Original Clinical Article

JOURNAL OF CHILDREN'S ORTHOPAEDICS

Health-related quality of life after conservatively and surgically-treated paediatric proximal humeral fractures

Thoralf R. Liebs
Ingmar Rompen
Steffen M. Berger
Kai Ziebarth

Abstract

Purpose: The health-related quality of life (HRQoL) after conservatively *versus* surgically treated paediatric proximal humeral fractures is poorly understood. We assessed the HRQoL after this injury and asked if HRQoL was associated with age, radiological classification or treatment chosen.

Methods: We identified 228 patients who were treated for proximal humeral fractures between 2004 and 2017. These patients completed the Quick Disabilities of the Arm, Shoulder and Hand (Quick-DASH) (primary outcome), the Paediatric Quality of Life Inventory (PedsQL) and questions regarding patient satisfaction. Fractures were classified radiologically following the Paediatric Comprehensive AO Classification.

Results: We were able to follow-up on 190 children; 147 (mean age 8.7 years (0.8 to 15.7)) sustained a metaphyseal and 43 (mean age 11.6 years (3.7 to 15.8)) sustained a Salter Harris type I or II injury. Most fractures (90%) were simple, 10% were multifragmentary. In total, 137 children (72%) were treated nonoperatively, 51 (27%) were treated by elastic stable intramedullary nailing (ESIN). After a median follow-up of 7.6 years (0.8 to 14.3) there was an overall mean Quick-DASH of 4.3 (SD 9.3) for girls and 1.2 (SD 3.1) for boys. The mean function score of the PedsQL was 94.7 (SD 11.1) for girls and 98.0 (SD 6.0) for boys. The mean psychosocial score of the PedsQL was 92.0 (SD 11.1) for girls and 94.1 (SD 11.6) for boys. Most children (79%) were very satisfied with the cosmetic result and 74% were very satisfied with the treatment overall. Surgery and female sex were associated with lower satisfaction.

Conclusion: In this cohort of 190 patients, where immobilization for mildly displaced fractures, and closed reduction and ESIN was used for displaced fractures, there was equally excellent mid- and long-term HRQoL when assessed by the Quick-Dash and the PedsQL.

Level of Evidence: Therapeutic, Level IV

Cite this article: Liebs TR, Rompen I, Berger SM, Ziebarth K. Health-related quality of life after conservatively and surgically-treated paediatric proximal humeral fractures. *J Child Orthop* 2021;15:204-214. DOI: 10.1302/1863-2548.15.210054

Keywords: fracture; humerus; health-related quality of life; surgery; elastic stable intramedullary nailing; conservative treatment

Department of Pediatric Orthopaedics and Traumatology, Clinic for Pediatric Surgery, Inselspital Bern University Hospital, University of Bern, Bern, Switzerland

Correspondence should be sent to: PD Dr. Thoralf R. Liebs, Inselspital Bern University Hospital, University of Bern, Department of Pediatric Orthopaedics and Traumatology, Clinic for Pediatric Surgery, Freiburgstrasse 15, 3010 Bern, Switzerland
E-mail: liebs@liebs.eu

Introduction

Fractures of the proximal humerus are common in both children and adolescents. Many of these fractures are mildly displaced and are treated nonoperatively. For severely displaced fractures, however, some paediatric orthopaedic surgeons consider reposition and internal fixation as a treatment alternative. Commonly, in such decision-making, not only factors such as angulation and displacement are considered, but also the patient's age and growth remaining from the proximal physis. Several operative techniques have been described for this injury, such as open reduction,[1] internal fixation with Kirschner (K)-wires,[1] plates,[1] screws[1] or a palm tree technique.[2] However, retrograde elastic stable intramedullary nailing (ESIN)[3-5] has evolved as a commonly accepted treatment method for displaced fractures.[6]

In a recent review[7] it was noted that there are no agreed upon criteria regarding acceptable angulation and displacement qualifying paediatric proximal humeral fractures for nonsurgical treatment. Another author[8] mentioned that the "published literature is inadequate in the stratification of proximal humerus fractures by age and displacement" and emphasized that the "long-term outcomes of patients older than 10–13 years treated operatively and non-operatively with severely displaced fractures" are still unknown.

Indeed, there are only a limited number of reports on the outcome of these patients. Canavese et al[9] reported

JOURNAL OF CHILDREN'S ORTHOPAEDICS

on 52 children who were treated by ESIN for displaced fractures. After a mean follow-up of 1.5 years that study reported good functional results as measured by the Quick Disabilities of the Arm, Shoulder and Hand (Quick-DASH). In another study, using the Quick-DASH as an outcome measure in 32 patients treated for severely displaced proximal humeral fractures, Chaus et al[10] concluded that "in a matched cohort of patients with proximal humerus physeal fractures, there was no difference in occurrence of complications, rate of return to activity, or cosmetic satisfaction". The authors further noted that "functional outcomes [...] tended to be higher among fractures that underwent nonoperative treatment. Among non-operatively treated fractures, less than desirable outcomes were more common in older patients, particularly those older than 12 years of age". Of note, the description of the surgical technique is missing in that report; the authors published radiographs in which an open reduction with pin fixation was performed.

However, in a recent meta-analysis it was noted that regarding functional outcomes there were "...statistically significant differences between the treatment methods. The best results were recorded in the group of patients treated by ESIN, followed by K-wire osteosynthesis and conservative treatment".[6]

Up to this time, there are only a limited number of studies assessing health-related quality of life (HRQoL) in children after they have sustained a proximal humeral fracture. Furthermore, most publications are based on populations in whom all patients received surgery. As such, it is unknown if the HRQoL of these patients differs by fracture severity or treatment performed or if there are any other factors associated with the mid- to long-term outcome.

Therefore, we have initiated this study to evaluate the HRQoL after both conservative and surgical treatment of proximal humeral fractures in children and adolescents.

We examined: 1) the HRQoL of patients who sustained a proximal humeral fracture during childhood or adolescence and who were treated at a large regional paediatric trauma centre; 2) if HRQoL was associated with the AO radiological fracture pattern; 3) if children who were treated conservatively were as satisfied as children who were treated surgically; and 4) if there were other factors associated with HRQoL or patient satisfaction.

Patients and methods

This is a retrospective analysis, in which patients who underwent treatment for a proximal humeral fracture were contacted by postal mail. The study protocol was approved by the local ethics committees (institutional review board of the paediatric clinics of Inselspital, University of Bern (approval number 1601 from 20 January 2016) and the Ethics Commission of the Canton of Bern (Basec-No. 2016-00011 from 03 May 2016), both in Switzerland).

Several methodological details are identical to sister studies in which the HRQoL was assessed after fractures of the supracondylar humerus and lateral third of the clavicle in children and adolescents.[11,12]

Patient population

All sequential patients with an age of up to 16 years, who sustained a proximal humeral fracture during the period between 1st January 2004 and 30th April 2017 and who were treated at our institution were candidates for inclusion in the study. Our institution is one of the leading paediatric trauma centres in Switzerland, serving more than one million inhabitants in the German-speaking part of Switzerland.

