Original article

Comparative study on the treatment of Rockwood type III acute acromioclavicular dislocation: Clinical results from the TightRope® technique vs. K-wire fixation

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A B S T R A C T

Background and hypothesis: The aim of this study was to address the inconsistency regarding the operative treatment of Rockwood type III acromioclavicular joint separation. We compared results after single- and double TightRope® reduction with results after acromioclavicular transfixation via K-wires only and additional ligament augmentation in acute acromioclavicular (AC) joint separations graded Rockwood type III, and hypothesized that the TightRope® technique leads to better clinical and radiological results.

Materials and methods: We conducted a retrospective clinical cohort study and included 42 consecutive patients (mean age 43 years [24–66]) diagnosed and operatively treated between 2004 and 2012 (mean follow-up was 54.6 months [15–118]). Specific shoulder scores as well as scores reflecting the patients’ overall mental and physical health status were used. Radiological evaluation was also performed.

Results: The SF12 test revealed comparability between all subgroups. Specific shoulder tests and a visual analogue scale demonstrated comparable results. Radiographic measurements showed a significant reduction in the AC distance and CC distance after surgery in all subgroups. The early complication rate was 9.5% for all patients, while late complications occurred in 14.3% of all cases.

Conclusions: Compared to the established methods, the operative TightRope® procedures represent a safe alternative in Rockwood III injuries. All investigated techniques predominantly led to good and excellent clinical results in acute Rockwood type III AC joint instabilities. Avoidance of material removal and shorter hospital stays appear to speak in favour for the TightRope® technique.

Level of evidence: IV.

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1. Introduction

Acute acromioclavicular joint separations (AC separation) are commonly diagnosed in young adults. Although the incidence ranges around 3–4/100,000, acromioclavicular separation accounts for 12% of all clinically relevant shoulder injuries [1,2]. Furthermore, 50% of all shoulder injuries in male athletes affect the acromioclavicular joint [3–5]. Treatment is commonly guided by Rockwood’s classification [6]. According to current recommendations, non-operative treatment is advised in Rockwood type I and II graded lesions, while type IV–VI injuries are treated operatively. For type III injuries, some authors advocate conservative treatment, while others have published good clinical results after operative procedures [7–11]. Literature reviews reveal a lack of reliable data in this field [12–15]. In a nationwide survey in 2014, 73% of the contacted surgeons preferred surgical treatment of Rockwood III injuries [16]. The hook plate is currently used by 44% of all surgeons, i.e. the “standard therapy”, while 27% prefer the arthroscopic TightRope® technique. It was previously proved that its usage is cost effective [17]. However, clinical results comparing the different devices are rare [18–20].

We hypothesize that usage of the TightRope® device leads to better clinical and radiological results and also offers benefits such as shorter operation time and in-hospital stay. We therefore compared the clinical and radiological data after TightRope® (TR) reduction with the results after acromioclavicular joint transfixation using K-wires (KW) in acute acromioclavicular (AC) joint separations graded Rockwood type III. A subgroup analysis was...
also performed to compare the single versus double TightRope® technique as well as transfixation using K-wires only (KW) and additional ligament transfer (KW-L).

2. Material and methods

We performed a retrospective clinical cohort study (level III) to reassess patients that were diagnosed and treated at our institution between January 2004 and December 2013. Following approval by the local ethics committee, all patients gave written informed consent. All investigations were therefore performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. All demographic data and injury mechanisms were drawn from the hospital’s electronic database.

Inclusion criteria:

• isolated acute Rockwood III injury (trauma ≤ 2 weeks);
• no previous acromioclavicular injury;
• operative treatment using the TightRope® system (Arthrex, Naples, USA), K-wire fixation only or K-wire fixation in addition to ligament augmentation;
• time of follow-up examination ≥ 12 months after operation;
• age ≥ 18 years.

Exclusion criteria:

• contraindication for surgery (e.g. acute infection, massive swelling);
• neurological diseases that affect shoulder function;
• diseases that preclude accurate clinical outcome evaluation (e.g. musculoskeletal disorders, psychiatric or metabolic disorders).

