Distal radio-ulnar joint instability in children and adolescents after wrist trauma

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Distal radio-ulnar joint instability in children and adolescents after wrist trauma

J. K. Andersson¹, T. Lindau², J. Karlsson³ and J. Fridén¹

Abstract
This study retrospectively evaluated the medical records and radiographs of patients younger than aged 25 that were referred for a second opinion due to ulnar-sided wrist pain and persistent distal radio-ulnar (DRUJ) joint instability. We identified 85 patients with a major wrist trauma before the age of 18. Median age at trauma was 14 years. Median time between trauma and diagnosis of DRUJ instability was 3 years. Sixty-seven patients (79%) had sustained a fracture at the initial trauma. The two most common skeletal injuries related to the DRUJ instability were Salter–Harris type II fractures (24%) and distal radius fractures (19%). In 19 patients (22%), the secondary DRUJ instability was caused by malunion or growth arrest. Eighteen patients (21%) had no fracture; in spite of this, they presented with subsequent symptomatic DRUJ instability. Fourteen of these 18 patients had a triangular fibrocartilage complex (TFCC) tear, confirmed by arthroscopy, open surgery, or magnetic resonance imaging. In conclusion, late DRUJ instability due to wrist fractures or isolated TFCC tears was found to be common in children and adolescents.

Level of evidence: IV

Keywords
Children, adolescents, wrist trauma, distal radio-ulnar joint instability, triangular fibrocartilage complex tears

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Introduction
Children’s fractures of the distal radius, ulna, and distal forearm are commonly assumed to be simple fractures that remodel easily and the patients recover well. Consequently, these fractures are typically treated non-surgically with closed reduction and cast immobilization. However, there is increasing evidence that adult and adolescent injuries with fractures or wrist injuries diagnosed as sprains are not as simple as previously anticipated and not all of them recover well (Adolfsson and Povlsen, 2004; Bergh et al., 2012). Available data on post-traumatic symptoms in children and adolescents indicate that ulnar-sided wrist pain and DRUJ instability are under-reported in many cases (Bae and Waters, 2006; Terry and Waters, 1998).

Fractures of the distal third of the forearm are common among children and represent approximately 75% of all forearm fractures (Bailey et al., 1989; Blount, 1967). Distal radius fractures comprise 20% to 35% of all fractures in children (Cheng and Shen, 1993; Landin, 1983). The distal radial physis is involved in approximately one-third of these fractures.

The distal radial physis accounts for 75% to 80% of the growth of the radius, and rapid growth is likely to predispose the distal radius to a fracture because the distal metaphysis is weak at this point. Fractures in this area have large remodelling potential. It has been claimed that 10° of radial-ulnar deviation, 25° of dorsal-volar angulation, and 50% of translation in...
distal radial fractures may be expected to remodel with continued skeletal growth in young patients with at least 2 years of skeletal growth left (Friberg, 1979; Houshian et al., 2004; Johari and Sinha, 1999; Zimmermann et al., 2004).

There is insufficient knowledge about the kind of fractures and degree of displacement that may predict subsequent complications among children and adolescents. Salter–Harris type I and II fractures are common, while Salter–Harris type III, IV, and V fractures are rare (Figure 1). Buckle fractures and minimally displaced fractures are thought to be the result of low-energy injury, whereas displaced fractures result from high-energy injuries, such as falls from a height or accidents during sport activities. Forearm fractures occur more distally with increasing age (Bailey et al., 1989; Davis and Green, 1976; Tredwell et al., 1984). It is generally postulated that isolated ligament injuries are uncommon in children.

Several anatomic structures stabilize the distal radio-ulnar joint (DRUJ), of which the triangular fibrocartilage complex (TFCC) is the most important, especially its foveal insertion (Af Ekenstam and Hagert, 1985; Haugstvedt et al., 2006a). It is well known that associated ligament injuries, particularly TFCC injuries, are common in non-osteoporotic adults with dislocated distal radial fractures (Andersson and Axelsson, 2011; Lindau et al., 2000a). Ulnar-sided wrist pain and DRUJ joint instability are the most common sequelae following radial fractures in adults and present as an independent worsening factor (Lindau et al., 2000b).