Patients were identified based on the radiological reports within our picture archiving and communication system.

For the purpose of this analysis, the inclusion criteria were limited to patients who have sustained a proximal humeral fracture. Exclusion criteria were: 1) other significant trauma requiring treatment; 2) initial treatment performed outside our institution; and 3) inability to complete the questionnaires because of cognitive or language difficulties. Please see the STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) participant flow chart in Figure 1 for further details.

Radiological analysis

Radiological analysis was performed to classify the fracture according to the AO classification scheme.[13] In that system fractures are categorized as epiphyseal (i.e. Salter-Harris 1 to 4, and fractures with an intraarticular flake) or metaphyseal (torus/buckle or complete metaphyseal). In both categories, fractures are further classified as being simple or multi-fragmentary. We did not attempt to assess the degree of retroversion of the proximal humerus.

In addition to assessing angulation and lateral displacement both before and after treatment, we have attempted to develop an approach that is more feasible to evaluate the amount of displacement, especially given the fact that radiographs are difficult to standardize in this injury. Therefore, we have introduced the concept of the 'proximal Rogers line'. The Rogers line is well known as the anterior humeral line in supracondylar fractures of the humerus, seen on lateral radiographs of the elbow. In non-injured elbows the Rogers line passes through the middle third of the capitulum of the humerus.

For the concept of the 'proximal Rogers line' we have recorded the amount of displacement of the humeral head by drawing a virtual line along the cortex of the shaft of the proximal humerus and assessing if that line passes through the humeral head. If that is the case in

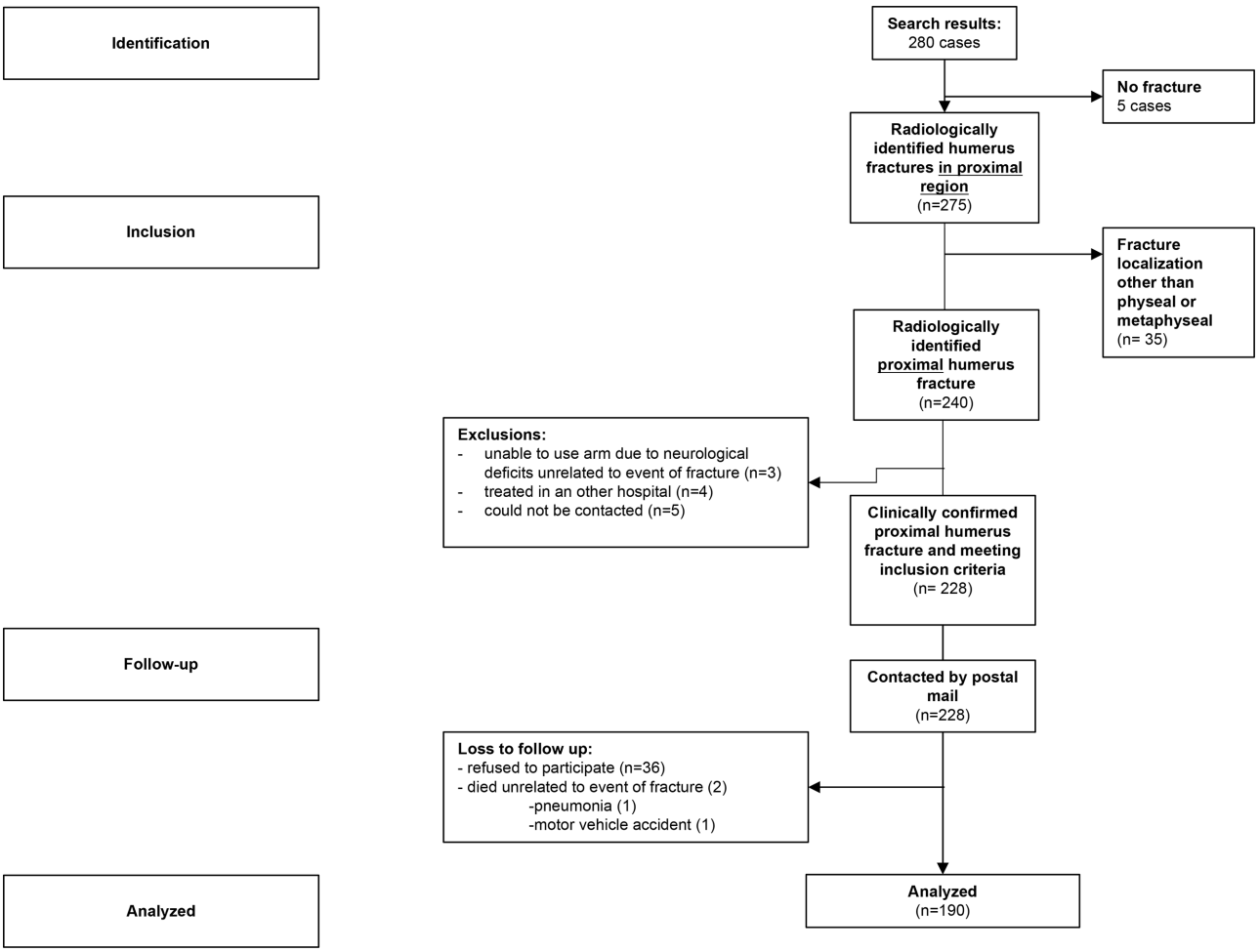

Fig. 1 Participant flow chart.

both the anteroposterior and the axial view, indicating no considerable displacement, then the proximal Rogers line is defined as one. However, if that line does not pass the humeral head, the radiographic view showing the maximum displacement is evaluated. The displacement of the humeral head is determined in quartiles in relation to the shaft of the humerus, comparable with the degree of spondylolisthesis assessed by Meyerding[14]. If there is full displacement then the proximal Rogers line is defined as 5, and if the lateral displacement results in a gap between the humeral shaft and the humeral head, indicating no bone contact, the proximal Rogers line is defined as 6. An illustration of this concept is shown in Figure 2.

The persons performing the image analysis (I. R., T. R. L.) were not aware of the patient's clinical result, thereby avoiding observer bias.

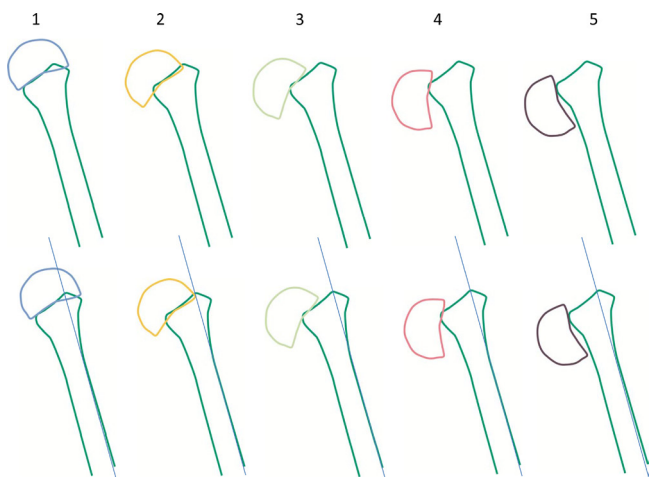

Fig. 2 Illustration of the proximal Rogers line. Only slips up to type 5 are shown; type 6 is defined as no bony contact between fragments.

