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Bot, A.G.J.; Doornberg, J.N.; Lindenhovius, A.L.C.; Ring, D.; Goslings, J.C.; van Dijk, C.N.

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Long-Term Outcomes of Fractures of Both Bones of the Forearm

By Arjan G.J. Bot, Job N. Doornberg, MD, PhD, Anneluuk L.C. Lindenhovius, MD, PhD, David Ring, MD, PhD, J. Carel Goslings, MD, PhD, and C. Niek van Dijk, MD, PhD

Investigation performed at the Department of Orthopaedic Surgery, Academic Medical Center, Amsterdam, The Netherlands

Background: Previous studies identified limited impairment and disability several years after diaphyseal fractures of both the radius and ulna, although the relationship between impairment and disability was inconsistent. This investigation studied skeletally mature and immature patients more than ten years after injury and addressed the hypotheses that (1) objective measurements of impairment correlate with disability, (2) depression and misinterpretation of nociception correlate with disability, and (3) patients injured when skeletally mature or immature have comparable impairment and disability.

Methods: Seventy-one patients with diaphyseal fractures of the radius and ulna were evaluated at an average of twenty-one years after injury. Twenty-five of the thirty-five patients who were skeletally immature at the time of injury were treated nonoperatively, and thirty-one of the thirty-six skeletally mature patients were treated operatively. Objective evaluation included radiographs, functional assessment, and grip strength. Validated questionnaires were used to measure arm-specific disability (the Disabilities of the Arm, Shoulder and Hand [DASH] score), misinterpretation of pain (Pain Catastrophizing Scale [PCS]), and depression (the validated Dutch form of the Center for Epidemiologic Studies-Depression scale [CES-D]).

Results: The average DASH score was 8 points (range, 0 to 54); 97% of patients had excellent or satisfactory results according to the criteria of Anderson et al., and 72% reported no pain. Both the forearm rotation and the wrist flexion/extension arc was 91% of that seen on the uninjured side; grip strength was 94%. There were small but significant differences in rotation (151° versus 169°, $p = 0.004$) and wrist flexion-extension (123° versus 142°, $p = 0.002$) compared with the results in the uninjured arm. There was no difference in disability between patients who were skeletally mature or immature at the time of injury. Pain, pain catastrophizing (misinterpretation of nociception), and grip strength were the most important predictors of disability.

Conclusions: An average of twenty-one years after sustaining diaphyseal fractures of both the radius and the ulna, patients who were skeletally immature or mature at the time of fracture have comparable disability. Disability correlates better with subjective and psychosocial aspects of illness, such as pain and pain catastrophizing, than with objective measurements of impairment.

Level of Evidence: Therapeutic Level IV. See Instructions to Authors for a complete description of levels of evidence.

Diaphyseal fractures of both the radius and the ulna that are treated with plate-and-screw fixation are associated with high union rates[1-5]. After fracture-healing, patients experience slight reduction of grip strength (15% to 25%)[4] and forearm rotation (10%)[4,5]. Only malunion[6-8] and severe open fractures are associated with an unsatisfactory outcome[9]. Closed reduction and casting is the treatment of choice in most patients under ten to twelve years of age with diaphyseal fractures of both bones, although fracture-dislocations and fractures in patients within a few years of skeletal maturity are often considered for open reduction and internal fixation[6,10-20].

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Several studies have addressed arm-specific disability (i.e., through an assessment of range of motion and strength and with use of the Disabilities of the Arm, Shoulder and Hand [DASH] score) and general health status (i.e., with use of the Short Form-36 [SF-36] score) after diaphyseal fractures of both forearm bones in adult patients. A North American study noted that disability at an average of thirty-four months after plate-and-screw fixation in adults correlated with pronation and grip strength[5]. A Canadian study reported that after an average of five years (range, two to thirteen years), arm-specific and general disability correlated with pain rather than with the limited residual impairments in motion and strength[4].

The purpose of this study was to investigate impairment and disability more than ten years after diaphyseal fractures of both the radius and the ulna. We tested the hypotheses that (1) pain and objective measurements of impairment correlate with disability; (2) depression and misinterpretation of nociception correlate with disability; and (3) patients injured when skeletally mature or immature have comparable long-term impairment and disability.