The aims of this study were, firstly, to evaluate whether children and adolescents present with different patterns of injuries compared with adults; secondly, to identify markers of a potentially complicated injury; and thirdly, to report the number of isolated TFCC ruptures in a selected group of patients requiring further attention due to persistent pain and/or instability problems following the initial treatment of wrist trauma.

Methods

In this retrospective study, all case records and radiographic images of patients under aged 25 were evaluated and reviewed. These patients were referred for a second opinion due to ulnar-sided wrist pain and DRUJ instability to the Department of Hand Surgery, Sahlgrenska University Hospital, Gothenburg, Sweden, between 2006 and 2011. We screened all ICD-10 diagnoses including all ligament injuries to the wrist, hand, and fingers. By excluding all cases with isolated finger injuries, we were able to isolate patients with wrist trauma only. Annually, approximately 800 cases of wrist trauma among children and adolescents are evaluated at the Queen Silvia Children’s Hospital in Gothenburg. Among those, approximately 400 are skeletal injuries and 400 are wrist sprains. The catchment area is approximately 100 000 paediatric patients.

A radiological assessment was performed by the first author and compared with the previous clinical radiologists’ reports, with full agreement. All patients had sustained a significant wrist trauma with or without fracture before aged 18 and were suffering from persistent ulnar-sided wrist pain and DRUJ instability. DRUJ stability was tested with the forearm held in neutral rotation by the examiner, who stabilized the hand and distal radius with a firm grip to make them one unit (Mrkonjic et al., 2012). Then, using the other hand, the examiner forced the ulna as the second unit in a dorsal/palmar direction, relative to the stabilized unit of the hand and radius. The stability of the DRUJ was compared with that of the uninjured, opposite side for reference. A recording was made of whether the DRUJ was deemed lax and whether or not the test caused pain. A TFCC test, referred to as the foveal sign test (i.e., tenderness on the palmar aspect of the fovea located proximal to the pisiform and ulnar to the flexor carpi ulnaris tendon), was also carried out.

Eighty-five patients fulfilled these criteria and were described in terms of the characteristics and demographics of patients and injuries; that is, type of trauma, treatment given, time to diagnosis of TFCC injury and/or DRUJ instability, and number and type of secondary operations needed to treat the DRUJ instability.

Median age at trauma was 14 [range 6.7–17.8] years. Forty-one of the 85 [48%] patients had sustained a high-energy trauma. The non-dominant side (54 cases, 64%) was more commonly injured. There were 47 girls (55%).

Figure 1. Salter–Harris classification of fractures.
Time from trauma to diagnosis of DRUJ instability ranged from immediate to 18 years (median 3 years), whereas time from trauma to diagnosis in the sub-group with an isolated TFCC injury was slightly shorter (median 2 years; range 0–14 years), compared with the entire cohort.

**Results**

Sixty-seven (79%) of the 85 children and adolescents with ulnar-sided wrist pain and DRUJ instability after wrist trauma had sustained a fracture at the time of trauma. Eighteen of the 85 patients (21%) presented with isolated DRUJ instability without any associated fracture or physeal injury at the time of trauma. Fourteen of these 18 patients were diagnosed with a TFCC injury by arthroscopy, open surgery, or magnetic resonance imaging (MRI). The remaining four patients with clinical instability were not further investigated and, as a result, the cause of instability cannot be proven, but it is likely to have been caused by a TFCC detachment in the absence of any bony cause of instability.

The most common skeletal injury with subsequent DRUJ instability was Salter–Harris type II injury (in total 20/85; 24%), frequently with initial displacement and/or concomitant ulnar styloid fracture (12 cases, 14%; Figure 2). The second most common skeletal injury was a distal radius fracture not involving the physis (in total 16/85, 19%; Figure 3). The majority of these injuries demonstrated a considerable initial displacement, together with an ulnar styloid fracture (13 cases, 15%) (Table 1). Eight distal or diaphyseal forearm fractures were observed (9%), and four of them developed malunion. The median age (11.5 years, range 6.7–16 years) was lower in the subgroup with forearm fractures compared with the entire group. Twelve cases of infraction, buckle, or greenstick fractures were observed. Five of them had an associated ulnar styloid fracture.