Data collection

Beginning on 15th August 2016 we sent information about the study, a consent form and questionnaires to the patients (or their parents, depending on current age) by postal mail. Please see the STROBE participant flow

chart in Figure 1 for further details. Non-responding participants were reminded three times by mail. Participants still not responding were contacted by phone to determine the reason for non-responding. At that time it was attempted to complete the questionnaire by phone.

We used the disease-specific Quick-DASH[15] as the primary outcome measure, for which a validated translation to our language (German) exists.[16] Responses were recorded on a five-point Likert scale (no, mild, moderate, severe difficulty, unable). Scores were standardized to a score of 0 to 100, with higher scores indicating more disability. If more than 10% of the items were not answered, a Quick-DASH score was not calculated and regarded as missing. The minimal clinically important difference for the Quick-DASH questionnaire has been calculated to be 8 points.[17]

As a secondary outcome for the analysis of self-reported HRQoL we selected the Paediatric Quality of Life Inventory (PedsQL)[18] which is available in a validated version in our language. Scores were standardized to a score of 0 to 100, with higher scores indicating more physical function and more psychosocial function.

Data on demographics, dates of the injury, the side (right/left) and the treatment chosen were collected from both the radiological analysis and from the electronic patient chart. In the questionnaire, we included an item about handedness and about concomitant injuries.

Overall, we were able to follow up on 190 patients (113 girls, 77 boys) who sustained a proximal humerus fracture at a mean age of 9.3 years (0.8 to 15.8).

Treatment algorithm

Our treatment algorithm consists of applying a sling in mildly displaced fractures and ensuring adequate analgesic medication. A radiological control is performed after five to seven days. A typical radiograph of a boy who was treated conservatively is shown in Figure 3a and 3b. In severely displaced fractures we aimed to perform closed reduction and fixation with retrograde ESIN in the standard technique, introduced through the radial side of the distal metaphysis of the humerus, by using a 3 cm to 4 cm long incision. In order to avoid an iatrogenic injury to the radial nerve by slipping along the anterior aspect of the humerus, we used a drill instead of a broach to perforate the radial aspect of the metaphysis of the distal humerus. By using manoeuvres such as traction, abduction and external rotation, it was always possible to reduce the fracture under fluoroscopic control, so that the retrograde elastic nail could be passed into the proximal fragment. We always inserted a second nail of the same diameter as well, aiming to achieve spreading of the nail tips within the proximal fragment to gain additional stability, especially against sheer and rotational forces. We did not attempt to restore the original retroversion of the proximal humerus.

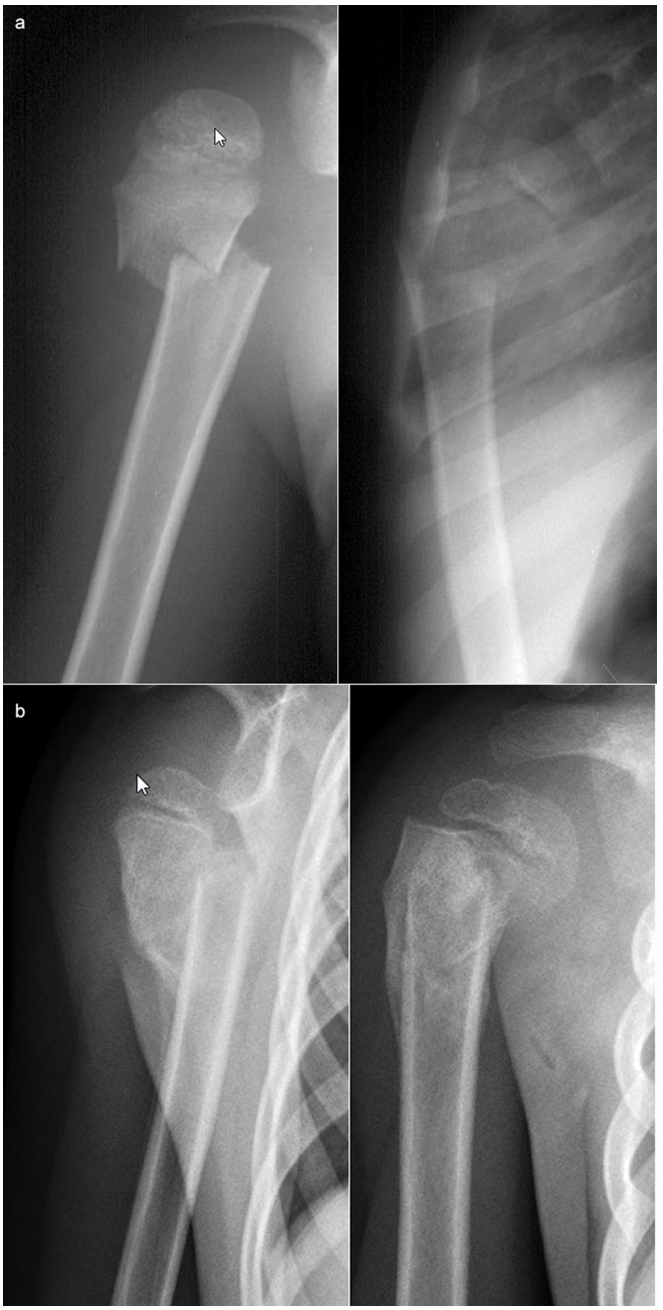

Fig. 3 a) A typical radiograph obtained at presentation; b) after four weeks of a patient treated conservatively. These radiographs are from a 4 years and 4 mths old boy who fell from a ladder.

Typical radiographs of a boy who was treated with retrograde ESIN are shown in Figure 4a and 4b. It must be noted that there were no strict criteria for or against surgery, and fracture displacement, patient's expectations, patient's age and remaining growth of the proximal physis were considered in the decision-making process.