Materials and Methods

Study Design

Between 1974 and 2002, all patients who received operative treatment for fractures of both bones of the forearm at our institution were included in a trauma fracture database and classified according to the AO/OTA (Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association) Comprehensive Classification of Fractures[21]. In this database we identified 157 patients who were treated for diaphyseal fractures of both forearm bones (AO/OTA 22 classification type A3, B3, or C1, C2, or C3) before 1999, allowing for at least ten years of follow-up[22]. Thirty-four of these patients were excluded: seven of the thirty-four patients had incomplete demographic data, seven were visitors (tourists or exchange students), and twenty had died.

The remaining 123 patients were invited for a long-term follow-up visit at our outpatient clinic under a protocol approved by our institutional review board. Thirteen of these patients were excluded: four of the thirteen patients were pregnant during the study period; three had complete brachial plexus injuries that did not resolve; three had severe central nervous system injuries; one was mentally challenged; and two patients had generalized musculoskeletal disorders. From the remaining 110 eligible patients, twelve (11%) declined participation, seven (6%) lived abroad, and twenty (18%) did not respond or could not be contacted after three written and three phone requests.

Seventy-one (65%) of the 110 patients were evaluated at a mean time of twenty-one years (range, thirteen to thirty-three years) after injury. Sixty-five were evaluated by an independent observer who was not involved in the care of the patients, four were evaluated at home, and two were unable to visit our university hospital but were evaluated by an orthopaedic surgeon at their local hospital. Informed consent was obtained from all patients in the study.

Three treatment strategies were identified: closed reduction and cast immobilization in thirty patients, external fixation in three patients, and open reduction and plate-and-screw fixation in thirty-eight patients, one of whom had initial temporary external fixation.

Patient Characteristics

There were forty-four men and twenty-seven women, with a mean age at the time of follow-up of forty-two years (range, nineteen to eighty-one years) (see Appendix). Skeletal maturity was determined on radiographs taken at the time of injury. Thirty-six patients were skeletally mature (mean age, thirty-one years) and thirty-five were skeletally immature (mean age, eleven years) at the time of injury. In the mature group, fifteen fractures were classified as simple (type-A3) fractures, fourteen were wedge (type-B3) fractures, and seven were complex (type-C) fractures. In the immature group, thirty-one fractures were classified as simple (type-A3) fractures, four were wedge (type-B3) fractures, and no fractures were complex (type-C) fractures. Twenty-four patients (34%) had open fractures; ten of these patients were in the skeletally immature group and fourteen were in the skeletally mature group[23].

Thirty-two patients, including twenty-nine (81%) of the thirty-six patients in the mature group and three (9%) of the thirty-five patients in the immature group, sustained high-energy trauma. The mechanisms of injury in the mature group were a fall from a height (two patients), a motor-vehicle accident (twenty-one patients), industrial accidents (four patients, all with severe crush injuries), and a fireworks explosion (two patients). The mechanisms of injury in the immature group were a motor-vehicle accident (two patients) and an industrial accident involving a severe crush injury (one patient). The injuries of thirty-nine patients were sustained during a low-energy fall (thirty-two in the immature group and seven in the mature group). Twenty-two patients had multiple-system trauma (two in the immature group, and twenty in the mature group). The mature group had twenty-nine fractures of other limbs (thirteen upper-extremity fractures and sixteen lower-extremity fractures). In the immature group, one patient had ipsilateral fractures of both the upper and the lower extremity. Forty-nine patients sustained no other injury (sixteen in the mature group and thirty-three in the immature group). Eleven patients in the mature group had ipsilateral concomitant nerve injuries, including radial nerve injury in six, partial brachial plexus injuries in two, ulnar nerve injury in four, and median nerve injury in two patients. One patient in the immature group had a radial nerve lesion.

