to review and update the literature regarding outcomes of the IJS as an additional stabilizer for both acute and chronic elbow injuries. The emphasis was directed to analyze the ability of the IJS to maintain radiographic joint reduction, with the resultant range of motion and associated complication profile.

IJS-DEVICE DESCRIPTION AND SURGICAL PROCEDURE

The internal joint stabiliser

The IJS consists of a smooth axis pin placed in the axis of rotation which is connected though a connecting arm to a dorsal plate fixed to the proximal ulna with three screws (Fig. 1a and b). Placed on two orthogonal planes, two hinges on the lateral connecting arm enable a variable orientation of the axial pin to the ulnar plate accommodating anatomical variability. As the best position is defined, a proximal and a distal screw lock definitively the internal device. At this point, the concentric joint reduction is maintained, and the motion is allowed by the smooth axial pin into the distal humeral epiphysis.
Table 1
Indications of the IJS. Retrospective case series are listed focussing on indications for use of the IJS (single-case reports, reports with less than 5 patients and dealing with an internal device achieved intraoperatively crafting a Steinmann pin were excluded).

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>No. of patients</th>
<th>Age</th>
<th>Follow-up (mo)²</th>
<th>Implant removal</th>
<th>Time (mo)</th>
<th>Indication (rate %)</th>
<th>Acute cases</th>
<th>Chronic cases</th>
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<td>Terrible triad</td>
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<td>Complex trauma</td>
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<td>Monteggia fracture-dislocation</td>
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<td>Lateral condyle and capitellum fracture</td>
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<td>Elbow dislocation with</td>
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<td></td>
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<td>Radial head fracture</td>
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<td></td>
<td>Coronoid fracture</td>
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<tr>
<td>Orbay et al.</td>
<td>2017</td>
<td>26</td>
<td>57</td>
<td>6</td>
<td>n.d.</td>
<td>100%</td>
<td>12</td>
<td>1</td>
<td>2</td>
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<tr>
<td>Sochol et al.</td>
<td>2018</td>
<td>20</td>
<td>48.8</td>
<td>11.3</td>
<td>2</td>
<td>30%</td>
<td>8</td>
<td>1</td>
<td>2</td>
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<tr>
<td>Pasternack et al.</td>
<td>2020</td>
<td>10</td>
<td>50.8</td>
<td>13.4</td>
<td>2.5</td>
<td>90%</td>
<td>6</td>
<td>1</td>
<td>2</td>
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<td>Pardo-Garcia et al.</td>
<td>2021</td>
<td>5</td>
<td>37.4</td>
<td>9.8</td>
<td>3.5</td>
<td>100%</td>
<td>5</td>
<td>1</td>
<td>1</td>
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<td>Salazar et al.</td>
<td>2022</td>
<td>22</td>
<td>46</td>
<td>12.5</td>
<td>4.75</td>
<td>82%</td>
<td>8</td>
<td>1</td>
<td>2</td>
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<tr>
<td>Fene et al.</td>
<td>2022</td>
<td>17</td>
<td>41</td>
<td>9</td>
<td>4</td>
<td>100%</td>
<td>7</td>
<td>1</td>
<td>2</td>
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<tr>
<td>Sheth et al.</td>
<td>2022</td>
<td>30</td>
<td>43</td>
<td>10</td>
<td>3.5</td>
<td>17%</td>
<td>20</td>
<td>3</td>
<td>2</td>
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<tr>
<td>London et al.</td>
<td>2023</td>
<td>29</td>
<td>50.7</td>
<td>6.3</td>
<td>nd</td>
<td>86%</td>
<td>29</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>171</td>
<td>47.8</td>
<td>8.3</td>
<td>3</td>
<td>76%</td>
<td>95 (60%)</td>
<td>1 (0.6%)</td>
<td>2 (1.2%)</td>
</tr>
</tbody>
</table>

Abbreviation: IJS = internal joint stabiliser; n.e., not evaluated; n.d., not defined.