All patients were invited to a routine follow-up after four weeks. Typically, at that time radiographs show con-

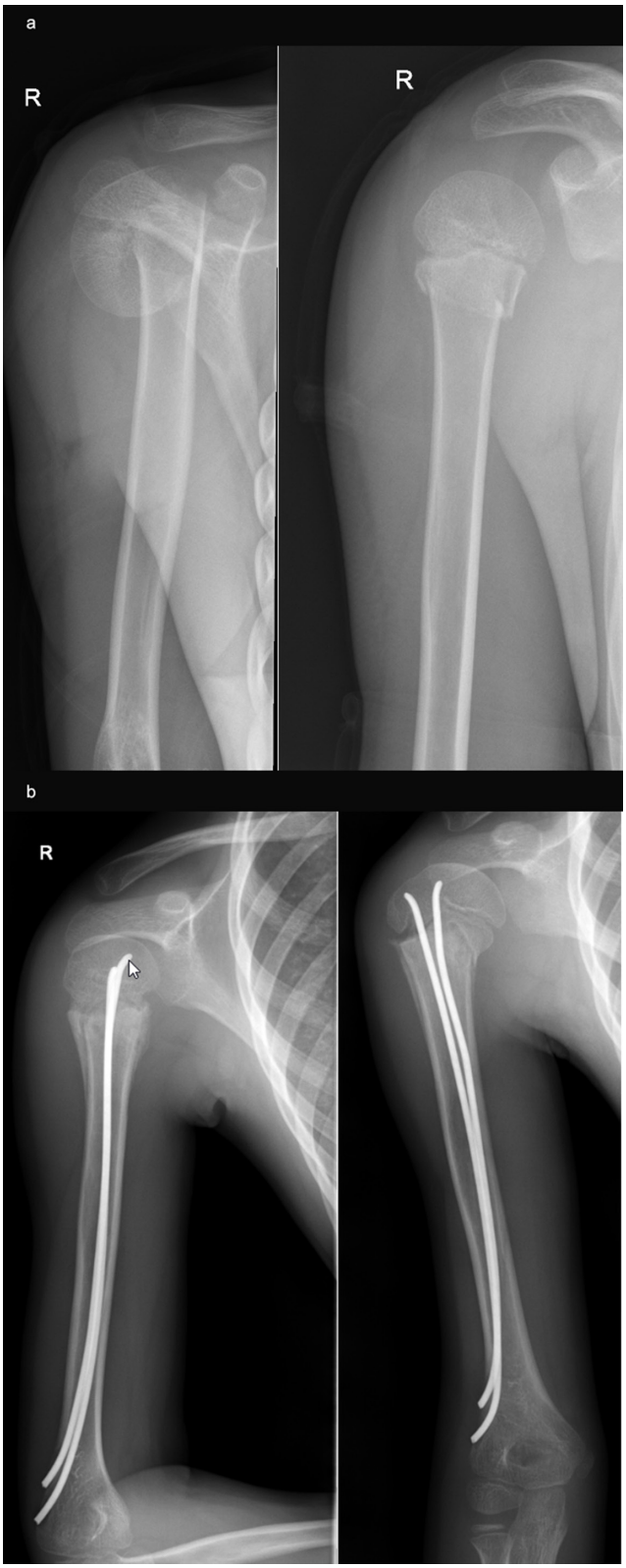

Fig. 4 a) A typical radiograph obtained at presentation; b) after four weeks of a patient treated by elastic stable intramedullary nailing. These radiographs are from a 7 years and 11 months old boy who fell from a swing that was 3 m high.

siderable callus formation and on physical examination the proximal humerus is not painful to palpation. In that case, the sling is discontinued, if it was not discontinued by the patients on their own behalf already. Patients were invited for another visit after four weeks if range of movement was limited. Only after that time, eight weeks after the injury, was physiotherapy considered, which was rarely needed in our experience.

Implant removal was usually performed between six and nine months after the injury, using the same approach and scar on the lateral side of the distal humeral metaphysis.

Statistical analysis

After the description of the main outcome measure, we performed bivariate analysis in which we have analyzed the HRQoL in relation to age, sex, the AO type radiological classification and the type of surgical treatment.

As there was a pronounced ceiling effect in most outcomes, i.e. most cases were grouped near the best possible outcome, that data distribution could not be adequately represented using box plots. For this reason, we have chosen violin plots instead. These might be unfamiliar at first glance, however, they more adequately give a graphical representation of the data distribution. The width of the plot is proportional to the number of data points, displaying the probability density of the data (comparable with a histogram turned 90°).

In addition, we calculated a composite malposition index based on displacement, taking into account the angulation, lateral displacement and the proximal Rogers line. We searched for associations between this displacement index and the primary outcome.

In addition, as part of an exploratory analysis, we performed two binary logistic regressions with backward variable elimination using the Wald criteria, trying to identify associations using a multivariate approach. In one regression analysis, patient satisfaction with treatment (very satisfied *versus* a little satisfied, a little unsatisfied and unsatisfied) served as the dependent variable. For the other analysis, we used a composite score of HRQoL as the outcome, where patients who fulfilled the following criteria were considered as good results: Quick-DASH < 10 (on a scale of 1 to 100) and both dimensions of the PedsQL (physical and psychosocial) > 90 (on a scale of 0 to 100). We tested the following explanatory variables: age at the time of the injury (years), sex, maximum radiographic angulation before and after treatment, maximum radiographic lateral displacement before and after treatment (percentage of shaft width), proximal Rogers line (1 to 6) and treatment (ESIN *versus* conservative).

All p-values are two-tailed; no corrections were made for multiple comparisons. Statistical analysis was performed using SPSS (SPSS Inc, Chicago, Illinois) and R.[19]

Results

In total, we were able to follow-up on 190 children with a mean age of 9.3 years (0.8 to 15.8). Of these, 147 children (77%; mean age 8.7 years (0.8 to 15.7)) sustained a metaphyseal fracture and 43 children (23%; mean age 11.6 years (3.7 to 15.8)) sustained an epiphyseal fracture (i.e. Salter-Harris type I or II). The majority (90%) of fractures were simple (mean age 9.3 years (0.8 to 15.8)), 10% were multi-fragmentary (mean age 10 years (1.8 to 15.6)). We did not identify any Salter-Harris type III or IV fractures and no fractures with an intraarticular flake.

In total, 137 children (72%) were treated nonoperatively, 51 were treated by ESIN (27%). One child was treated with an external fixator and one with K-wires (Table 1). After a median follow-up of 7.6 years (0.8 to 14.3) there was a mean Quick-DASH of 4.3 (SD 9.3) (at a scale of 0 to 100) for girls and 1.2 (SD 3.1) for boys, with lower values representing better quality of life (Figure 5).