Treatment

We considered the term *treatment* to mean the treatment on the day of injury, and we considered the term *complication* to mean any deviation from that treatment. Of the thirty-five skeletally immature patients, twenty-five (71%) were treated with closed reduction and cast immobilization and ten were treated with plate-and-screw fixation. Of the thirty-six skeletally mature patients, twenty-eight (78%) were treated with plate-and-screw fixation, five were treated with closed reduction and cast immobilization, and three were treated with external fixation. In total, thirty patients were initially treated with closed reduction and cast immobilization for at least six weeks, with a maximum treatment time of twelve weeks (range, two to twelve weeks). Five of these thirty patients underwent open reduction and internal fixation with plates and screws after loss of reduction.

Twenty-eight skeletally mature patients and eight skeletally immature patients were treated with open reduction and internal fixation of both the ulna and radius. Two skeletally immature patients were treated with only one plate, which was affixed to the radius in one patient and to the ulna in the other.

Four patients with open fractures had initial external fixation but later underwent conversion to plate-and-screw fixation at sixteen days, three months, four months, and six months, respectively, after the injury.

Plate-and-screw fixation had been performed by at least twenty different orthopaedic trauma and general trauma surgeons, and no standard protocols were used. The volar approach of Henry (for the radius) and the subcutaneous approach (for the ulna) were used in the majority of patients[24]. In six patients, the surgical approach was not documented.

Internal fixation was performed with 3.5-mm dynamic compression plates (Synthes, Zeist, The Netherlands) in thirty-three patients. In seven patients, a one-third tubular plate was used, and, in one patient, a 3.5-mm dynamic compression plate was used for the radius and a one-third tubular plate was used for the ulna. No bone-grafting was performed primarily. The postoperative protocol was not standardized, but it included short-term immobilization for less than one week in an above-the-elbow splint with the forearm in the neutral position, followed by active-assisted range-of-motion exercises according to a similar protocol to that used in the study by Droll et al.[4].

Complications and Subsequent Procedures

Four skeletally immature patients and one skeletally mature patient who were initially treated with cast immobilization had loss of reduction while wearing the cast and were subsequently treated with open reduction and internal fixation (three skeletally immature patients and one skeletally mature patient) and/or intramedullary nail fixation (one skeletally immature patient) within two to thirty-six days after injury.

The skeletally immature patient who was treated with intramedullary nail fixation after initial cast treatment developed a deep infection that was treated with debridement, removal of the intramedullary nail, and oral antibiotics. Another skeletally immature patient developed an infection within the pin-track of an external fixator, which was treated with removal of the external fixator, debridement of the pin site, and oral antibiotics. Three weeks later, plates and screws were placed in this patient.

Two skeletally mature patients and one immature patient had a deep wound infection along with osteomyelitis after sustaining high-energy open fractures. A skeletally mature patient with an external fixator had a deep infection that was treated with removal of the fixator, debridement, and placement of antibiotic-impregnated methylmethacrylate beads. Plates and screws were applied ten days later with autogenous cancellous bone-grafting. A deep infection developed five months after this procedure, with the fracture united, and was treated with debridement, removal of implants, and open wound-packing. After this procedure, the patient remained free of infection.

Another deep infection was treated successfully with serial debridement and parenteral antibiotics. One skeletally immature patient developed osteomyelitis with a draining sinus, which resolved with parenteral antibiotic treatment followed by oral antibiotic treatment.

Other complications included two patients (one skeletally mature and one skeletally immature patient) who had pain and stiffness that were disproportionate to what was merited and who were diagnosed with complex regional pain syndrome. One skeletally immature patient was diagnosed with an exertional compartment syndrome in the forearm twenty years after the original injury and was treated surgically.

There were five refractures after closed reduction and cast immobilization. One patient in the mature group had a refracture seven months after injury and was treated with plate-and-screw fixation. Three patients in the skeletally immature group had a refracture after three, three, and twelve months, respectively, and were treated with repeat closed reduction and casting. One of these patients had a second manipulation for a 30° malalignment of the radius. Another patient in the skeletally immature group had two refractures (four and eleven months after the index injury), the first of which was treated with casting and the second of which was treated with open reduction and internal fixation. All refractures healed.

Seven operatively treated patients (including the one with the infected nonunion, described above) had a second surgery to address delayed fracture-healing an average of five months (range, four to seven months) after injury. All seven fractures healed after plate-and-screw fixation and autogenous cancellous bone-grafting.

