Comparison of Short and Long Arm Plaster Casts for Displaced Fractures in the Distal Third of the Forearm in Children

BY GAVIN R. WEBB, MD, ROBERT D. GALPIN, MD, FRCSC, AND DOUGLAS G. ARMSTRONG, MD

Investigation performed at The Women's and Children's Hospital of Buffalo, Buffalo, New York

Background: Various methods of cast immobilization have been recommended for the treatment of distal forearm fractures in children. The purpose of this study was to determine if short arm casts are as effective as long arm casts in the treatment of displaced fractures of the distal third of the forearm in these patients.

Methods: In a prospective randomized trial, consecutive patients, four years of age or older, who presented to The Women's and Children's Hospital of Buffalo with a displaced fracture of the distal third of the forearm were randomized to treatment with a short or long arm plaster cast. Radiographs were analyzed for displacement, angulation, and deviation at the time of injury, after reduction, and at subsequent follow-up intervals. The cast index at the fracture level, used to assess the quality of the cast molding, was determined from the postreduction radiographs. Changes between postreduction and final values for displacement, angulation, and deviation; the ranges of motion of both wrists and elbows; the need for physical therapy; and responses to a questionnaire used to evaluate the effects of the cast on activities of daily living were compared between the groups.

Results: One hundred and thirteen of the 151 patients who were assessed for eligibility were analyzed. The follow-up rate was 92%, and the average duration of follow-up was eight months. Sixty long arm casts and fifty-three short arm casts were used. There were no significant differences between the two groups with regard to patient demographics, initial fracture characteristics, mechanism of injury, cast index, or the change in displacement, angulation, or deviation during treatment. The fractures that lost reduction in the cast had significantly higher cast indices, indicating poor cast-molding. A comparison of partially and completely displaced fractures revealed no difference between the groups with regard to the change between the postreduction and final amount of displacement. Patients treated with a short arm cast missed fewer school days and were less likely to require assistance with various activities of daily living.

Conclusions: A well-molded short arm cast can be used as effectively as a long arm cast to treat fractures of the distal third of the forearm in children four years of age and older, and they interfere less with daily activities.

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

Forearm fractures in children and adolescents are very frequent injuries, with the distal metaphysis being the most common site[1-3]. Approximately 75% of all forearm fractures in children involve the distal third of the forearm[4]. Various methods of cast immobilization have been recommended in order to prevent the recurrence of angulation or displacement. Currently, there is no clear consensus regarding treatment of fractures of the distal third of the radius and ulna, although much of the literature supports the use of long arm casts[4-14]. A long arm cast prevents flexion and extension of the elbow as well as forearm rotation, which theoretically minimizes the risk of angulation or displacement. However, there is also support for the use of below-the-elbow immobilization to treat these injuries, as Charnley advocated "radial slabs" for distal radial fractures[15]. A short arm cast that is well molded to the normal contours of the arm should control supination and pronation.

In a retrospective review of 558 fractures of the distal third of the forearm treated in a well-molded short arm cast, Chess et al. described a cast index to determine the quality of the molding of the cast to the normal contours of the child's forearm[16]. The index was determined by dividing the sagittal width of the cast by the coronal width of the cast at the frac-

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ture site (Fig. 1) and was shown to be 0.7 for a cast used on the distal part of a normal forearm of a child. Chess et al. reported that 10% of the fractures in their series had substantial changes in angulation, and all of the failures following supination-extension injuries were related to poor cast-molding as demonstrated by the cast index. These results suggest that short arm casts, if applied with appropriate molding, can be effective in the treatment of fractures of the distal third of the forearm in children.

Short arm casts have the potential advantage of resulting in less temporary disability and inconvenience than long arm casts, as elbow motion is allowed. However, long arm casts theoretically are more likely to maintain reduction because elbow motion is restricted and the long wrist flexors and extensors cannot deform the fracture. Most children are more active than most adults and may therefore be more likely to sustain deformity at the fracture site if the cast does not fully immobilize the joints on either side of it. Furthermore, a less experienced surgeon or resident may be more likely to achieve a satisfactory result if he or she uses a long arm cast to fully immobilize a fracture in a child. We designed a prospective randomized trial to compare short arm and long arm casts for the treatment of displaced fractures of the distal third of the forearm in children. Our hypothesis was that short arm casts are as effective as long arm casts in the treatment these injuries.