Table 1 Preoperative malalignment by treatment performed

	Treatment				
Count	Nonoperative	ESIN	External fixator	Kirschner-wires	Total
Preoperative malalignment*					
Minor	62	0	0	0	62
Intermediate	70	24	1	1	96
Severe	5	27	0	0	32
Total	137	51	1	1	190

*please see methods section for definition of malalignment
ESIN, elastic stable intramedullary nailing

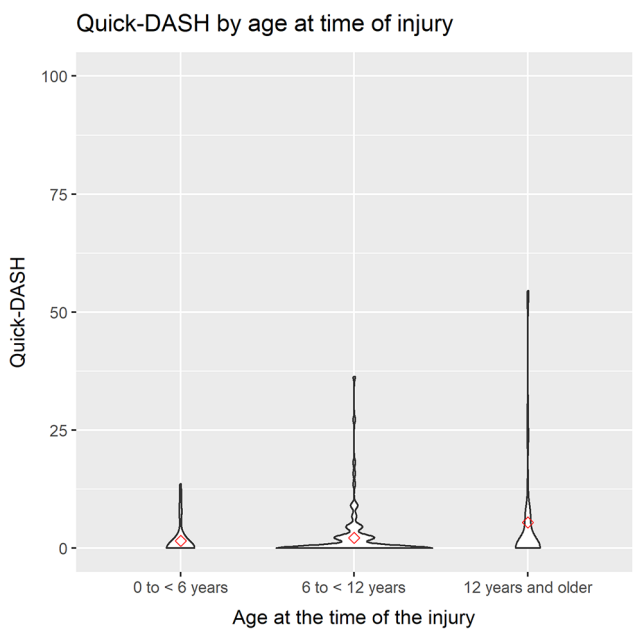

Fig. 5 The Quick Disabilities of the Arm, Shoulder and Hand (Quick-DASH) by age groups.

The mean function score of the PedsQL for girls was 94.7 (SD 11.1) at a scale of 0 to 100, with higher values representing better quality of life (boys: 98.0 (SD 6.0)) and the mean psychosocial score of the PedsQL for girls was 92.0 (SD 11.1) at a scale of 0 to 100, with higher values representing better quality of life (boys: 94.1 (SD 11.6)) (Tables 2, 3 and 4, Figures 6 and 7).

In total, 149 out of 188 children (79%) were very satisfied with the cosmetic result and 140 out of 189 children (74%) were very satisfied with the treatment overall.

There were no statistically significant associations between the AO classification (Figure 8), the displacement index or treatment (Figure 9) with regard to the primary outcome measure. However, girls consistently demonstrated inferior HRQoL than boys, and younger age at the time of injury was associated with better outcomes. Satisfaction with cosmetic result was associated with conservative treatment *versus* surgical treatment.

In both multivariate models, using the composite score of HRQoL and patient satisfaction as the outcome, sex was identified as a statistical significant association, and the proximal Rogers line was significantly associated with the composite score of the HRQoL in the backward variable elimination process (Tables 5 and 6).

Discussion

This study showed that conservative treatment of mildly displaced and surgical treatment of severely displaced paediatric proximal humeral fractures is associated with similar good HRQoL as measured with the Quick-DASH and the PedsQL at a median follow-up of 7.6 (0.8 to 14.3) years. Surgical treatment consisted of closed reduction and mainly retrograde ESIN. Our analysis is by far the largest covering paediatric proximal humeral fractures; it is one of the few assessing the HRQoL in this population and it is one of the few analyses that was not limited to surgical cases only. These good results were independent of radiological fracture patterns. However, we noted an association of higher patient satisfaction with lower age at time of the injury, better outcomes in boys *versus* girls and improved reposition as measured by the newly introduced proximal Rogers line.

HRQoL and associated factors

The main focus of our study was to report the HRQoL of our population. In our cohort of 190 children there were similar good mean scores for the primary outcome Quick-DASH and the secondary outcomes PedsQL-physical function and PedsQL-psychosocial function, regardless of AO fracture classification group. This indicates that the AO fracture classification might be of inferior importance in this patient group.

Table 2 Outcomes by age group (age at time of injury)

	0 to < 6 yrs				6 to < 12 yrs				12 yrs and older				Total			
	Mean	SD	n	%	Mean	SD	n	%	Mean	SD	n	%	Mean	SD	n	%
Quick-DASH (0 to 100)	1.6	3.5			2.3	5.4			5.7	11.8			3.1	7.6		
PedsQL physical function (0 to 100)	97.9	7.3			96.6	8.4			93.6	12.2			96.0	9.5		
PedsQL psychosocial function (0 to 100)	94.6	9.1			93.2	10.7			90.9	13.7			92.9	11.3		
Satisfaction with cosmetic result																
Very satisfied			34	*92*			86	*86*			29	*57*			149	*79*
Rather satisfied			3	*8*			*7*	*7*			8	*16*			18	*10*
Moderately satisfied							*5*	*5*			9	*18*			14	*7*
A little satisfied											1	*2*			1	*1*
Not satisfied at all							2	*2*			4	*8*			6	*3*
Satisfaction with treatment when looking back																
Very satisfied			33	*89*			*75*	*74*			32	*63*			140	*74*
Rather satisfied			3	*8*			19	*19*			12	*24*			34	*18*
Moderately satisfied			1	*3*			*7*	*7*			3	*6*			11	*6*
A little satisfied											3	*6*			3	*2*
Not satisfied at all											1	*2*			1	*1*

Quick-DASH, Quick Disabilities of the Arm, Shoulder and Hand; PedsQL, Paediatric Quality of Life Inventory

Table 3 Outcomes by classification according to AO regarding simple *versus* mulitfragmentary fracture

	Simple fracture				Multifragmentary fracture				Total			
	n	Mean	SD	%	n	Mean	SD	%	n	Mean	SD	%
Quick-DASH (0 to 100)	170	3.11	7.89		20	2.63	4.74		190	3.06	7.61	
PedsQL physical function (0 to 100)	170	95.99	9.71		20	96.41	7.26		190	96.04	9.46	
PedsQL psychosocial function (0 to 100)	170	92.8	11.4		20	93.5	10.65		190	92.88	11.3	
Satisfaction with cosmetic result												
Very satisfied	136			*81*	13			*65*	149			*79*
Rather satisfied	16			*10*	2			*10*	18			*10*
Moderately satisfied	12			*7*	2			*10*	14			*7*
A little satisfied	1			*1*					1			*1*
Not satisfied at all	3			*2*	3			*15*	6			*3*
Satisfaction with treatment when looking back												
Very satisfied	128			*76*	12			*60*	140			*74*
Rather satisfied	28			*17*	6			*30*	34			*18*
Moderately satisfied	11			*7*					11			*6*
A little satisfied	1			*1*	2			*10*	3			*2*
Not satisfied at all	1			*1*					1			*1*

Quick-DASH, Quick Disabilities of the Arm, Shoulder and Hand; PedsQL, Paediatric Quality of Life Inventory

Table 4 Outcomes by classification according to AO regarding epiphyseal and metaphyseal fracture

	Epiphyseal fracture				Metaphyseal fracture				Total			
	n	Mean	SD	%	n	Mean	SD	%	n	Mean	SD	%
Quick-DASH (0 to 100)	43	2.7	6.4		147	3.2	8.0		190	3.1	7.6	
PedsQL physical function (0 to 100)	43	96.5	7.1		147	95.9	10.1		190	96.0	9.5	
PedsQL psychosocial function (0 to 100)	43	93.5	10.5		147	92.7	11.6		190	92.9	11.3	
Satisfaction with cosmetic result												
Very satisfied	31			*72*	118			*81*	149			*79*
Rather satisfied	6			*14*	12			*8*	18			*10*
Moderately satisfied	4			*9*	10			*7*	14			*7*
A little satisfied					1			*1*	1			*1*
Not satisfied at all	2			*5*	4			*3*	6			*3*
Satisfaction with treatment when looking back												
Very satisfied	34			*79*	106			*73*	140			*74*
Rather satisfied	6			*14*	28			*19*	34			*18*
Moderately satisfied	2			*5*	9			*6*	11			*6*
A little satisfied	1			*2*	2			*1*	3			*2*
Not satisfied at all					1			*1*	1			*1*