One patient had extensor tenolysis and three patients (two skeletally mature and one skeletally immature) had tendon transfers to compensate for substantial muscle loss after high-velocity open fractures.

Of the total of forty-six patients who were treated with open reduction and internal fixation primarily or in a subsequent procedure, twenty-seven patients (59%) had implant removal a mean of twenty-five months (range, thirteen to forty-eight months) after surgery. No refractures occurred in this group.

Evaluation

Arm-specific disability was evaluated with use of the validated Dutch form of the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire[25]. Scores range between zero and one hundred points, with a higher score indicating worse upper-extremity-specific disability and pain. Pain was scored as the mean of three different questions on the DASH, concerning pain at rest, pain with activity, and sleeping difficulties. The maximum possible pain score was five (severe pain resulting in sleep difficulties) and the minimum was one (no pain).

Depression during the previous week was quantified with use of the validated Dutch form of the Center for Epidemiologic Studies-Depression scale (CES-D)[26]. Scores range between zero and sixty points, with a higher score indicating a higher level of depression[26]. A mean CES-D of 13 was measured in a healthy Dutch population (scores above 16 indicate a depressive disorder)[26].

The validated Dutch version of the Pain Catastrophizing Scale (PCS) was used to measure misinterpretation or overinterpretation of nociception (i.e., the tendency toward excessively negative interpretation of nociception as indicating harm or hopelessness)[27,28]. Nociception is the physiological response to actual or potential tissue damage, and pain is the interpretation of nociception. Nociception occurs on a spectrum between healthy (e.g., stretch pain or post-workout pain) and unhealthy (e.g., a burn from a hot stove). The concept of "catastrophizing" captures the tendency to interpret nociception as more unhealthy than merited. The PCS contains thirteen questions regarding over-interpretation and misinterpretation of nociception. Scores range between 0 and 62 points, with a higher score indicating a more exaggerated negative orientation toward pain[28]. Scores between 12.1 and 13.9 are considered normal[27,28].

Range of motion was measured in a standardized fashion with a handheld goniometer by an independent observer not involved in the patient's care. Forearm rotation was measured with the elbow in 90° of flexion and with the arm at the patient's side. Elbow and wrist flexion and extension were measured, as was wrist radial and ulnar deviation. Grip strength was measured with use of a Jamar dynamometer (Asimow Engineering, Santa Monica, California) with the elbow at 90° of flexion and the forearm in neutral rotation. Grip strength was also calculated as a percentage of the unaffected arm. For patients with contralateral injuries, normative measurements, adjusted for age and sex[29], were used as controls.

Standardized anteroposterior and lateral radiographs of both bones of the injured forearm were made, with the forearm in neutral position, at the long-term follow-up visit. The radiographs were evaluated by two independent observers (J.C.G. and A.G.J.B.) in a blinded fashion. The amount and location of the radial bow were measured on the anteroposterior radiograph with use of the method described by Schemitsch and Richards[7]. First, a line is drawn from the bicipital tuberosity to the most ulnar aspect of the radius at the wrist[7]. Next, the point of maximum radial bow is connected to this line with a perpendicular line; the length of this line is the maximum radial bow in millimeters[7]. The location of the radial bow is the distance from the bicipital tuberosity to the perpendicular line, divided by the length of the total line from elbow to wrist[7].

The result was rated according to the method of Anderson et al.[1]: the result was considered excellent when union occurred with $<10°$ loss of wrist flexion-extension and $<25\%$ loss of pronation-supination; satisfactory when union occurred with $<20°$ loss of wrist flexion-extension and $<50\%$ loss of pronation-supination; unsatisfactory when union occurred with $>30°$ loss of wrist flexion-extension and $>50\%$ loss of pronation-supination; and a failure when there was nonunion with or without loss of motion.

Statistical Analysis

Continuous data were presented as the mean when normally distributed; otherwise, the medians were reported. Post-hoc power analysis with use of the Student t test indicated that a minimum of thirty patients per group provided 77% power to detect a 0.71 standard deviation difference in the arc of forearm rotation of skeletally mature and immature patients.