The values are reported as mean with rate within round brackets.
used. Once the isometric point on the lateral epicondyle is defined visually and with the help of a centreing guide, the correct axis of rotation is easily reached with a specific aiming guide. This aiming guide allows the connection of the isometric point to another medial point on the trochlear notch. For the most accurate axis recreation, the axis guide must engage as medial as possible 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 the access for the guide. The fluoroscopy is suggested to confirm the proper K-wire position. Then, the K-wire is measured and drilled using the 2.7-mm cannulated drill. The K-wire is thereafter removed, and the axial pin is inserted. The lateral collateral ligament can be repaired using a transosseous technique or with an anchor that is inserted usually immediately posteriorly and proximally to the axial pin [18]. The limbs of the sutures are whipstitched through the ligament but tied down only after the IJS placement is completed.

Once completed on humeral side, the proximal ulna is approached for baseplate positioning. Bone surface is cleared from overlying soft tissue, and the baseplate is temporarily positioned and fixed with the first screw placed through the oblong hole, aiming distally to the coronoid process. Application of the first screw through the centre-sliding slot makes a correction on plate position, which is 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 axial pin is tightened to the connecting rod, and only after fluoroscopic and clinical check of concentric reduction, both proximal and distal screws on connecting rod are secured. Adjusting the connecting rod and boom in this way, the device may be finally tailored to the patient-accommodating anatomic variations (Fig. 2). The full range of motion is checked to detect any potential bony impingement of the connecting arm with the lateral epicondyle (Fig. 3a and b). In that case, bone excision and flattening are warranted. The stability was again confirmed, and the excessive length of connecting bar was trimmed. Finally, stitches on the lateral collateral ligament are tied, and the skin is closed after an accurate haemostasis.

Implant removal

Being an internal stabilizer, the device is supposed to be removed with a minimally invasive second surgery. Even though the device removal was suggested by the author after a period of 6–8 weeks to avoid potential hardware breakage [8,11], current literature generally shows the safety of a delayed removal after 3–4 months from surgery (Table 1) [13,15,16,19]. Thus, a more complete tissue healing and joint stability can be achieved, but a longer period of use can increase the rate of symptomatic hardware. However, reports of safety and feasibility of the internal device maintained for longer follow-ups are increasing over time [11,20].

Outcomes

Since the first description by Orbay in 2014 [11], different studies have shown favourable and consistent results with the IJS [8,9,11–13,16,17,19,20]. To date, the IJS shows a remarkable high rate of maintained concentric reduction and functional range of motion [17].

The final functional score were usually satisfactory with the Disabilities of the Arm, Shoulder, and Hand score ranging from 14 to 30.3 and Mayo Elbow Performance Score ranging from 78 to 94 (Table 2). With a mean flexion-extension arc of 92°–134° and from 97° to full mean pronation-supination arc, the range of motion observed with the IJS is slightly higher than those achieved using either a hinged external fixation (81°–112° and 96°–151°, respectively) and trans-articular fixation (99°–102° and 142°, respectively) [2–5,15]. Sheth et al. have compared the function, Range of Motion (ROM) and complications in patients with elbow-fracture dislocations treated with (30 patients) and without (34 patients) an IJS [15]. At mean follow-up of 16 ± 17 months, there were no differences in the flexion-extension arc, complications, and functional scores between cohorts [15]. However, a mean of 15° less pronation was observed in the IJS group [15].

Recurrent instability

With eight cases of recurrent instability out of the pooled 171 cases thus far described (Table 2) [8,12–16,19–21], the rate of recurrent instability of 4.7% is almost comparable to that of transarticular fixation but is remarkably lower than the hinged external fixators [2,4,5,8,16].

Focussing on these cases, the coronoid fracture represents the main reason for the recurrent instability [8,15,16]. In a multicenter trial of 24 patients, Orbay et al. observed persistent joint instability in a patient (4%) with a coronoid fracture of 50% of height [8]. The other case was described by Pasternack et al. in a patient suffering a terrible triad injury, but the authors felt this was due to coronoid insufficiency [16]. The third was a patient with a terrible triad including an O’Driscoll anteromedial type-2 coronoid fracture [15]. As described by Sheth et al. [15], the fixation of the comminuted coronoid fragment treated acutely with a suture lasso technique fixation failed 3 months after surgery [15]. As a conclusion drawn by these cases, IJS placement may not be sufficient to maintain a concentric reduction in the setting of large or comminuted coronoid fractures, and an adequate fixation or coronoid reconstruction may be required.