Quick-DASH, Quick Disabilities of the Arm, Shoulder and Hand; PedsQL, Paediatric Quality of Life Inventory

Our results compare well with the few published articles in the literature that have analyzed the HRQoL in these patients. However, these studies look at surgical patients only and have lower patient numbers. For example, Kraus et al[20] reported a mean DASH of 1.66 (SD 4.44; 0 to 17.5) in 16 severely displaced ESIN-treated patients (mean age 10.1

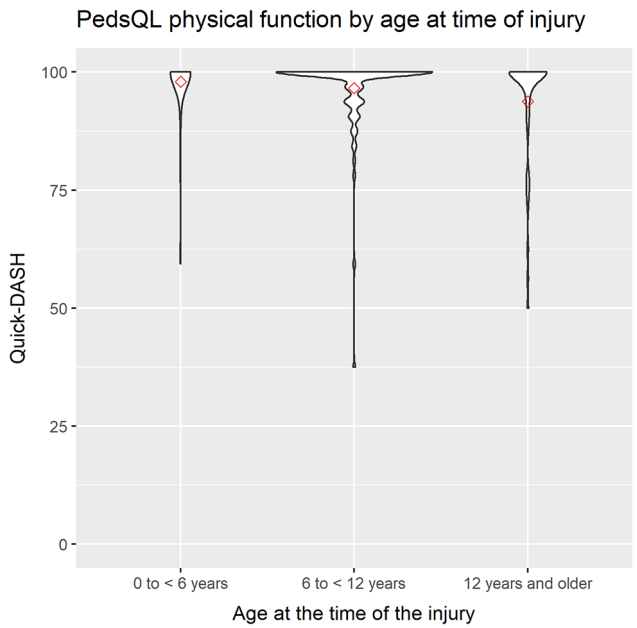

Fig. 6 Paediatric Quality of Life Inventory (PedsQL) physical function by age groups

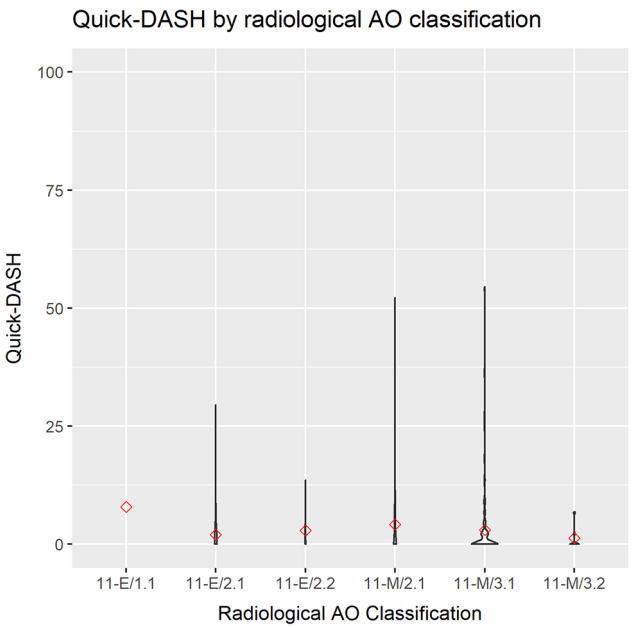

Fig. 8 Quick Disabilities of the Arm, Shoulder and Hand (Quick-DASH) by radiological AO classification.

Fig. 7 Paediatric Quality of Life Inventory (PedsQL) psychosocial function by age groups

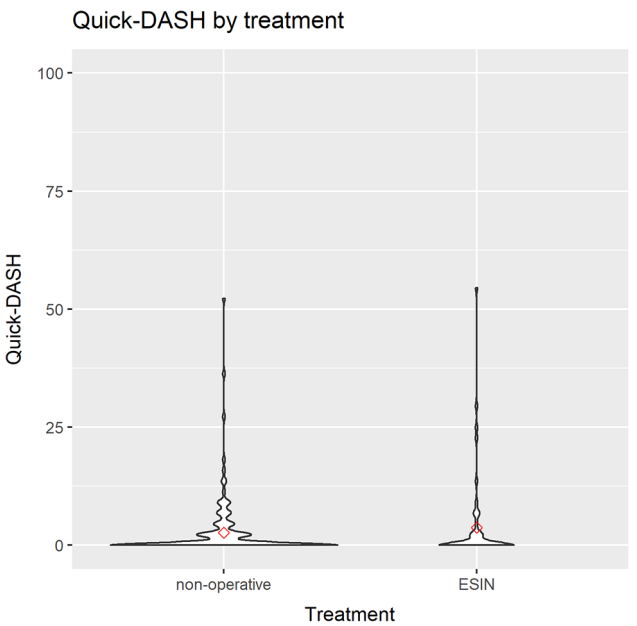

Fig. 9 Quick Disabilities of the Arm, Shoulder and Hand (Quick-DASH) by treatment (elastic stable intramedullary nailing (ESIN) *versus* nonoperative).

years) with Neer-Horowitz Type 3 and 4 fractures. Canavese et al[9] reported on 52 children who were treated by ESIN for displaced fractures. After a mean follow-up of 1.5 years the authors reported a Quick-DASH of 0.4 (mean age 10.6 years) for one and 1.8 (mean age 11.6 years) for another institution. Rajan et al[21] reported on 14 patients treated by ESIN. The mean DASH score was 2.3 (0 to 7.5) in that cohort.