In bivariate analysis, the association between the DASH score with continuous independent variables was investigated with use of the Spearman correlation. The association between the DASH score with dichotomous independent variables (presence of associated arm injuries, compound fractures, sex, injury to dominant arm, occupation/heavy work [white/blue collar]) and skeletal maturity at the time of injury was investigated with use of the Mann-Whitney U test. The Kruskal-Wallis test for ordinal data was used for analysis of AO fracture type (type A3, B3, C1, C2, and C3). Associations with a p value of <0.05 were considered significant.

TABLE I Evaluation Scores*

Variable	No. (%)	Median (Range)	Interquartile Range†
Duration of final follow-up *(yr)*		21 (13 to 33)	
DASH entire cohort		4 (0 to 54)	0 to 8
DASH skeletally immature		3 (0 to 29)	0 to 7
DASH skeletally mature		5 (0 to 54)	1 to 10.5
PCS entire cohort		7 (0 to 40)	2 to 10
PCS skeletally immature		6 (0 to 22)	2 to 10
PCS skeletally mature		7.5 (0 to 40)	1 to 11
CES-D entire cohort		12 (8 to 33)	12 to 16
CES-D skeletally immature		13 (9 to 22)	12 to 15
CES-D skeletally mature		12 (8 to 33)	12 to 18
Pain entire cohort	20 (28%)		

*DASH = Disabilities of the Arm, Shoulder and Hand; PCS = Pain Catastrophizing Scale; and CES-D = Center for Epidemiological Studies-Depression scale. †25th to 75th percentile.

The number of independent variables that can be included in a multivariate model is limited by the overall sample size of the study. Therefore, we inserted seven variables (one variable for every ten patients) that were significant ($p < 0.03$) in the multivariate analysis. For each model, a multivariate analysis of variance was performed to assess significance, which indicates a linear relationship between at least one of the independent variables and the dependent variable (i.e., the DASH score). Backwards stepwise multiple linear regression analysis was used to analyze the ability of the independent variables to account for variation in the dependent variables, thereby accounting for confounding between the independent variables. This multiple linear regression model produced the adjusted R-squared (R^2), reflecting the percentage of the overall variability in the dependent variable explained or accounted for by the independent variables included in the multiple linear regression model.

Source of Funding
There was no external funding source.

Results

Long-Term Functional Outcome (Tables I and II)

Outcome Measures

The average DASH score of 8 points (and standard deviation of ±12 points) was near the mean DASH score (10.1) in healthy individuals in the United States[30]. There were no significant differences in DASH, CES-D, PCS, grip strength, and radiographic measures of mean location of radial bow and mean radial bow between skeletally mature and immature patients. The mean CES-D and PCS were comparable with Dutch community norms[26-28]. There were small but significant differences in the average wrist and forearm motion compared with the opposite arm. There were small but significant differences in elbow flexion-extension, wrist flexion-extension, pronation-supination, and radioulnar deviation arc favoring patients who were skeletally immature when they sustained the injury (Tables I and II). There was no significant difference in average pain score at the time of long-term follow-up between patients with and without retained plates and screws (mean 1.41 vs. mean 1.38; $p = 0.88$). The result, according to the system of Anderson et al.[1], was excellent or satisfactory in sixty-nine patients (97%) and unsatisfactory in two (3%). Because all fractures had healed by the time of follow-up, there were no failures according to the rating of Anderson et al.

TABLE II Range of Motion and Grip Strength at the Time of Final Follow-up*

	Skeletally Immature	Skeletally Mature	P Value
Motion			
Elbow flexion-extension arc *(deg)*	153 (100%)	143 (97%)	0.003
Wrist flexion-extension arc *(deg)*	142 (99%)	123 (89%)	0.001
Pronation-supination arc *(deg)*	169 (96%)	151 (87%)	0.002
Radioulnar deviation arc *(deg)*	59 (94%)	50 (87%)	0.008
Grip strength *(kg)*	32 (98%)	29 (89%)	Not significant

*Values are given as the mean, with the percent of that measured in the uninjured arm in parentheses.