In the case of persistently unstable joint, Sochol et al. observed that the axis pin was well fixed in the distal humerus leading to break the boom arm [12]. Despite a following surgical site infection, the patient maintained a stable joint after the revision surgery but with a limited range of motion ranging from 5° to 95° [13].
Complications

In spite of an extremely low rate of recurrent instability, the overall complication rate with LJS seems to be consistent, ranging from 21% to 65.5% [14,15,17]. As a matter of fact, 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 (Table 3) [8,14]. Moreover, the highest rates are found in series dealing merely with acute terrible triad injuries [14,16]. In their recent multicenter study on terrible triad injuries [14], London et al. achieved complications in 19 out of 29 patients (65.5%), of whom 12 required reoperation (41.3%) [14]. Similarly in the series by Pasterneck et al. [16], 40% of patients (4 out of 10 cases) with complications requiring additional surgery suffered from terrible triad injuries. Even though for a limited number of patients, the worst results and the highest complication rates seem strictly related to these severe injuries. The acute elbow injuries, and in specific the terrible triad, are remarkably challenging to treat. For the large oedema, inflammation, and blood loss, the acute injuries are more prone to develop ulnar nerve injuries or heterotopic ossification.

The issues directly related to the internal device are usually less common [6,12]. The rates of radiolucient line around axial pin and hardware failure (base plate broken or connecting rod disassembly) range from 0%–47% and 0%–23%, respectively [8,12,14–16]. Among the highest rates observed, London et al. have recently shown, in their cohort of patient with only acute terrible triad injuries, a remarkably high complication rate (24.1%, 7 out of 29) related to the device itself with a 13.8% of reoperation rate [14]. Similarly, Sheth et al. found four implants (23%, 4 out of 17 patients reviewed with radiographs) disassembled at the connecting rod and non-progressive radiolucencies of 1–2 mm in width around the axis pin in 8 patients (47%, 8 out of 17 patients reviewed with radiographs) [15]. Less frequent complications are represented by the seroma especially after the device removal and the symptomatic hardware due to its prominence in the subcutaneous layer [9,15].

**DISCUSSION**

The treatment of residual elbow instability is challenging and is associated with a high rate of complications and reoperation. The hinged external fixation provides a significant support, but the frame is clumsy and heavy, the recreation of the axis of rotation is difficult, and the high pin-related complication rate is concerning. All these issues negatively affect clinical outcomes and its surgical appeal. Conversely, the internal-joint stabilizer is easily implanted, is more comfortable for the patients, and is not affected by pin-related complications. All these benefits largely outweigh the drawbacks and can help physicians to face residual instability or protect tenuous fixation in both acute and chronic settings.

To date, different studies have shown favourable and consistent results with a lower complication rate than a dynamic external fixator [2–5, 8,15,21]. As the main goal of a joint stabilizer, the rate of recurrent instability of 0%–10.3% is remarkably lower than 3–30% of a hinged external fixator [2,4,5,8,12,17]. Even though similar to transarticular fixation [3,4], the recurrent instability rate must be observed in association with the range of motion achieved. With a mean flexion-extension arc of 92°–134° and from 97° to the full mean pronation–supination arc, the range of motion observed with the LJS is slightly higher than those achieved using either a hinged external fixator (81°–112° and 96°–151°, respectively) and trans-articular fixation (99°–102° and 142°, respectively) [2–5]. However, a study by Sheth et al. has recently observed a significant reduction of pronation in patients managed with LJS when compared to a similar group without the LJS [15]. They suggest the lateral position of the connecting arm of the device as a potential generator of scar tissue around the capsule or annular ligament, leading to the pronation impairment [15]. As a matter of fact, they further advise the greater soft-tissue injuries in the group of patients with an LJS as a remarkable factor as well [15].

The roots of these favourable results are the easier recreation of the joint axis of rotation and the short lever arm of the hinge. The connection of the isometric point on the lateral condyle with another isometric medial point in the trochlear notch is easily reproduced with the axial guide. At the same time, the LJS being an internal hinge with the humeral pin directly in the axis of rotation, the lever arm is minimised, and the flexibility is avoided.