Four (5%) Salter–Harris type III-IV injuries were found (Figures 4 and 5). Two of these four fractures developed a growth arrest with a subsequent malunion and instability. Three (3%) Galeazzi fractures (Figure 6) were noted, two of them with the radius fracture in the distal third (so-called type I Galeazzi fracture).

Overall, 17 of the 85 (20%) patients had an initial displacement of more than 20°. Associated ulnar styloid fractures were found in 37 cases (44%). Sixteen (19%) had a fracture at the base of the ulnar styloid and 21 (25%) had an ulnar styloid fracture at the tip. The number of concomitant TFCC-lesions in the subgroup with initial skeletal trauma appears to be high, as in total 34 secondary TFCC repairs or anatomic

**Figure 2.** Salter–Harris type II fracture with 10 mm dorsal dislocation and a separate fracture of the ulnar styloid, leading to DRUJ instability, pain, and non-union of the ulnar styloid.

DRUJ-ligament reconstructions were performed later on, in 24 of these 67 patients (Figure 7).

Nineteen patients (22%) suffered from subsequent growth arrest or significant malunion related to and causing the DRUJ instability (Figures 3 and 5).

Median age was 15 (range 7.0–17.6) years in the subgroup with DRUJ instability without fracture (i.e., isolated TFCC injury), which was not significantly higher compared with the entire group.

**Initial treatment**

The complexity of these patients and injuries in terms of initial treatment and secondary surgical procedures is shown in Table 2 and Figure 7. Only two of the 20 patients with Salter–Harris type II fracture had primary K-wire fixation or re-reduction, but 16 underwent a secondary operation. All 12 patients with infraction, buckle, or greenstick fractures were initially treated with a cast, but nine of them required a
subsequent operation. Five of eight (60%) patients with forearm fractures required secondary surgery. All three Galeazzi fractures were apparently initially treated with cast only or reposition and cast; none were treated with internal fixation. Four of the 18 patients without any fracture or physeal injury, but with subsequently diagnosed isolated TFCC injury/DRUJ instability, were initially treated with a cast.

Secondary reconstructions

In total, 65 of 85 patients underwent 105 corrective secondary reconstructive procedures due to DRUJ instability (average 1.3, SD 1.0, range 0–5 operations/patient). Two patients had a total of five operations.

Twelve of the 85 patients had up to three different surgical procedures at the same time. Ten additional patients with painful DRUJ instability have declined further reconstructive procedures.

In the presence of malunion, corrective radius osteotomies ($n = 7$) or ulnar shortening osteotomies ($n = 10$) were performed, depending on the preoperative measurements of the malunions.

In the subgroup of 18 patients with DRUJ instability without fracture, we noted 19 secondary operations (average 1.1, SD 1.0, range 0–3 operations/patient). Seven TFCC repairs were performed in this subgroup; none of them needed reoperation. We also noted a subgroup among the skeletal injuries ($n = 4$) in the present study with initial minor carpal avulsion

Table 1. Injury pattern and aggravating factors in 85 identified cases with wrist trauma and persisting DRUJ problems. The table shows all fractures, associated injuries, and secondary malunion or growth arrest. Note the high number of DRUJ instability in the absence of fractures or physeal injuries.

<table>
<thead>
<tr>
<th>Type of injury</th>
<th>Patients, n</th>
<th>Significant displacement</th>
<th>Ulnar styloid-base fracture</th>
<th>Ulnar styloid-tip fracture</th>
<th>Secondary malunion or growth arrest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salter–Harris II</td>
<td>20</td>
<td>9</td>
<td>3</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Salter–Harris III-IV</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Distal radius fracture outside the physis</td>
<td>16</td>
<td>3</td>
<td>8</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Infraction, buckle, or greenstick fracture</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Distal or diaphyseal forearm fracture</td>
<td>8</td>
<td>4</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Galeazzi fracture</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Minor carpal avulsion injury or delayed diagnosis of ulnar styloid fracture</td>
<td>4</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>No fracture or physeal injury, isolated TFCC injury/DRUJ instability</td>
<td>18</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>85</strong></td>
<td><strong>17 (20%)</strong></td>
<td><strong>16 (19%)</strong></td>
<td><strong>21 (25%)</strong></td>
<td><strong>19 (22%)</strong></td>
</tr>
</tbody>
</table>

Figure 3. Distal radial fracture at trauma (a) causing later malunion with decreased radial inclination (b), leading to incongruity of the sigmoid notch and subsequent DRUJ instability.
injuries or delayed diagnosis of ulnar styloid fracture. This subgroup needed altogether five later arthroscopic copies and two TFCC repairs.