TABLE III Results of Bivariate Analysis*

Variables	Correlation with Total DASH	P Value
Spearman correlation		
Elbow flexion-extension	–0.263	0.027
Pronation-supination	–0.283	0.017
Wrist flexion-extension	–0.320	0.006
Radioulnar deviation arc	–0.311	0.008
Grip strength	–0.334	0.007
Age at injury	0.286	0.016
Age at the time of follow-up	0.249	0.036
Pain	0.533	<0.001
Number of surgeries	NS	0.140
Follow-up time	NS	0.800
CES-D	0.276	0.020
PCS	0.261	0.028
Mann-Whitney U test		
Skeletally mature (yes/no)	NS	0.167
Associated injury (yes/no)		0.020
Open injury (yes/no)	NS	0.480
Sex (F/M)	NS	0.570
Injury to dominant arm (yes/no)	NS	0.341
Occupation	NS	0.540
Kruskal-Wallis test		
AO/OTA fracture type, 5 categories	NS	0.206

*DASH = Disabilities of the Arm, Shoulder and Hand; NS = not significant; CES-D = Center for Epidemiological Studies-Depression scale; PCS = Pain Catastrophizing Scale; AO/OTA = Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association.

Bivariate and Multivariate Analysis (Tables III and IV)

With bivariate analysis, there was a significant association between DASH scores and the arc of forearm rotation, the arc of wrist flexion and extension, the arc of radioulnar deviation, the arc of elbow flexion and extension, CES-D, PCS, age at injury, pain, and associated injuries. There was no significant association between DASH scores with radial bow, number of surgical procedures, follow-up time, patients that were skeletally mature at the time of injury, open injury, limb dominance, sex, occupation, and AO fracture type.

TABLE IV Results of Multivariate Analysis

Models and Variables	Adjusted R^2*	P Value
Best Model		
Grip strength	0.559	<0.001
Pain		
PCS†		
Ipsilateral injury		
Model 2		
Pain	0.40	<0.001

*R^2 = percentage of the overall variability in the dependent variable explained or accounted for by the independent variables in the model. †PCS = Pain Catastrophizing Scale.

Backward stepwise multiple linear regression was executed, starting with pronation-supination arc, grip strength, age at injury, pain, ipsilateral injury, CES-D, and PCS. This type of regression analysis initially includes all variables and then removes the least important and statistically nonsignificant variables one by one until the model retains only the strongest, significant explanatory variables. The final model included grip strength, pain, and PCS and accounted for 56% of the variability in DASH scores ($R^2 = 0.559$, $p < 0.001$). A model with pain alone explained 40% of the variability in DASH scores ($R^2 = 0.40$, $p < 0.001$).

Discussion

The long-term outcome of fractures of both forearm bones in our study is similar to the results reported in the short-term and mid-to-long-term follow-up studies, with the majority of patients having satisfactory outcome, modest reduction in grip strength and range of motion, and limited arm-specific disability[1-5]. As compared with the skeletally mature cohort, patients in the skeletally immature cohort had slightly but significantly better motion, on the average, but no difference in grip strength or disability.

This study should be interpreted in light of several shortcomings. The retrospective study design allows many opportunities for the introduction of bias, and we tried to minimize these by relying on the prospective trauma database and the long-term follow-up data collected as part of this study. Because the patients were treated over many years and by many surgeons, no consistent protocols were used and treatment strategies evolved. Many of the differences reported, although significant, are small and may be clinically irrelevant. The heterogeneity of injury characteristics and treatment also affects interpretation. The majority of the skeletally immature group were treated with a cast, had low-energy injuries, and had simple OA/OTA fractures (type A)[22]. Most of the skeletally mature patients were treated with plate-and-screw fixation and had high-energy injuries, and only 42% of the fractures were OA/OTA type A[22].

In line with the results of Lindenhovius et al. (41%), Doornberg et al. (36%), and Droll et al. (45%), pain explained 40% of the variation in DASH scores in our study[4,31,32]; in addition, this study shows that measures of misinterpretation of nociception and depression did help explain the relationship between pain and disability. These findings are notable because, even in a group of patients with limited impairment and disability, subjective factors such as pain and psychosocial factors such as depression and pain-catastrophizing are the factors that provide the best explanation of differences between impairment and disability.