As a relative drawback of this design, the axis pin occupies the anatomic origin of the LUCL, hindering the correct ligament repair. Thus, the repair should be placed as close as possible to the isometric point. A recent biomechanical study has showed as anterior and inferior to the axial pin is the only anchor's position not interfering with the joint motion [22]. However, most of the authors prefer a position posterior and superior to the axial pin for the anchor or the bone tunnels [18]. In this way, a wider area of the lateral condyle can be used for the ligament repair around the pin at physiological tension under the protection of the LJS. Once the internal device has been removed, the ligament can scar back to the isometric point completing the healing process. Even though considered as a device drawback, the axial pin position does not seem clinically remarkable. As a reason of this clinical observation, the ligament humeral insertion is an area rather than a point on the lateral condyle.

With this design, the internal stabilizer provides an additional joint stability which is comparable to an external fixator during a varus stress [23]. Nonetheless, complex acute fractures or fracture’s sequelae with...
Table 3

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>No. of patients</th>
<th>Implant related Surgery related</th>
<th>Radiolucent lines</th>
<th>Stiffness</th>
<th>Periincisional cellulitis</th>
<th>Stenosis</th>
<th>Ulnar Nerve Dysfunction</th>
<th>Heterotopic Ossification</th>
<th>Osteoarthrosis</th>
<th>Stiffness</th>
<th>Periincisional cellulitis</th>
<th>Radiolucent lines</th>
<th>Persistent edema</th>
<th>Periarticular cellulitis</th>
<th>Seroma</th>
<th>Nerve injury</th>
<th>Wound infection</th>
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<td>Sheth et al. 2021</td>
<td>5</td>
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<td>Salazar et al. 2022</td>
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<td>Fene et al. 2022</td>
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<td>London et al. 2023</td>
<td>29</td>
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</table>

Abbreviation: IJS = Internal Joint Stabilizer

Significant coronoid insufficiency represent a notable limit of this device, and an adequate fixation or coronoid reconstruction may be required [8, 15,16]. To address this limitation, the IJS could be applied on the medial side of the elbow to better counteract a coronoid deficiency or a strenuous coronoid fixation [24]. A recent biomechanical study has actually demonstrated comparable efficacy of a medial internal device to a traditional static lateral external fixation to maintain elbow stability in a coronoid-deficient elbow (O'Driscoll type 2–subtype III fractures) [25]. In a case report, Sheth et al. have shown the benefit of medially placed IJS in a patient with a significant comminution of anteromedial coronoid fracture [24]. At the final follow-up of 15 months, flexion-extension arc improved from 10° to 130°, with full pronation-supination and without any nerve irritability [24].

Even though an acute terrible triad represents the most frequent injury to the potential need of a supplement stabilization, residual instability can potentially arise in the setting of chronic injuries as well [9,18]. To reestablish a complete arc of motion with a congruous joint, an extensive soft-tissue release and sometimes muscle lengthening are needed with the potential risk of residual joint instability [18]. Ma et al. have achieved successful results treating persistent elbow instability in 14 patients with an IJS and a standardized protocol that comprised ulnar neurolysis, bone and ligamentous repair, and early rehabilitation [9]. After a median of 24 months from acute elbow-fracture dislocation treated either conservatively or surgically and at a minimum follow-up of 1 year, the median extension-flexion arc was 113° (75°–140°) and supination-pronation arc of 148° (70°–175°). Then, with no recurrent instability observed during and after device removal, the authors supported ligaments reattachment instead of complicated ligament reconstruction since the internal device can restore a lasting joint stability even in a subacute/chronic setting. In spite of a 50% of complication rate (7 of 14), only two complications were related to the IJS (hardware breakage and seroma formation), but no additional surgery was required.

Besides the specific elbow injury, different patients ‘features can play a significant role in the decision-making process. Compared to an external frame which deserves an adequate compliance, IJS is more suitable and simple to use for complex patients [20]. Patients suffering a cerebral insult or impaired cognitive function, those who are elderly, or abused alcohol, drugs, or tobacco are usually unwilling to perform regular pin-site care, tolerate an external frame or be regularly followed-up [20]. A completely internal stabilizer may be accordingly more easily accepted, and the complication rate can be reduced.