Materials and Methods

After approval was obtained from our institutional review board, all displaced fractures of the distal third of the forearm seen at the emergency department of The Women's and Children's Hospital of Buffalo between April 2002 and December 2003 were included in the study unless they met any of the exclusion criteria. The exclusion criteria were an open fracture, a pathologic fracture, a refracture through preexisting fracture lines, and a fracture in a patient younger than four years of age or one with closed physes. Informed consent for participation in this study was obtained from the parents prior to treatment randomization by the orthopaedic residents, all of whom had been fully trained in the proper application of plaster casts. Additional assent was obtained from all patients who were seven years of age or older. Patients were then randomized to be treated with either a short or a long arm cast on the basis of whether the last digit of their medical record number was odd or even.

The fracture was manipulated and reduced by a third or fourth-year orthopaedic resident in the fashion described by Charnley[15]; appropriate analgesia and sedation were provided by the emergency department staff. The arm was then held by an assistant while a circumferential plaster-of-Paris cast was applied. If no assistant was available, fingertraps were applied prior to the reduction, but the arm was not suspended until after the manipulation was performed. When the patient was being treated with a long arm cast, the short arm portion was applied first and molded and then the plaster was extended above the elbow. Postreduction radiographs were analyzed to determine the acceptability of the reduction. Malaligned fractures were reduced again and placed in the same type of cast. If an acceptable closed reduction could not be obtained, the patient was scheduled for operative treatment.

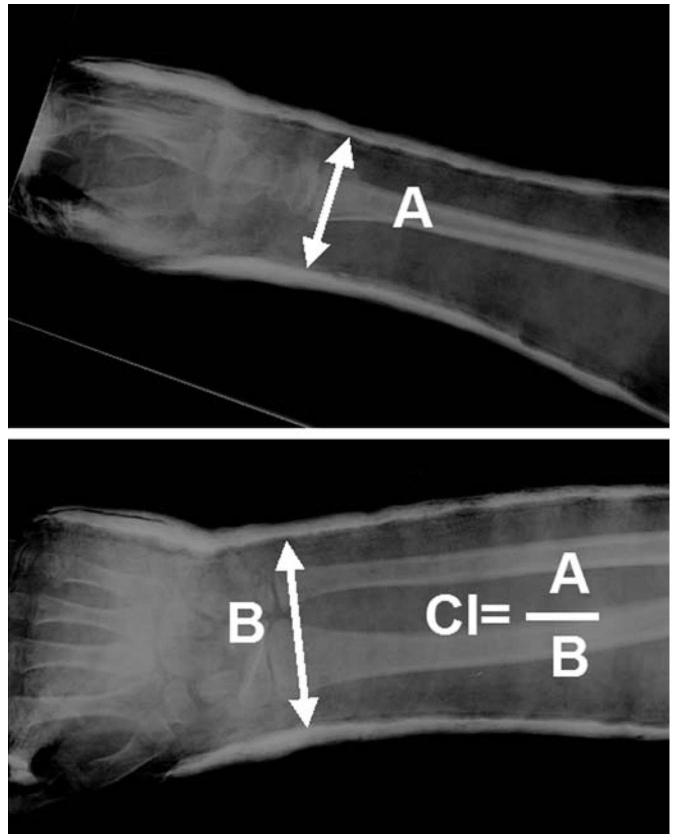

Fig. 1
The cast Index (CI) is determined by dividing the sagittal cast width (A) by the coronal cast width (B) at the fracture site.

The patients were followed according to the standard protocol at our institution. The initial follow-up visit was within seven to ten days after the injury, and radiographs were made with the cast in place at that time. If the alignment was still acceptable, the initial cast was left in place and the patient was followed again at four weeks after the injury with repeat radiographs with the arm in the cast. If the reduction was considered to be unacceptable at the first follow-up visit, a remanipulation, in the operating room, with the patient under general anesthesia was scheduled.

At four weeks after the injury, the cast was either removed or left in place, depending on the radiographic and clinical evidence of healing. Long arm casts were cut to short arm casts at this point if further immobilization was required. If the cast was left in place, the patient was seen two weeks later for radiographs to be made with the arm out of the cast. The angulation, deviation, and displacement of the fracture fragments were measured with standard means, with use of the computerized on-screen ruler and goniometer (SIENET PACS; Siemens Medical Solutions, Malvern, Pennsylvania), on all digital radiographs. The cast index was calculated by dividing the inner sagittal width of the cast by the inner coronal width of the cast on the initial postreduction radiograph. Both measurements were made at the level of the fracture for consistency. The ideal cast index is 0.7 for the distal third of the forearm. A high cast index indicates poor cast-molding[16]. Loss of reduction was defined as an increase of >10° of angulation or deviation and >20% displacement compared with the postreduction values.