DASH scores (mean, 8 points) in this cohort were low as compared with the DASH scores found by Droll et al. (19 ± 18) and Goldfarb et al. (12 ± 10), and even when compared with the general population in the United States (10 points)[4,5,30]. This is consistent with other studies[32] from the Netherlands, where DASH scores are lower than in the United States—something that merits further study. It has also been documented that there are marked differences between the Netherlands and the United States in the use of narcotic pain medications after fracture surgery[33]. We hypothesize that culture may have a strong influence on pain intensity and DASH scores, particularly in the correlation between impairment and disability.

In conclusion, our data confirm the findings of Droll et al. that skeletally mature patients have limited impairment after plate-and-screw fixation of fractures of both the radius and the ulna and extend this finding to patients who are skeletally immature at the time of injury, the majority of whom are treated with closed reduction and cast immobilization. This study also confirms that disability correlates better with subjective and psychosocial aspects of illness, such as pain and pain catastrophizing, than with objective measures of impairment.

Appendix

eA A table summarizing patient demographics is available with the electronic version of this article on our web site at jbjs.org (go to the article citation and click on "Supporting Data"). ■

Arjan G.J. Bot
Job N. Doornberg, MD, PhD
Anneluuk L.C. Lindenhovius, MD, PhD
C. Niek van Dijk, MD, PhD
Department of Orthopaedic Surgery,
Academic Medical Center Amsterdam, Meibergdreef 9,
1100 DD Amsterdam, The Netherlands.
E-mail address for A.G.J. Bot: a.g.j.bot@gmail.com

David Ring, MD, PhD
Orthopaedic Hand and Upper Extremity Service,
Massachusetts General Hospital, Yawkey Center,
Suite 2100, 55 Fruit Street,
Boston, MA 02114

J. Carel Goslings, MD, PhD
Trauma Unit, Department of Surgery,
Academic Medical Center,
Meibergdreef 9,
1100 DD Amsterdam, The Netherlands

References

1. Anderson LD, Sisk D, Tooms RE, Park WI 3rd. Compression-plate fixation in acute diaphyseal fractures of the radius and ulna. J Bone Joint Surg Am. 1975;57:287-97.

2. Chapman MW, Gordon JE, Zissimos AG. Compression-plate fixation of acute fractures of the diaphyses of the radius and ulna. J Bone Joint Surg Am. 1989;71:159-69.

3. Dodge HS, Cady GW. Treatment of fractures of the radius and ulna with compression plates. J Bone Joint Surg Am. 1972;54:1167-76.

4. Droll KP, Perna P, Potter J, Harniman E, Schemitsch EH, McKee MD. Outcomes following plate fixation of fractures of both bones of the forearm in adults. J Bone Joint Surg Am. 2007;89:2619-24.

5. Goldfarb CA, Ricci WM, Tull F, Ray D, Borrelli J Jr. Functional outcome after fracture of both bones of the forearm. J Bone Joint Surg Br. 2005;87:374-9.

6. Matthews LS, Kaufer H, Garver DF, Sonstegard DA. The effect on supination-pronation of angular malalignment of fractures of both bones of the forearm. J Bone Joint Surg Am. 1982;64:14-7.

7. Schemitsch EH, Richards RR. The effect of malunion on functional outcome after plate fixation of fractures of both bones of the forearm in adults. J Bone Joint Surg Am. 1992;74:1068-78.

8. Tarr RR, Garfinkel AI, Sarmiento A. The effects of angular and rotational deformities of both bones of the forearm. An in vitro study. J Bone Joint Surg Am. 1984;66:65-70.

9. Duncan R, Geissler W, Freeland AE, Savoie FH. Immediate internal fixation of open fractures of the diaphysis of the forearm. J Orthop Trauma. 1992;6:25-31.

10. Alpar EK, Thompson K, Owen R, Taylor JF. Midshaft fractures of forearm bones in children. Injury. 1981;13:153-8.

11. Bohm ER, Bubbar V, Yong Hing K, Dzus A. Above and below-the-elbow plaster casts for distal forearm fractures in children. A randomized controlled trial. J Bone Joint Surg Am. 2006;88:1-8.