In total, arthroscopy-assisted or open TFCC re-attachments were performed primarily in 23 patients. Some were re-operated on because of recurrent instability and others underwent DRUJ (Adams) ligament reconstructions, for example (Adams and Berger, 2002). As a result, a total of 33 TFCC re-attachments and eight Adams reconstructions were performed.

The total incidence of risk of late DRUJ instability after a single trauma in childhood is somewhat difficult to calculate in this cohort, mainly because of the uncertainty concerning the size of the catchment area, due to for instance, secondary and tertiary referrals. Although the approximate incidence number of late DRUJ instability after wrist trauma among children and adolescents in our area appears to be approximately 2%, as 85 patients were included in the present study during a 5 year period. Annually, approximately 800 cases of wrist trauma are evaluated at the Queen Silvia Children’s Hospital in Gothenburg.

Discussion

This study highlights the complexity of wrist injuries in children and adolescents. The most unexpected finding was the long-term DRUJ instability in the absence of an initial fracture. We therefore conclude that isolated TFCC tears (Table 1, Figure 8) in children and adolescents are not as rare as previously suggested (Bae and Waters, 2006; Terry and Waters, 1998). It has been biomechanically postulated that TFCC injuries are to be expected in non-osteoporotic adults when the dorsal angulation of a distal radius fracture exceeds 32° (Scheer and Adolfsson, 2011). It is therefore surprising that TFCC tears, eventually causing DRUJ instability, can occur in the absence of fractures in children, in whom we previously understood that ligament injuries are uncommon in relation to fractures in the growing bone. Furthermore, or rather because of this historical misconception, we report that the time from initial trauma to DRUJ instability diagnosis could be as long as 18 years. The need for the large number of secondary reconstructive procedures to stabilize the DRUJ found in this study is unexpected.

Our findings that the non-dominant side (n = 54) in girls (n = 47) was more commonly injured are in agreement with earlier reports (Terry and Waters, 1998).

A significant number of DRUJ problems occurred secondary to fractures, particularly Salter–Harris type II and distal radius fractures with initial displacement and/or associated ulnar styloid fracture. In the current study, 50% of the forearm fractures demonstrated late malunion, which caused the DRUJ instability. Malunion can also occur after growth arrest. In half the patients with Salter–Harris type III–IV fracture, malunion secondary to growth arrest caused DRUJ instability. It is well established that...
Galeazzi fractures in adults result in DRUJ pathology, either primarily or secondarily (Atesok et al., 2011). In fact, Galeazzi type I fractures (fractures in the distal third of the radial shaft) develop DRUJ instability in more than 50% of cases as opposed to other Galeazzi-type injuries (Korompilias et al., 2011). The fracture location can therefore be used for the pre-operative assessment of potential DRUJ instability in more than 50% of cases as opposed to other Galeazzi-type injuries (Korompilias et al., 2011). The fracture location can therefore be used for the pre-operative assessment of potential DRUJ instability in Figure 5. Salter-Harris type IV fracture at trauma (a), causing later growth arrest of the ulnar aspect of the radius and a subsequent Madelung-like deformity (b), including major DRUJ instability.

Figure 6. Galeazzi fracture at trauma (a). Note the fractured ulnar styloid at the base and diastasis of the DRUJ, suggesting a primary identifiable injury that was overlooked. After healing, the diastasis is not visible radiographically, but the DRUJ instability was found clinically at examination (b).
these cases. In our study, two of three patients had a type I fracture.