While these aforementioned studies cover surgically treated cohorts only, our study has the advantage that it covers both conservatively treated and surgically treated groups. However, in our study there were no strict criteria in which cases surgery and in which cases a conservative approach should be used. As that decision is complex it

Table 5 Logistic regression model with the composite score of health-related quality of life (HRQoL) as the endpoint

Variable	Odds ratio	Lower 95% CI	Upper 95% CI	p-value
Sex (female *vs* male)	0.334	0.142	0.783	0.012
Preoperative maximum angulation	0.968	0.945	0.991	0.007
Preoperative maximum lateral displacement	3.904	1.118	13.632	0.033
Postoperative maximum angulation	1.052	1.006	1.101	0.028
Postoperative proximal Rogers line (1 to 6)	0.556	0.337	0.917	0.022
Constant	6.333			0.001

The composite score of the HRQoL, that was used as the endpoint for this logistic regression analysis, is based on both the Quick Disabilities of the Arm, Shoulder and Hand and the Paediatric Quality of Life Inventory. For futher details please see the methods section of this article
CI, confidence interval

Table 6 Logistic regression model with patient satisfaction with treatment as the endpoint

Variable	Odds ratio	Lower 95% CI	Upper 95% CI	p-value
Age at the time of injury (yrs)	0.836	0.737	0.949	0.006
Gender (female *vs* male)	0.443	0.188	1.046	0.063
Postoperative proximal Rogers line (1 to 6)	0.687	0.443	1.067	0.095
Constant	49.048			0

CI, confidence interval

is not astonishing that no such agreed upon criteria have been published yet. We calculated a malposition score and we were able to show that in children with a strong displacement a surgical approach was used while in children with subtle displacement a nonoperative approach was used. For the intermediate cases the decision criteria were less clear and an analysis of the current literature did not reveal any guidelines regarding this topic. It would be of great interest, of course, if such treatment decision thresholds could be developed. However, given the methodological problems associated with the design of such studies it is easy to understand that such studies have not been performed yet. As a further project, we will aim to perform a matched pair analysis in the future. Anyhow, even such an approach remains retrospective, thereby limiting the validity of such an analysis.

While our study clearly demonstrates comparable results in both treatment groups, it became evident that not every patient is fully satisfied with the cosmetic result. In order to identify possible explanations, we have tested the hypothesis that the amount of initial displacement is associated with inferior results. However, that hypothesis could not be confirmed. On the other hand, we were able to identify an association of surgical treatment and inferior satisfaction with the cosmetic result, indicating that patients who sustained this injury are rather disturbed by the scar than by the functional results. This underlines that the functional results are generally good in this cohort.

Apart from age and sex we were not able to identify additional strong associations to inferior results, indicating that a certain amount of random noise must be expected in this patient group when using the Quick-DASH and the PedsQL. Further research is needed in order to assess the factors that are associated with the small number of patients who do not report full satisfaction and inferior HRQoL.

Limitations

Our observations must be interpreted in the light of several limitations: first, as this was a retrospective study and there were no strict criteria as when to perform surgery, there might have been fractures with more severe displacements that were treated nonoperatively and fractures with less severe displacements that underwent surgery, leaving a somewhat arbitrary aspect for surgical indications. As usually patient's age and remaining growth from the proximal physis are considered as well, the decision-making process is complex. Secondly, as this was a single-centre study it could be argued that external validity is limited. However, as we are the only institution in a wide geographical area covering paediatric trauma and we included all sequential patients suffering from this injury, a bias in the run-in phase is unlikely, making a high external validity probable.[11] However, it must be kept in mind that no single study is capable of providing full external validity, since it has been reported that great variation exists across and within countries for orthopaedic treatments.[22] Thirdly, the examined radiographs were made routinely at presentation to our institution and were not specifically prepared for this analysis. Therefore, the setting of these radiographs is comparable with the situation of the clinician.[11] The person classifying the fractures was not aware of the clinical result of the patient, therefore, the radiographic assessment could be regarded as blinded.[11] Fourthly, as this study has a retrospective design our study suffers from methodological weaknesses common in this design. This includes missing data on the HRQoL prior to the injury. While this is considered a methodological weakness in studies analyzing adult fractures, this does not apply to paediatric fractures. Usually, children have no physical limitations before an injury. Therefore, it should be allowed to assume that limitations of the disease-specific outcome measure used in this study are

in fact attributable to the injury.[11] Fifthly, the Quick-DASH has not yet been formally validated in this age group and in some cases the parents filled in the questionnaire based on their perceptions of their children's functioning, which might explain a ceiling effect of the instrument. However, the Quick-DASH has been used by several authors for evaluation of children with upper extremity fractures.[11,12,23-34] Therefore, the DASH/Quick-DASH appears to be the most commonly used outcome measure for paediatric fractures of the upper extremities. Sixthly, although we had a large sample size it is possible that we missed the identification of existing associations of HRQoL to fracture patterns. Given the good results of the overall group, which even exhibits a ceiling effect, it is unlikely that any such association would gain clinical relevance, if it existed. Finally, we have identified associations between the newly introduced proximal Rogers line and both the endpoints patient satisfaction and a composite score of HRQoL, consisting of the Quick-DASH and the PedsQL. The proximal Rogers line that was introduced in this study is a different method for the assessment of angulation, as it combines the angulation and the lateral displacement. The association of the proximal Rogers line was not identified in the univariate analysis, indicating that the association identified in the multivariate model could be an incidental finding. Therefore, that association should not be overinterpreted.

Conclusion

In conclusion, we report good HRQoL in children and adolescents who sustained paediatric proximal humeral fractures and who were treated nonoperatively for mildly displaced and surgically for displaced fractures. These results indicate that this treatment results in good treatment outcomes for this injury. However, a small percentage of patients are not fully satisfied. This group is associated with increasing age, female sex and surgery.

Received 02 March 2021, accepted after revision 23 April 2021

COMPLIANCE WITH ETHICAL STANDARDS

FUNDING STATEMENT

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

ETHICAL STATEMENT

Ethical approval: Helsinki declaration: this research involves human participants and has been conducted in compliance with the Helsinki declaration. Ethical review committee statement: the study protocol was approved by both the institutional review board of the Paediatric Clinics of Inselspital, University of Bern and the Ethics Commission of the Canton of Bern, both in Switzerland.

Informed consent: All participants (or their parents) provided written informed consent.

ICMJE CONFLICT OF INTEREST STATEMENT

All authors declare that they have no conflict of interest. There has been no funding for this analysis.

AUTHOR CONTRIBUTIONS

TL: Contributed significantly and is willing to take public responsibility for all aspects of the study, Study design, Data acquisition, Analysis and interpretation of data, Drafting the work, Critical revision of the manuscript, Providing final approval of the version to be submitted.

IR: Substantial contributions to the acquisition of data for the work and is willing to take public responsibility for data acquisition, Analysis and interpretation of the data, Critical revision of the manuscript, Provision of final approval of the version to be submitted.

SB: Substantial contributions to the acquisition of data for the work and is willing to take public responsibility for data acquisition, Analysis and interpretation of the data, Critical revision of the manuscript, Provision of final approval of the version to be submitted.

KZ: Substantial contributions to the acquisition of data for the work and is willing to take public responsibility for data acquisition, Analysis and interpretation of the data, Critical revision of the manuscript, Provision of final approval of the version to be submitted.

REFERENCES

1. **Binder H, Tiefenboeck TM, Payr S, et al.** Treatment of proximal humerus fractures in children and young adolescents. *Wien Klin Wochenschr* 2016;128:120-124.

2. **Ali AM, Fawzy SI, Moaty M, Abelaziz M.** Treatment of proximal humerus fractures in children with a modified palm tree technique. *J Pediatr Orthop B* 2018;27:99-102.

3. **Ligier JN, Metaizeau JP, Prévot J.** Closed flexible medullary nailing in pediatric traumatology. *Chir Pediatr* 1983;24:383-385.