The decision regarding the operative procedure was made by the operating surgeon after educating the patient about the risks and benefits of the surgical techniques. Patients provided their written informed consent before undergoing the operation.

2.1. Clinical and radiological evaluation

Patients were scored using the American Shoulder and Elbow Surgeons Evaluation Form (ASES), the Simple Shoulder Test (SST) and the University of California Los Angeles (UCLA) shoulder score. All patients answered the Visual Analogue Scale for pain (VAS). Patients also completed the SF12 form to gain information about health outcomes in general and in specific populations. The SF12 form is a shorter version of the popular generic measure of outcomes, the 36-item short form health survey (SF36), which covers different dimensions of health status. The SF12 consists of a Physical Component Summary Scale Score (PCS) and a Mental Component Summary Scale Score (MCS) [21]. The Western Ontario Shoulder Instability Index (WOSI) was used to rule out shoulder instability, which would distort the results. In this way, the comparability of subgroups was ensured despite various time intervals and operative techniques.

The distance between the acromion and lateral clavicle (AC), as well as that between the coracoid process and clavicle (CC) was measured on the day of admission based on true anteroposterior views of the affected shoulder [22,23]. The AC distance was measured between the centre of the medial aspect of the acromion and the centre of the lateral aspect of the clavicle. The CC distance was measured between the coracoid and inferior cortex of the clavicle (Fig. 1). Measurements from both groups were compared. Further X-rays were obtained within the first postoperative week as well as during the last follow-up (anteroposterior view) and results were compared with the distances on the patient’s healthy side when radiographs were available.

2.2. Statistic

Statistical analysis was carried out using SAS (version 9.2, TS Level 2M3, SAS Institute Inc., Cary, NC) and SPSS (version 21.0.0.0); the Kolmogorov–Smirnov test was used on all data to test for a normal distribution. Metric data were compared using Student’s t-test, the Wilcoxon test and the Kruskal–Wallis test. The mean, standard deviation (±SD) and range (min–max) are reported. Statistical significance was defined as \( P < 0.05 \). Post-hoc power analysis (G*Power 3.1.5; \( d = 0.8; \alpha = 0.05 \)) revealed a Power of > 0.5 (KW) resp. > 0.8 (KW-L; STR; DTR).

2.3. Surgical techniques

All patients were positioned in the beach-chair position under general anaesthesia. Fluoroscopy was used:

• the TightRope® is a device that consists of two buttons (clavicular and coracoid) that are joined by a continuous loop of No. 5 FiberWire®. Drill holes are applied transclavicular and transcoracoidal using a 2.0 mm K-wire. Afterwards, the K-wire is overdrilled using a 4.0 mm cannulated drill. Next, a Nitiol suture passing wire is inserted into the subcoracoid space, passing the cannulated drill. The Nitiol suture is retrieved to an anterior approach and loaded with the TightRope® device from the cranial approach. By pulling back the Nitiol suture caudally, the TightRope® is brought into position. The coracoid button flips beneath the coracoid process. A reduction manoeuvre is then performed and the device is held in position by knotting the clavicular button (single TightRope® [STR]) [24,25]. Anatomical reconstruction of both coracoclavicular ligaments (CC) was performed following the ligament insertions using two drill holes (2.5 and 4.5 cm medial of the lateral clavicle edge) and two tightropes (double TightRope® technique [DTR]) as described (Fig. 2) [26]. The procedures were performed via a mini-open technique;
• K-wires (strength 1.6 mm) were brought in from the lateral aspect of the acromion, aiming cranially at the centre of the lateral
clavicle (KW). Before passing the acromioclavicular joint, the clavicle was brought into position and K-wires were drilled in (Fig. 3). Augmented sutures or sutures of ruptured ligaments were performed following the technique described by Weaver and Dunn (KW-L) [27].

All patients followed a standardized postoperative treatment regimen [24].