Because this study revealed a variety of causes of late DRUJ instability in children and adolescents, we suggest that patients with these injuries should undergo extensive repeated examination of the wrist, repeated radiographs, and wrist arthroscopy, as recommended in adults [Adolfsson and Poulsen, 2004; Bergh et al., 2012], if they complain of ulnar-sided wrist pain and instability after a normal rehabilitation period secondary to a fracture or after a significant sprain. Accordingly, we recommend using arthroscopy as the gold standard, not only in diagnosing TFCC injuries, but also for other associated injuries, regardless of the patient’s age [Farr et al., 2012; 2012]. We also recommend using MRI in selected patients [Bergh et al., 2012], particularly to establish possible differential diagnoses and minimize the poor long-term outcome of these injuries. MRI is still though neither sufficiently sensitive nor specific to diagnose TFCC tears (Hahn et al., 2012; Hobby et al., 2001). In order to improve MRI diagnostic power, a number of prerequisites must be met: carefully calibrating the coil; specific training and interest of the musculoskeletal radiologist; and, perhaps most importantly, continuous interaction between the clinician performing the arthroscopy and the radiologist [Anderson et al., 2008; Bergh et al., 2012; Iordache et al., 2012; Tanaka et al., 2006].

The present study demonstrates that there is a significant subgroup of patients who do not recover well. We therefore recommend that radial physeal fractures and fractures with initial displacement with or without an ulnar styloid fracture should be followed up for longer than previously recommended; in our opinion, at least 2 years. Furthermore, the early correction of malunion and growth arrest must be regarded as a priority to prevent late DRUJ instability.

![Figure 7](image.png)

**Figure 7.** Total number of secondary procedures.

<table>
<thead>
<tr>
<th>Type and number of primary treatment</th>
<th>Patients, n</th>
<th>Cast</th>
<th>Reposition and cast</th>
<th>Primary pin-fixation or delayed re-reduction</th>
<th>Primary open surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salter–Harris II</td>
<td>20</td>
<td>7</td>
<td>11</td>
<td>2 [2*]</td>
<td>1</td>
</tr>
<tr>
<td>Salter–Harris III-IV</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Distal radius fracture outside the physis</td>
<td>16</td>
<td>8</td>
<td>5</td>
<td>4 [1*]</td>
<td>0</td>
</tr>
<tr>
<td>Infraction, buckle or greenstick fracture</td>
<td>12</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Distal or diaphyseal forearm fracture</td>
<td>8</td>
<td>1</td>
<td>6</td>
<td>3 [3*]</td>
<td>0</td>
</tr>
<tr>
<td>Galeazzi fracture</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Minor carpal avulsion injury or delayed diagnosis of ulnar styloid fracture</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No fracture or physeal injury; isolated TFCC injury/DRUJ instability</td>
<td>18</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>85</strong></td>
<td><strong>36</strong></td>
<td><strong>24</strong></td>
<td><em><em>9 [6</em>]</em>*</td>
<td><strong>2</strong></td>
</tr>
</tbody>
</table>

*Among those requiring re-reduction.
The main limitation of this study is its retrospective design and lack of conformity in assessing every patient in a reproducible manner. More importantly, we have a selective cohort of patients, making it somewhat difficult to suggest data for the incidence and prevalence of these long-term problems with DRUJ instability. This is due to the fact that our cohort partly represents our own local catchment area and partly represents tertiary referrals from our regional catchment area. Another study limitation is the lack of an independent radiologist to assess the radiographs and MRIs. This is relevant, especially in terms of diagnosing the correct Salter–Harris fracture type. In addition, it is possible that there was an incomplete clinical diagnosis in the four cases with isolated TFCC injuries, which were not independently confirmed by arthroscopy, operation, or MRI.

In conclusion, this study emphasizes the increased diligence required when dealing with wrist trauma in children and adolescents, as a substantial amount of delayed presentation of DRUJ instability after wrist fracture and/or sprain in children and adolescents was found. The most striking finding in this study was that several children and adolescents presented with DRUJ instability with isolated TFCC tears, without any fractures, which was previously almost unknown in the scientific literature.

**Conflict of interests**
None declared.

**Ethical approval**
This investigation conforms with the University of Gothenburg Human Research Protection Programme guidelines. Ethically approved by the ethical review board, Gothenburg, 24 April 2013 (Dnr: 977-12).

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**References**