The ranges of motion of the wrists and elbows on the injured and contralateral sides were measured with a goniometer and recorded when the cast was first removed for a baseline measurement. The patients were then instructed to perform range-of-motion exercises at home. They returned for a clinical examination at eight to ten weeks after the injury, at which time the ranges of motion of the wrists and elbows were recorded again. Physical therapy was prescribed for patients who did not have a normal range of motion at this follow-up visit. Those patients were seen for one last clinical check-up and measurement of motion. Patients who had a normal range of motion at the eight to ten-week follow-up appointment were discharged from additional follow-up visits. The usual practice at our institution is to discharge patients who have had a fracture of the distal third of the forearm once the fracture is fully healed and a full range of motion at the relevant joints has been regained. A questionnaire relating to the impact of the cast on activities of daily living was completed at the patient's final follow-up visit. A telephone interview with the patient or parent was conducted at least six months after the injury to determine whether there had been any refractures. The addition of this telephone interview was the only change to our usual treatment and follow-up protocol that was instituted in order to conduct this study.

Statistical Methods

An a priori power calculation was done to determine group size. It was determined that, with approximately fifty patients in each group, there was at least an 85% chance (statistical power) of detecting a mean difference of ≥4° in the change in angulation, from the postreduction to the final assessment, between cast groups. An alpha value of 0.05 and an independent Student t test were used in this calculation.

The clinical and radiographic outcomes of treatment with the short arm cast were compared with those of treatment with the long arm cast with use of parametric and nonparametric analyses as appropriate for the data. The independent-sample Student t test, Pearson chi-square test, and Mann-Whitney U test were performed with use of SPSS version-11.0 software (Chicago, Illinois). A p value of <0.05 was considered to be significant.

Results

Figure 2 provides a flow diagram of the patients' progress through the trial. One hundred and fifty-one patients presented with a fracture of the distal third of the forearm in the

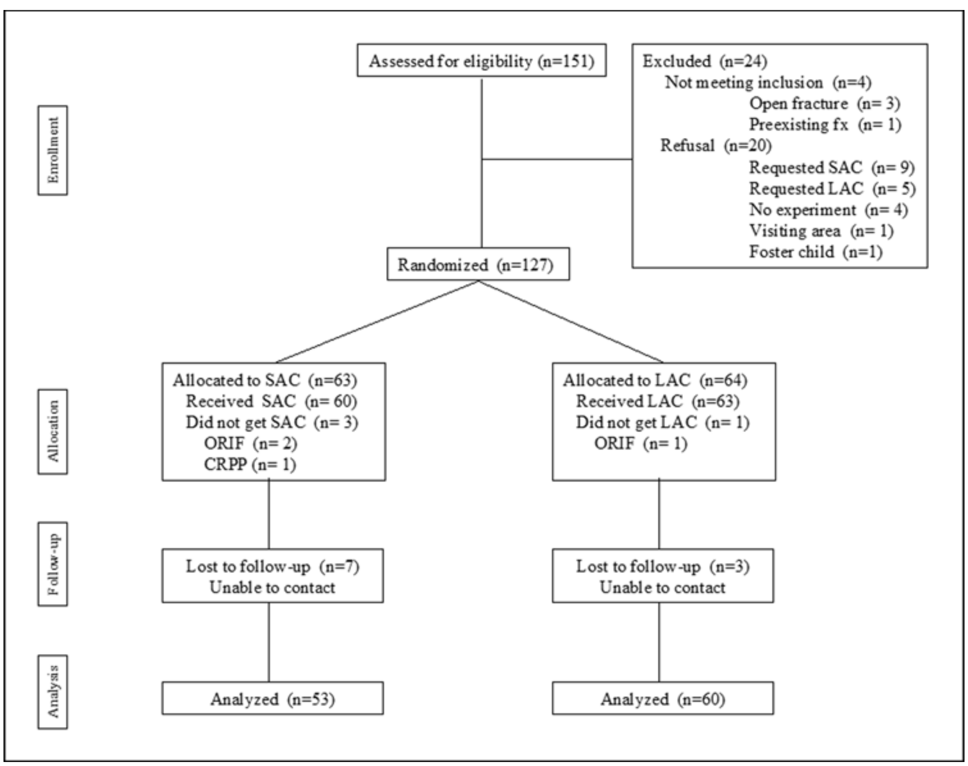

Fig. 2

Flow diagram of the patients' progress through the trial. SAC = short arm cast, LAC = long arm cast, ORIF = open reduction and internal fixation, and CRPP = closed reduction and percutaneous pinning.