12. Davis DR, Green DP. Forearm fractures in children: pitfalls and complications. Clin Orthop Relat Res. 1976;120:172-83.

13. Haasbeek JF, Cole WG. Open fractures of the arm in children. J Bone Joint Surg Br. 1995;77:576-81.

14. Ostermann PA, Richter D, Mecklenburg K, Ekkernkamp A, Muhr G, Hahn MP. [Pediatric forearm fractures: indications, technique, and limits of conservative management]. Unfallchirurg. 1999;102:784-90. German.

15. Rodríguez-Merchán EC. Pediatric fractures of the forearm. Clin Orthop Relat Res. 2005;432:65-72.

16. Sauer HD, Mommsen U, Bethke K, Langendorff HU. [Fractures of the proximal and middle-third of the lower arm in childhood (author's transl)]. Z Kinderchir Grenzgeb. 1980;29:357-63. German.

17. Schlickewei W, Oberle M. [Forearm fractures in children]. Unfallchirurg. 2005; 108:223-32. German.

18. Schmittenbecher PP. State-of-the-art treatment of forearm shaft fractures. Injury. 2005;36 Suppl 1:25-34.

19. Slongo TF. The choice of treatment according to the type and location of the fracture and the age of the child. Injury. 2005;36 Suppl 1:12-9.

20. Wilson JC Jr, Krueger JC. Fractures of the proximal and middle thirds of the radius and ulna in children. Study of end results with analysis of treatment and complications. Am J Surg. 1966;112:326-32.

21. Marsh JL, Slongo TF, Agel J, Broderick JS, Creevey W, DeCoster TA, Prokuski L, Sirkin MS, Ziran B, Henley B, Audigé L. Fracture and dislocation classification compendium - 2007: Orthopaedic Trauma Association Classification, Database and Outcomes Committee. J Orthop Trauma. 2007;21(10 Suppl):S1-133.

22. Fracture and dislocation compendium. Orthopaedic Trauma Association Committee for Coding and Classification. J Orthop Trauma. 1996;10 Suppl. 1:v-ix, 1-154.

23. Gustilo RB, Anderson JT. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses. J Bone Joint Surg Am. 1976;58:453-8.

24. Henry AK. Extensile exposure applied to limb surgery. 2nd ed. Edinburgh: Churchill Livingstone; 1973.

25. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The Upper Extremity Collaborative Group (UECG). Am J Ind Med. 1996;29:602-8.

26. Cuijpers P, Smit F, Willemse G. Predicting the onset of major depression in subjects with subthreshold depression in primary care: a prospective study. Acta Psychiatr Scand. 2005;111:133-8.

27. Osman A, Barrios FX, Gutierrez PM, Kopper BA, Merrifield T, Grittmann L. The Pain Catastrophizing Scale: further psychometric evaluation with adult samples. J Behav Med. 2000;23:351-65.

28. Severeijns R, van den Hout MA, Vlaeyen JW, Picavet HS. Pain catastrophizing and general health status in a large Dutch community sample. Pain. 2002;99:367-76.

29. Günther CM, Bürger A, Rickert M, Crispin A, Schulz CU. Grip strength in healthy Caucasian adults: reference values. J Hand Surg Am. 2008;33:558-65.

30. Hunsaker FG, Cioffi DA, Amadio PC, Wright JG, Caughlin B. The American Academy of Orthopaedic Surgeons outcomes instruments: normative values from the general population. J Bone Joint Surg Am. 2002;84:208-15.

31. Doornberg JN, Ring D, Fabian LM, Malhotra L, Zurakowski D, Jupiter JB. Pain dominates measurements of elbow function and health status. J Bone Joint Surg Am. 2005;87:1725-31.

32. Lindenhovius AL, Buijze GA, Kloen P, Ring DC. Correspondence between perceived disability and objective physical impairment after elbow trauma. J Bone Joint Surg Am. 2008;90:2090-7.

33. Lindenhovius AL, Helmerhorst GT, Schnellen AC, Vrahas M, Ring D, Kloen P. Differences in prescription of narcotic pain medication after operative treatment of hip and ankle fractures in the United States and The Netherlands. J Trauma. 2009;67:160-4.