4. **Kelly DM.** Flexible intramedullary nailing of pediatric humeral fractures: indications, techniques, and tips. *J Pediatr Orthop* 2016;36(suppl 1):S49-S55.

5. **Pogorelić Z, Kadić S, Milunović KP, et al.** Flexible intramedullary nailing for treatment of proximal humeral and humeral shaft fractures in children: a retrospective series of 118 cases. *Orthop Traumatol Surg Res* 2017;103:765-770.

6. **Hohloch L, Eberbach H, Wagner FC, et al.** Age- and severity-adjusted treatment of proximal humerus fractures in children and adolescents-A systematical review and meta-analysis. *PLoS One* 2017;12:e0183157.

7. **Popkin CA, Levine WN, Ahmad CS.** Evaluation and management of pediatric proximal humerus fractures. *J Am Acad Orthop Surg* 2015;23:77-86.

8. **Pahlavan S, Baldwin KD, Pandya NK, Namdari S, Hosalkar H.** Proximal humerus fractures in the pediatric population: a systematic review. *J Child Orthop* 2011;5:187-194.

9. Canavese F, Athlani L, Marengo L, et al. Evaluation of upper-extremity function following surgical treatment of displaced proximal humerus fractures in children. *J Pediatr Orthop B* 2014;23:144-149.

10. **Chaus GW, Carry PM, Pishkenari AK, Hadley-Miller N.** Operative versus nonoperative treatment of displaced proximal humeral physeal fractures: a matched cohort. *J Pediatr Orthop* 2015;35:234-239.

11. **Liebs TR, Ryser B, Kaiser N, et al.** Health-related quality of life after fractures of the lateral third of the clavicle in children and adolescents. *J Pediatr Orthop* 2019;39:e542-e547.

12. **Liebs TR, Burgard M, Kaiser N, et al.** Health-related quality of life after paediatric supracondylar humeral fractures. *Bone Joint J* 2020;102-B:755-765.

13. **Slongo T, Audige L, AO Paediatric Classification Group.** Distal metaphyseal fractures (13-M). In: Slongo T, Audige L, AO Paediatric Classification Group (eds). *AO pediatric comprehensive classification of long-bone fractures (PCCF)*. Davos, Switzerland: AO Foundation, 2007:55.

14. **Meyerding, HW.** Spondylolisthesis; surgical fusion of lumbosacral portion of spinal column and interarticular facets; use of autogenous bone grafts for relief of disabling backache. J Int Coll Surg 1956;26:566-591.

15. **Bot SD, Terwee CB, van der Windt DA, et al.** Clinimetric evaluation of shoulder disability questionnaires: a systematic review of the literature. *Ann Rheum Dis* 2004;63:335-341.

16. **Germann G, Harth A, Wind G, Demir E.** Standardisation and validation of the German version 2.0 of the Disability of Arm, Shoulder,Hand (DASH) questionnaire. *Unfallchirurg* 2003;106:13-19.

17. **Mintken PE, Glynn P, Cleland JA.** Psychometric properties of the shortened disabilities of the Arm, Shoulder, and Hand Questionnaire (QuickDASH) and Numeric Pain Rating Scale in patients with shoulder pain. *J Shoulder Elbow Surg* 2009;18:920-926.

18. **Mahan ST, Kalish LA, Connell PL, et al.** PedsQL correlates to PODCI in pediatric orthopaedic outpatient clinic. *J Pediatr Orthop* 2014;34:e22-e26.

19. **R Development Core Team.** *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing, 2008.

20. **Kraus T, Hoermann S, Ploder G, et al.** Elastic stable intramedullary nailing versus Kirschner wire pinning: outcome of severely displaced proximal humeral fractures in juvenile patients. *J Shoulder Elbow Surg* 2014;23:1462-1467.

21. **Rajan RA, Hawkins KJ, Metcalfe J, et al.** Elastic stable intramedullary nailing for displaced proximal humeral fractures in older children. *J Child Orthop* 2008;2:15-19.

22. **Ackerman IN, Dieppe PA, March LM, et al.** Variation in age and physical status prior to total knee and hip replacement surgery: a comparison of centers in Australia and Europe. *Arthritis Rheum* 2009;61:166-173.

23. **Al-Aubaidi Z, Pedersen NW, Nielsen KD.** Radial neck fractures in children treated with the centromedullary Métaizeau technique. *Injury* 2012;43:301-305.

24. **Lawrence JT, Patel NM, Macknin J, et al.** Return to competitive sports after medial epicondyle fractures in adolescent athletes: results of operative and nonoperative treatment. *Am J Sports Med* 2013;41:1152-1157.

25. **Isa AD, Furey A, Stone C.** Functional outcome of supracondylar elbow fractures in children: a 3- to 5-year follow-up. *Can J Surg* 2014;57:241-246.

26. **Marengo L, Canavese F, Cravino M, et al.** Outcome of displaced fractures of the distal metaphyseal-diaphyseal junction of the humerus in children treated with elastic stable intramedullary nails. *J Pediatr Orthop* 2015;35:611-616.

27. **Moraleda L, Valencia M, Barco R, González-Moran G.** Natural history of unreduced Gartland type-II supracondylar fractures of the humerus in children: a two to thirteen-year follow-up study. *J Bone Joint Surg [Am]* 2013;95-A:28-34.

28. **Belthur MV, Iobst CA, Bor N, et al.** Correction of cubitus varus after pediatric supracondylar elbow fracture: alternative method using the taylor spatial frame. *J Pediatr Orthop* 2016;36:608-617.

29. **Davids JR, Lamoreaux DC, Brooker RC, Tanner SL, Westberry DE.** Translation step-cut osteotomy for the treatment of posttraumatic cubitus varus. *J Pediatr Orthop* 2011;31:353-365.

30. **Smith JT, McFeely ED, Bae DS, et al.** Operative fixation of medial humeral epicondyle fracture nonunion in children. *J Pediatr Orthop* 2010;30:644-648.

31. **Schulz J, Moor M, Roocroft J, Bastrom TP, Pennock AT.** Functional and radiographic outcomes of nonoperative treatment of displaced adolescent clavicle fractures. *J Bone Joint Surg [Am]* 2013;95-A:1159-1165.

32. **Namdari S, Ganley TJ, Baldwin K, et al.** Fixation of displaced midshaft clavicle fractures in skeletally immature patients. *J Pediatr Orthop* 2011;31:507-511.

33. **Randsborg PH, Fuglesang HF, Røtterud JH, Hammer OL, Sivertsen EA.** Long-term patient-reported outcome after fractures of the clavicle in patients aged 10 to 18 years. *J Pediatr Orthop* 2014;34:393-399.

34. **Bogdan A, Quintin J, Schuind F.** Treatment of displaced supracondylar humeral fractures in children by humero-ulnar external fixation. *Int Orthop* 2016;40:2409-2415.