TABLE I Patient Demographics and Fracture and Cast Characteristics

	Short Arm Cast	Long Arm Cast	P Value
Age*† *(yr)*	10.15 ± 2.9	9.53 ± 3.1	0.284
Male gender	43/53 (81%)	42/60 (70%)	0.171
Duration in cast* *(days)*	37.6 ± 8.8	40.6 ± 10.1	0.099
Follow-up time *(mo)*	7.61 (3.5-11)	7.87 (3.5-11)	0.177
Follow-up rate *(%)*	53/60 (88.3%)	60/63 (95.2%)	
Cast index*	0.710 ± 0.048	0.721 ± 0.065	0.302
Initial displacement* *(%)*	46.8 ± 42.5	51.3 ± 42.3	0.181
Initial angulation* *(deg)*	25.8 ± 11.6	27.7 ± 12.1	0.775
Initial deviation* *(deg)*	5.1 ± 7.8	6.6 ± 9.4	0.097
Postreduction displacement* *(%)*	8.4 ± 17.4	9.6 ± 13.7	0.673
Postreduction angulation* *(deg)*	5.8 ± 4.6	5.5 ± 4.7	0.754
Postreduction deviation* *(deg)*	0.45 ± 1.7	0.97 ± 2.6	0.229

*The values are given as the mean and standard deviation. †The age range in the series was four to sixteen years.

specified time-frame, and they were assessed for eligibility. Twenty-four patients were excluded: four met exclusion criteria, and twenty revfused to participate. Nine of the patients who refused to participate specifically requested a short arm cast and five requested a long arm cast. This left 127 patients to be randomized. Four were then excluded because they required operative treatment for an irreducible fracture and ten were lost to follow-up, leaving 113 patients for analysis. The average age was 9.8 years (range, four to sixteen years), and 75% of the patients were male. The average duration of follow-up was 7.7 months (range, 3.5 to eleven months), and the follow-up rate was 92%. Sixty long arm casts and fifty-three short arm casts were used. As shown in Table I, there were no differences between the cast-type groups with respect to the above parameters. There was also no significant difference between the two groups with regard to the initial or postreduction displacement, angulation, or deviation of the fracture; cast index; distribution of fracture types (p = 0.647) (Fig. 3), or fracture mechanism. The mechanism was supination-extension (apex-volar angulation) for 92.5% of the fractures treated with a short arm cast and 90% of those treated with a long arm cast. The mechanism of the remaining fractures was flexion-pronation (apex-dorsal angulation), and the frequency of that mechanism also did not differ according to cast type (p = 0.65).

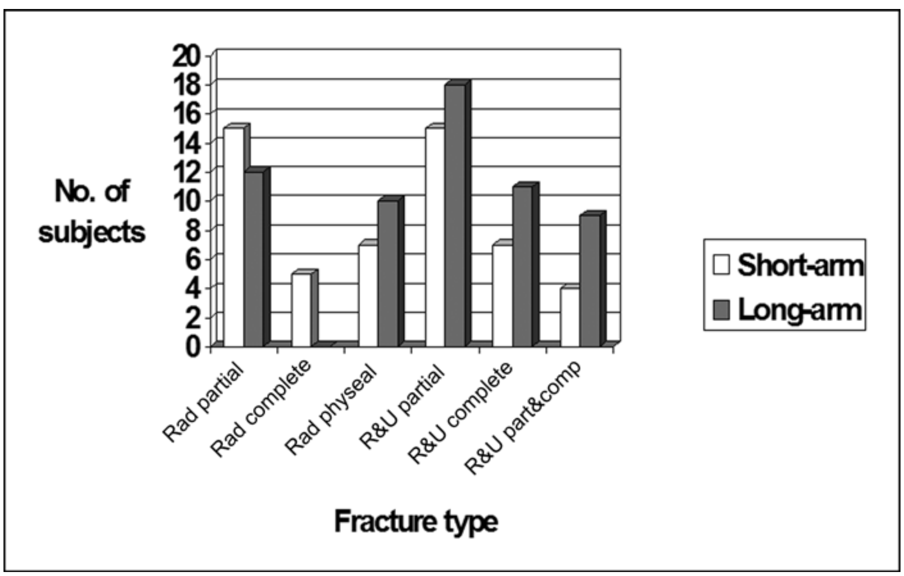

Fig. 3

Distribution of fracture types according to cast type. There was no significant difference between two cast-treatment groups (p = 0.647). Rad = radius, R&U = radius and ulna, and part&comp = one bone with partial displacement and the other with complete displacement.