2.4. Postoperative course

Postoperatively, the arm was placed in a sling for a minimum of 4 weeks. Passive mobilization and pendulum exercises were allowed on postoperative day 1. Active abduction and flexion up to 30–40° was started 14 days after the operation. K-wires were removed about 6 weeks after the initial surgery. By this time, the patient was allowed to do active flexion and abduction up to 70° and 90°, respectively. By the 7th week after the initial surgery, the range of active movement was extended. Muscle strengthening exercises were delayed until the 12th week.

3. Results

Out of 278 patients, 99 underwent surgery. A total of 72 patients fulfilled the inclusion criteria and were contacted. The participation rate was 68.1% (n = 49). Questionnaires were completed by 58.3% (n = 42). Mean postoperative follow-up was 54.6 months (15–118); the KW-L/KW mean follow-up was 84.9 months (26–118) and the STR/DTR follow-up was 31.4 months (15–68), representing the change in operative treatment strategies over the last decade.

Most patients were injured by bicycle accidents (35.7%), followed by unspecified falls (26.2%) and accidents in sports such as soccer, skiing, American football, running or combat sports, accounting for 26.1% of the overall population (Table 1).

The SF12 scoring revealed that the mental (P = 0.08) and physical status (P = 0.84) of all investigated subgroups were similar to normal values from health surveys in Germany and the United States of America. The various time intervals with regard to operative treatment therefore did not bias results in further subgroup analysis. Also, the WOSI results did not differ significantly between subgroups (P = 0.62). Therefore, concomitant shoulder instability that would distort the results could be ruled out (Table 2).

Clinical scoring revealed similar results in the ASES, SST and UCLA assessments for all subgroups. There were no significant differences in experience of pain, although there were small differences between groups (Table 2).

The radiological evaluations showed a significant reduction in acromioclavicular dislocation. Compared to the healthy side, the AC and CC distances were no longer significantly larger (Table 3). At the last follow-up, the AC distance and CC distance showed no significant increase compared to the healthy side.

Acute complications such as material loosening (KW-L: n = 2; STR: n = 1) and impaired wound healing (DTR: n = 1) accounted for 9.5% of all cases while late complications such as frozen shoulder (KW: n = 1), arthritis (KW: n = 1; DTR: n = 1) or recurrent dislocation (KW-L: n = 1; KW: n = 1; DTR: n = 1) were observed in 14.3% of all cases. There were no severe complications such as nerve damage, or fracture of the clavicle or coracoid process.

4. Discussion

Inconsistencies in the correct treatment of acromioclavicular joint separation have a long history. While previous literature reviews have recommended conservative procedures for patients with Rockwood type III (R III) injuries, recent publications showing better outcomes after surgical treatment of RIII injuries have rekindled the discussion about the best treatment option [8,12,28,29]. In 2014, Kosten et al. found that physically active young adults in particular seem to have a slight advantage in outcome when treated operatively [30]. Guo and Xiao agreed with this finding but recommended more research to provide evidence for the best treatment in patients with RII AC dislocations [31]. The need to remedy these shortcomings is obvious. Pallis et al. reported an average of 18.4 days lost per athlete due to acromioclavicular injury. The average time lost to injury for low-grade sprains was 10.4 days compared with high-grade injuries at 63.7 days. Furthermore, 71% of all patients from the study population chose to undergo CC/AC ligament reconstruction [32]. Concerning the relevance of acromioclavicular joint separations in the athletic population, it is hardly surprising that multiple operative techniques have been published over the years. Given the fact that most surgeons (73% in 2014) tend to operate on acromioclavicular injury graded R III, the question of which is the best operative technique has been raised [16].
Surgical treatment of acromioclavicular joint injuries has dramatically changed in the last decade. Whereas the use of the formerly popular K-wire techniques has decreased (37% in 2001 to 6% in 2014), the TightRope® system now seems to be being used more frequently (27% in 2014), despite the fact that long-term results are sparse [16,25,33–36]. Kirschner wires were introduced in 1909 and their use in acromioclavicular joint dislocation has led to acceptable clinical results over the decades [10,37–39]. In 1972, Weaver and Dunn described an operative technique for the treatment of acromioclavicular injuries, especially complete acromioclavicular separations [27]. Modifications have been described since then, and good results have been achieved for acute as well as chronic acromioclavicular dislocations [40–42]. The TR technique also represents a promising method for stabilizing acute acromioclavicular joint separation [25,33,34,43]. The early results are encouraging, not only in the higher grades of AC dislocations (AIV–V) but also in IIII dislocations [44]. While biomechanical studies have indicated that TR systems are superior to established operative methods in the treatment of AC dislocations, clinical studies are rare [17,18,45–47]. Contrary to our assumption that better clinical results would lead to the replacement of K-wire techniques, we found that both clinical and radiological findings within the TR groups were at least equal to the results found in the KW groups. No significant differences were found between patients treated with K-wires alone, an additional Weaver–Dunn procedure, single TightRope® or double TightRope®. We therefore confirmed the findings of Vrgoc et al., who recently published good results comparing TightRopes® and K-wire transfixation in Rockwood III and IV dislocations [48]. However, these authors were reporting on different types of dislocation and relatively small subgroups (n = 2). Furthermore, K-wires were combined with additional FiberTapes®. This modification might have influenced the results [48].