The overall complication rate in patients with a residual elbow instability managed with an IJS remains significant, ranging from 21% to 40%. These values are somewhat similar to the complication rates previously reported with hinged external fixation (37.5%–50%) and distal radius fractures (6%–35%) [4,6], but these data need to be carefully analysed. Most of these complications are not related to the IJS itself but to the specific elbow injuries, such as heterotopic ossification, ulnar neuropathy, joint contracture, and superficial infection [8,14]. The high rate of acute terrible triad lesions, which is the most frequent indication observed thus far, may skew the final assumptions on the complication rate [14].

Then, the complications directly related to the internal device are usually less common [5,12]. The radiolucent lines around the pin may be observed in 0%–47% of the patients [15]. These are likely the consequences of the continuous motion of the pin in the distal humerus. Despite a smooth surface, an imperfect recreation of the axis of rotation can lead to an abnormal motion and to bone lysis around the pin to achieve the needed room for a frictionless motion. The most frequent complications are reported in the International Joint Stabilizer within various bone defects [24] and the hardware failure is almost always in both hardware breakage and disassembly.
above the anconeus muscle in the subcutaneous layer can become symptomatic with some local tenderness and discomfort [15]. Even though not commonly observed [15], the hardware prominence can be more frequent in thin patients. Further studies are needed to confirm the real rate of these issues directly related to the internal device, being the highest value observed in few reports (Table 3).

However, the complications directly related to the internal device appear as minor and easily reversible with the device removal. In contrast, an external fixator has a notable 15%–38% rate of associated complications, such as pin-track problems (infection, mobilisation and breakage), iatrogenic fracture, wound complications, and nerve injury [6].

The primary drawback of the internal stabilizer is represented by the need of a secondary surgery for its removal. Even though needling of a smaller skin incision, the patients may complain about it, and they must be advised on the second surgery for implant removal. This is recommended by the author at approximately 6–8 weeks after the index surgery [8,11,17], 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, most authors are showing, as evidence of a well-tolerated device, a safe delayed removal at 3–4 months from the index surgery [12,20]. At this time, a complete tissue healing and a better definition of injury’s sequela can be achieved. Thus, the second surgery for IJS removal can be exploited to perform adjunct procedures as needed, such as capsular release or heterotopic ossification excision [12,20]. Longer the the period from the index surgery to implant removal, more lasting the recovered arc of motion can be assured and soft-tissue or bone constraints be removed as well. In a recent report of Pasternack et al., four out of ten patients (40%) required additional procedures which occurred at an average of 231 days after IJS implantation [16]. Beating that these procedures were performed after device explantation (an average of 68 days after index surgery), a more delayed removal could have avoided a surgical session, providing a significant benefit for the patients [16].

As a matter of fact, the device removal can be even indefinitely delayed in selected patients without symptomatic hardware or radiographic complications, as argued by Sochol et al. [12]. Similarly, reports on patients lost to the follow-up suggest that the internal device may be well tolerated for a long period [12]. This situation can be experienced with complex patients as those with psychological disease or merely not willing to respect the follow-up schedule, or lost to the follow-up with potential and irreversible complications. However, the impact and consequences of IJS in long-term follow-ups is currently unknown. For this reason, a planned device removal remains usually preferred since a device breakage of failure can likely happen over time, unless the centre of rotation is perfectly identified.

The results assumed from the present review must be considered after description of some limitations. Primarily, the quality of the review is minimally less cumbersome than an external frame. In addition, the use of a secondary surgery for implant removal with following consequences must be better clarified.

CONCLUSION

The IJS represents an effective and reliable option as a temporary stabilizer for the treatment of residual elbow instability in both acute and chronic settings. Allowing an early joint motion while maintaining a concentric reduction, the internal device protects bone and soft-tissue healing after complex reconstruction and avoids concerning complications associated to the hinged external fixators. Even though an internal device can be prominent and provide some aesthetic discomfort, the IJS is generally less cumbersome than an external frame. In addition, the use of an IJS is not associated to a significant complication rate directly related to the device. However, future studies are advocated to evaluate other potential indication and to standardize device management, minimizing complications or adverse events. The timing of device removal with following consequences must be better clarified.

References

A. De Crescenzo et al.  