TABLE II Mean Differences Between Postreduction and Final Values for Displacement, Angulation, and Deviation According to Cast Type

	Short Arm Cast*	Long Arm Cast*	P Value
Change in displacement *(%)*	0.28 ± 1.52	1.9 ± 6.02	0.06
Change in angulation *(deg)*	2.08 ± 3.11	3.37 ± 5.15	0.116
Change in deviation *(deg)*	0.57 ± 2.13	1.72 ± 4.36	0.084

*The values are given as the mean and standard deviation.

There was no significant difference between the two groups with regard to the change between the postreduction and final values for displacement, angulation, or deviation (Table II). Eleven fractures—nine treated with a long arm cast and two treated with a short arm cast—lost reduction in the cast ($p = 0.045$). The cast index differed significantly ($p = 0.001$) between the group that lost reduction (mean index [and standard deviation], 0.79 ± 0.06) and the group that maintained reduction (0.71 ± 0.05). The cast type also differed significantly ($p = 0.045$) between the two groups. Three patients, all treated with a long arm cast, had an increase of >15° of angulation or deviation and a >30% increase in displacement compared with postreduction values. The mean cast index for those patients was 0.81 ± .005, which was significantly different from the index for all other patients ($p = 0.001$). Figure 4 shows the cast indices for the patients who maintained reduction and those who lost reduction, grouped by cast type.

Comparison of the partially and completely displaced fractures demonstrated a significant difference, in both cast-type groups, with regard to the magnitudes of the postreduction and final displacement values (Fig. 5). However, there was no significant difference between the partial and complete fractures, treated with either cast type, with regard to amount of reduction lost—i.e., there was no significant difference with respect to the change between the postreduction and final values of displacement, angulation, or deviation (Fig. 6). In other words, the reduction of completely displaced fractures was not as anatomic as that of partially displaced fractures, but there was no difference in the maintenance of that reduction with either cast type.

When the cast was initially removed, the range of elbow motion was significantly less in the group treated with a long arm cast, but there was a minimal (if statistically significant) difference in the final range of motion between the two cast-treatment groups. At the time of cast removal, the difference in the arcs of elbow motion between the injured and contralateral sides averaged 1.1° ± 3.6° in the short-arm-cast group and 29.8° ± 15.9° in the long-arm-cast group ($p < 0.001$). The differences in the arcs of wrist motion between the injured and contralateral sides at the time of cast removal av-

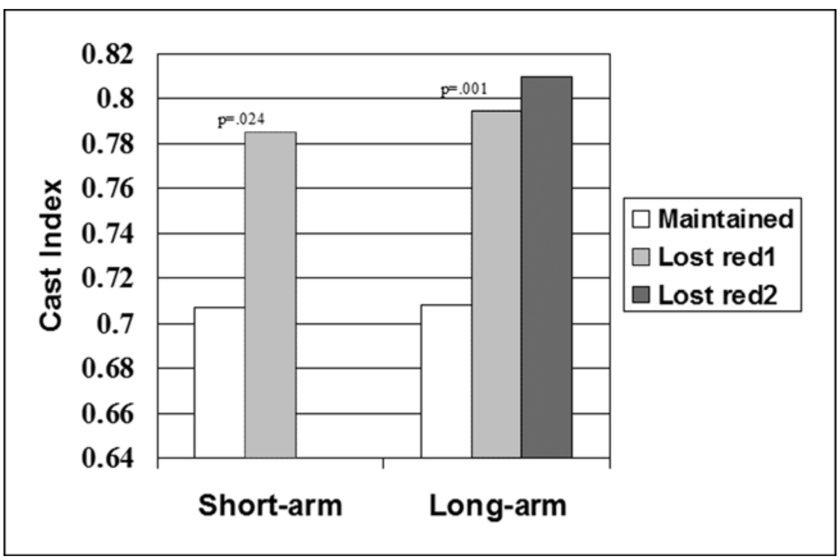

Fig. 4

Cast indices for the fractures that maintained reduction and those that lost reduction, according to cast type. There was a significant difference in the cast index between those that maintained and those that lost reduction in both cast-treatment groups. Lost red1 = lost reduction of 10° of angulation or deviation or >20% displacement, and Lost red2 = lost reduction of >15° of angulation or deviation or >30% displacement.