### Table 1
Demographics.

<table>
<thead>
<tr>
<th></th>
<th>KW</th>
<th>KW-L</th>
<th>STR</th>
<th>DTR</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>6</td>
<td>11</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>Male (n)</td>
<td>5</td>
<td>10</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>Age (years)</td>
<td>38 ± 7</td>
<td>39 ± 13</td>
<td>37 ± 12</td>
<td>37 ± 14</td>
</tr>
<tr>
<td>Operation time (min)</td>
<td>95 ± 41.8</td>
<td>73.5 ± 28.5</td>
<td>57.33 ± 12.9</td>
<td>92.8 ± 35.8</td>
</tr>
<tr>
<td>Hospital stay (days)</td>
<td>3.5 ± 1.4</td>
<td>5.7 ± 5.3</td>
<td>2.9 ± 3.5</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

KW: K-wires; KW-L: K-wires additional ligament transfer; STR: single TightRope® technique; DTR: double TightRope® technique.

### Table 2
Shoulder scores.

<table>
<thead>
<tr>
<th></th>
<th>KW-L</th>
<th>KW</th>
<th>STR</th>
<th>DTR</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASES</td>
<td>88.2 ± 19.7</td>
<td>88.3 ± 14.2</td>
<td>96.8 ± 15.4</td>
<td>84.2 ± 23.1</td>
<td>0.70</td>
</tr>
<tr>
<td>SST</td>
<td>87.1 ± 30.9</td>
<td>84.5 ± 22</td>
<td>97.2 ± 7.4</td>
<td>87.8 ± 26</td>
<td>0.25</td>
</tr>
<tr>
<td>UCLA</td>
<td>30.8 ± 6.3</td>
<td>28.3 ± 4.8</td>
<td>30.7 ± 6.5</td>
<td>28.7 ± 9.1</td>
<td>0.6</td>
</tr>
<tr>
<td>WOSI</td>
<td>41.2 ± 26.7</td>
<td>62.2 ± 38.6</td>
<td>50.25 ± 37.2</td>
<td>57.7 ± 46.5</td>
<td>0.62</td>
</tr>
<tr>
<td>VAS</td>
<td>43.91 ± 10.09</td>
<td>48.33 ± 2.36</td>
<td>44.58 ± 9.46</td>
<td>42.69 ± 11.37</td>
<td>0.76</td>
</tr>
</tbody>
</table>

KW-L: K-wires additional ligament transfer; KW: K-wires; STR: single TightRope® technique; DTR: double TightRope® technique; ASES: American Shoulder and Elbow Surgeons Evaluation Form; SST: Simple Shoulder Test; UCLA: University of California Los Angeles shoulder score; WOSI: Western Ontario Shoulder Instability Index; VAS: Visual Analogue Scale for pain.

### Table 3
Radiographic results: AC and CC distances (mm) pre- and post-surgery (SD), compared to healthy side and at last follow-up (f/u).