TABLE III Responses to Activities of Daily Living Questionnaire, According to Cast Type

	Short Arm Cast	Long Arm Cast	P Value
Missed school* *(days)*	0.56 ± 0.89	1.6 ± 1.3	0.001
Needs help dressing	6/48 (13%)	48/58 (83%)	0.001
Able to shower	39/45 (87%)	18/54 (33%)	0.001
Needs help in school	7/35 (20%)	26/40 (65%)	0.001
Needs help using toilet	2/47 (4%)	23/35 (66%)	0.001
Needs help eating	4/45 (9%)	14/44 (32%)	0.03
Unable to write	5/23 (22%)	31/40 (78%)	0.001
Time to regain range of motion* *(days)*	7.3 ± 5.1	17.3 ± 8.4	0.001
Activities of daily living			0.001
No difficulty	24/49 (49%)	0/58 (0%)	
Difficult, no help required	22/49 (45%)	23/58 (40%)	
Difficult, help required	3/49 (6%)	35/58 (60%)	

*The values are given as the mean and standard deviation.

eraged 47.1° ± 19.3° and 53.6° ± 22.6° in the short and long-arm-cast groups, respectively, which was not a significant difference between the cast-type groups (p = 0.193). The mean final difference in the arc of elbow motion between the injured and uninjured sides was 0.4° ± 1.8° in the short-arm-cast group and 3.1° ± 5.9° in the long-arm-cast group, which was a significant difference between cast-type groups (p = 0.016). The final differences between the injured and normal sides with regard to the arc of wrist motion averaged 6.3° ± 8.6° and 10.7° ± 14.8° in the short and long-arm-cast groups, respectively (p = 0.142). One patient who was treated with a long arm cast required three weeks of physical therapy to regain a full range of motion of the elbow.

The results obtained with the questionnaire are shown in Table III. Patients who were treated with a long arm cast missed significantly more days of school and a significantly higher percentage of them required help to dress, were unable to write, required help in school, and had difficulty with activities of daily living. The self-reported time required to regain a normal range of motion of both the wrist and the elbow was 17.3 ± 8.4 days for those treated with a long arm cast and 7.3 ± 5.1 days for those treated with a short arm cast (p = 0.001).

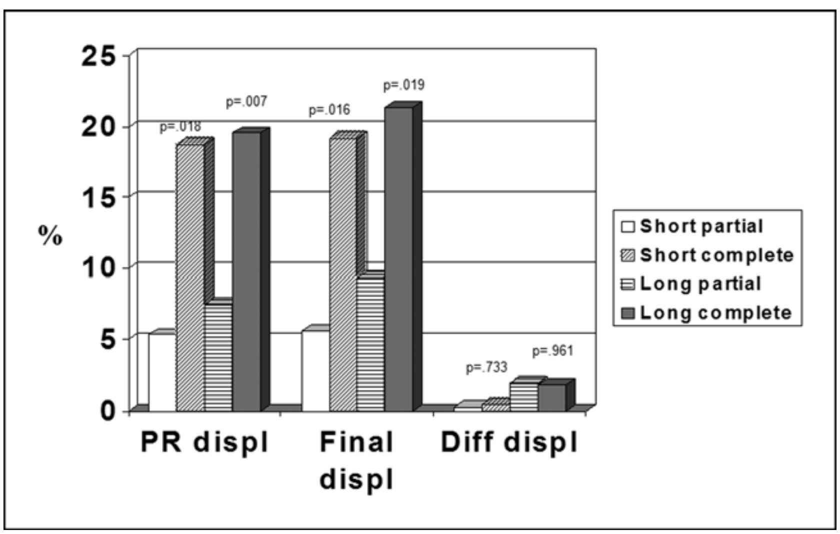

Fig. 5

The magnitudes of the postreduction and final displacements were significantly greater for the complete fractures than for the partial fractures, but there was no significant difference in the change in displacement from the postreduction to the final values between the partial and the complete fractures in either cast-treatment group. PR displ = postreduction displacement, Final displ = final displacement, and Diff displ = difference between the postreduction and final displacement.

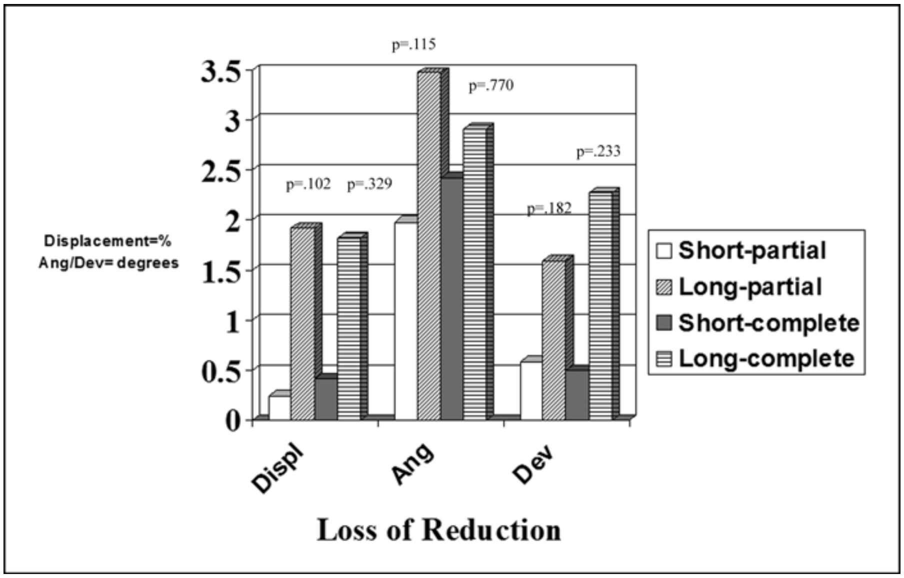

Fig. 6

There was no significant difference between the partial and complete fractures, in either cast-treatment group, with respect to the change between the postreduction and final values for displacement, angulation, or deviation. Displ = displacement, Ang = angulation, and Dev = deviation.

When asked to subjectively rate the effect of the cast on activities of daily living, 94% of the patients treated with a short arm cast said that they either had no difficulty or had some difficulty that did not require assistance. In comparison, 60% of the patients treated with a long arm cast found their activities of daily living to be difficult enough to require assistance.

There were no refractures in either group.

Discussion

The short and long-arm-cast groups were similar with respect to age, gender, fracture type, and initial fracture characteristics, which indicated that the randomization had been effective. Only eleven fractures lost reduction. The only variables that differed significantly between the patients who lost reduction and those who maintained reduction were the cast type and cast index. Significantly more patients treated with a long arm cast lost reduction ($p = 0.045$), but lost reduction was associated with poor cast molding (a higher cast index) in both cast-type groups. The finding of more cases of lost reduction in the long-arm cast group was unexpected. A possible explanation for it is that long arm casts are technically more difficult to apply, which results in poorer molding around the forearm. However, there was no significant difference in the mean cast index between the short and long arm casts. Perhaps the mean cast index does not accurately represent the number of poorly molded casts in each group. Because it is measured on the basis of the inner cast diameter, the cast index can be affected by the amount of padding if the padding is applied asymmetrically. In other words, the cast index would be altered if more padding were applied to one side of the forearm rather than evenly circumferentially. Similarly, asymmetric swelling could also be a source of error in the cast index.

A potential limitation of this study is that ten patients were lost to follow-up. Seven of the ten had been treated with a short arm cast. It is unknown whether the reduction of those fractures had been maintained in the cast. If all ten fractures lost reduction according to our parameters, a total of nine fractures treated with a short arm cast and twelve treated with a long arm cast would have lost reduction in the study. However, if a worst-case scenario were assumed and those cases were assigned the highest values for displacement (30%), angulation (18°), and deviation (23°) seen in the study, there would still be no significant differences between the two cast groups. When these cases are included, the respective means and standard deviations in the short and long-arm-cast groups are 3.75% ± 9.73% and 3.24% ± 8.42% ($p = 0.76$) for displacement, 3.93° ± 5.93° and 4.06° ± 5.93° ($p = 0.90$) for angulation, and 3.18° ± 7.53° and 2.73° ± 6.24° ($p = 0.72$) for deviation.