<table>
<thead>
<tr>
<th></th>
<th>Pre-surgery</th>
<th>Post-surgery</th>
<th>Healthy side</th>
<th>Last f/u</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACD (mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KW-L</td>
<td>14.24 ± 4.23</td>
<td>3.33 ± 2.65</td>
<td>2.93 ± 0.69</td>
<td>4.88 ± 3.67</td>
</tr>
<tr>
<td>P-value</td>
<td>&lt;0.001</td>
<td>n.s.</td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td>KW</td>
<td>12.43 ± 2.81</td>
<td>4.90 ± 4.04</td>
<td>3.10 ± 1.41</td>
<td>4.33 ± 2.64</td>
</tr>
<tr>
<td>P-value</td>
<td>0.015</td>
<td>n.s.</td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td>STR</td>
<td>13.17 ± 4.41</td>
<td>4.73 ± 3.07</td>
<td>2.48 ± 1.41</td>
<td>6.55 ± 7.99</td>
</tr>
<tr>
<td>P-value</td>
<td>&lt;0.001</td>
<td>n.s.</td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td>DTR</td>
<td>14.89 ± 4.14</td>
<td>5.81 ± 3.14</td>
<td>3.34 ± 1.05</td>
<td>7.44 ± 7.73</td>
</tr>
<tr>
<td>P-value</td>
<td>&lt;0.001</td>
<td>n.s.</td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td>CCD (mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KW-L</td>
<td>19.81 ± 3.93</td>
<td>9.75 ± 2.83</td>
<td>10.68 ± 0.99</td>
<td>10.62 ± 2.74</td>
</tr>
<tr>
<td>P-value</td>
<td>&lt;0.001</td>
<td>n.s.</td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td>KW</td>
<td>19.12 ± 6.08</td>
<td>13.15 ± 5.82</td>
<td>13.90 ± 0.99</td>
<td>12.68 ± 3.51</td>
</tr>
<tr>
<td>P-value</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td>STR</td>
<td>16.73 ± 5.09</td>
<td>10.22 ± 2.18</td>
<td>8.80 ± 1.73</td>
<td>11.33 ± 2.83</td>
</tr>
<tr>
<td>P-value</td>
<td>0.003</td>
<td>n.s.</td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td>DTR</td>
<td>20.81 ± 6.8</td>
<td>7.55 ± 3.39</td>
<td>10.44 ± 2.03</td>
<td>9.84 ± 2.26</td>
</tr>
<tr>
<td>P-value</td>
<td>&lt;0.001</td>
<td>0.007</td>
<td>n.s.</td>
<td></td>
</tr>
</tbody>
</table>

ACD: acromioclavicular distance; CCD: coracoclavicular distance; KW: K-wires; KW-L: K-wires additional ligament transfer; STR: single TightRope® technique; DTR: double TightRope® technique; n.s.: not significant.
Nevertheless, when compared to established operative treatment options, the TightRope® technique reveals equally good results. Darabos et al. compared the technique with results after application of the Bosworth screw and found similar radiological and clinical efficacy in the treatment of acute Rockwood type III AC dislocations [20]. When comparing TightRope® to GraftRope and the reconstruction of CC ligaments, Vascellari et al. also found good results using these techniques [49]. However, none of the studied techniques demonstrated reliability in maintaining anatomical reduction after surgery [49]. Jensen et al. and Adreani et al. compared the TR system to the clavicular hook plate, as most surgeons tend to use this device for the treatment of acute acromioclavicular joint dislocation [16]. Although they did not solely focus on R III injuries, it was shown that both techniques led to mostly good and excellent clinical results [19,50]. In a recent meta-analysis, Arirachakaran et al. conclude that the short-term outcomes in acute high-grade acromioclavicular joint injuries displayed higher postoperative functional scores after treatment with loop suspensory fixation such as the TR system when compared to hook plate fixation [51]. Yet, statistically significant differences in regard to postoperative pain and complications were not found between the groups. The authors urged on further research with increased sample sizes, mid-term or long-term follow-up periods and prospective randomized, controlled trials to determine as to what extend loop suspensory fixation is superior to hook plate fixation or not [51].