When the parameters considered to indicate lost reduction were increased to a >30% change in displacement and a >15° change in angulation or deviation, there were only three patients, all treated with a long arm cast, who lost reduction. With the remodeling potential of this patient population, even this amount of lost reduction has minimal clinical relevance. As Blount showed, normal anatomy is restored in the immature forearm over time, even with bayonet apposition of the fracture fragments[4]. No fractures in our study required repeat reduction because of substantial displacement during immobilization. The consequence of lost reduction in this patient population is a deformity that takes longer to remodel and that can be an initial cosmetic concern to the patient and parents.

Analysis of the patients according to whether they had a completely or partially displaced fracture also demonstrated no differences between the results, in either cast-type group. More displacement remained after reduction, and at the time of final follow-up, of the completely displaced fractures. However, there was no difference in the amount of reduction lost during the immobilization between the completely and partially displaced fractures. This suggests that short arm casts are equally effective for partially and completely displaced fractures.

As expected, there was a significant difference in the range of elbow motion between the long and short-arm-cast groups after the casts were removed. By the time of final follow-up, this difference was very small and clinically irrelevant, although it remained statistically significant. Children seem to tolerate immobilization of the elbow better than adults, as illustrated by the fact that only one patient required short-term physical therapy to regain a normal range of motion. It appears that loss of motion in association with the use of a long arm cast is not an important short or long-term issue for children.

The questionnaire demonstrated significant differences between the two groups in terms of activities of daily living during the period of cast treatment. The questionnaire took into account patients who were not yet enrolled in school at the time of the injury and also those who normally required assistance for the activity in question. Also, patients who normally wrote with the contralateral arm were excluded from the question about writing ability. The questionnaire results support the idea that children have less difficulty functioning while wearing a short arm cast. However, it should be noted that the children wearing the long arm cast missed an average of only one more day of school than did the short-arm-cast group. While statistically significant, this difference has minimal clinical relevance.

In our practice, as in this study, we limit the use of short arm casts to patients who are at least four years old. In general, the forearm of a patient who is younger than four is too short to hold a short arm cast in place. We therefore extend the cast above the elbow in 90° of flexion for these younger patients.

Plaster of Paris was used to make the casts in this study. We have found it to be easier to mold and more forgiving of swelling than fiberglass. We are not comfortable with applying cylindrical fiberglass casts for the treatment of acute fractures, and we caution against extrapolating our results to casts made with different material. Judicious molding should be used to minimize swelling. Detailed instructions should be provided to the patient and family regarding strict elevation of the arm for the first twenty-four to forty-eight hours. In addition, warning signs that would necessitate a follow-up call or a return visit should be explained to them.

This study supports the use of a well-molded short arm cast for the treatment of fractures of the distal third of the forearm in children who are four years of age or older. In agreement with the retrospective review by Chess et al.[16], our study showed the importance of proper molding of the cast. This was true for both short and long arm casts. This study adds the strength of a prospective randomized trial to the information provided by the previous review. Whereas most of the poorly molded casts in that previous series were applied by junior house staff or non-orthopaedic personnel, our casts were all applied by orthopedic residents in their third or fourth year of training, with varied amounts of experience in pediatric orthopaedics. There is a learning curve in the application of a well-molded cast, and the majority of poorly molded casts were applied by residents early in their pediatric orthopaedic training. If well-molded short arm casts are to be used to treat these fractures, it is essential that the individual applying the cast is well trained in the principles of cast treatment.

Most of the literature supports use of long arm casts to treat fractures of the distal third of the forearm in children. Our prospective randomized trial demonstrated no difference in the ultimate outcome of treatment between short and long arm casts used for fractures of the distal third of the radius and ulna in children and adolescents four years of age or older. Thus, either a long or a short arm cast can be used, but proper molding of either is mandatory. Short arm casts, however, can result in less inconvenience to the patient and family. ■

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Gavin R. Webb, MD
Seacoast Orthopedics and Sports Medicine, Marsh Brook Professional Center, 237 Route 108, Somersworth, NH 03878-1517. E-mail address: gavinwebb@md.aaos.org

Robert D. Galpin, MD, FRCSC
Department of Orthopaedics, The Women's and Children's Hospital of Buffalo, 219 Bryant Street, Buffalo, NY 14222. E-mail address: rgalpin@acsu.buffalo.edu

Douglas G. Armstrong, MD
Department of Orthopedics, Rainbow Babies and Children's Hospital, 11100 Euclid Avenue, Cleveland, OH 44120. E-mail address: douglas.armstrong@uhhs.com

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