4.1. Single TightRope® or Double TightRope®

Despite the above-mentioned data, there is ongoing discussion about whether the single (STR) or double (DTR) technique is preferable. While surgeons consider anatomic reconstruction to be best, drilling towards the ligament insertion could interfere with ligament healing [52]. Patzer et al. described shorter CC distances in the DTR group compared to the STR group. However, there were no significant differences in the CC distance and scores [53]. We confirmed these findings, with no significant differences in either CC or AC distances. Furthermore, the clinical outcomes were similar. In contrast to Patzer et al., our findings are limited to R III injuries and different results might be found when comparing higher grades of injury. The slight increase in ACD and CCD seen on last follow-up was described previously by Gerhardt et al. [35]. The authors found that partial horizontal instability and migrating flip buttons were responsible. However, good clinical results were reported.

4.2. Length of operation and hospital stay

With regard to duration of operation and in-hospital stay, advantages were apparent for the TR groups. However, it should be taken into account that transfixation by K-wires was typically done by surgical interns as part of their training. The operation time would likely be shorter if K-wires were inserted by experienced surgeons. Financial benefits have previously been demonstrated with regard to the shorter operation time, lower physician costs, total operation and theatre costs, but material costs were significantly higher for the TR device [17]. However, earlier discharge from hospital as seen in the TR groups is not merely related to the techniques, but rather a common trend towards shorter hospital stays in recent years [54].

4.3. Complications

Complication rates were comparable to those shown by other authors [55]. Thiel et al. reported on two cases in which reduction failed and one case with a loss of reduction using the TR system in a cohort of 12 patients [56]. Likewise Motta et al. reported a loss of reduction in four cases out of 20. The authors stated that using flip buttons might not be indicated in patients with joint hyperlaxity because they are able to obtain immediate stability only in the vertical plane and not in the horizontal plane. Antero-posterior movements of the acromioclavicular joint might rub the FiberWire® against the bone tunnels, leading to wear and cutting [57]. As for the use of KW, Leidel et al. described K-wire migration in 4% (n = 3) and secondary dislocation of the AC joint in 11% (n = 8) after wire removal. Infection was observed in none of the 70 patients operatively treated for R III injury [10]. When comparing the complication rates of different surgical techniques in patients graded R III, Li et al. found no significant differences between groups [58]. In a meta-analysis comparing loop suspensory fixation and hook plate devices, authors reported on occurrence of wound problems, loss of reduction, implant migration and osteolysis within the loop suspensory fixation group as well as in the hook plate group [51]. However, the risk of having complications between the two groups was similar and a pooled relative risk of 0.62 (95% CI: 0.30, 1.32), without statistical significance between the investigated groups, was reported [51].

4.4. Strengths and limitations

A weakness of this study is its retrospective design and the loss of follow-up. Furthermore, one can assume that the divergent observation periods between KW/KW-L and TR may have influenced the outcome. However, using the SF12 as a valuable non-shoulder-specific health assessment tool helped to demonstrate the comparability of the investigated subgroups. Another strong point is the application of different shoulder scores that were used in other publications describing acromioclavicular joint dislocations, rather than using just one score, although specific tests for the acromioclavicular joint such as the acromioclavicular joint instability score (ACJI) and Taft score were not used [9,10,19,44,56,59].

5. Advances in knowledge

This is the first study comparing the clinical results of established K-wire techniques with relatively new TightRope® systems as a treatment option for isolated acromioclavicular joint separation graded Rockwood type III.

6. Conclusions

The results of the present study reject the hypothesis that TR systems are superior to the established method of K-wire fixation. However, the findings show that they are equivalent to techniques such as hook plate fixation or K-wire transfixation. Although the results of the present study do not allow promoting either one of the investigated procedures, one has to acknowledge that TR is a minimally invasive technique and there is no obligatory implant removal, which are striking advantages of this new system. Moreover, the arthroscopic use of TR techniques allows the diagnosis and therapy of concomitant glenohumeral injuries [19]. These results justify the clinical use of TR systems.

Disclosure of interest

The authors declare that they have no competing interest.

References

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