

A Prospective Study on the Effectiveness of Cotton Versus Waterproof Cast Padding in Maintaining the Reduction of Pediatric Distal Forearm Fractures

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Background: Distal forearm fractures, one of the most common fractures seen in the pediatric population, are regularly treated by closed reduction and casting. Our study investigates the effectiveness of Gore-Tex-lined casting in maintaining the reduction of 100% displaced distal forearm fractures compared with traditional cotton-lined casts.

Methods: We screened all patients from February 2007 to July 2009 who presented to Children's Hospital in Birmingham, AL with a distal radius fracture. Only patients with 100% displaced distal radius fractures were eligible to be assigned to either the cotton-lined or Gore-Tex-lined cast groups. Power analysis was performed to identify an adequate patient sample size. The mean maximum change between initial post-reduction x-rays and follow-up x-rays for anterior-posterior (AP) angulation, AP displacement, lateral angulation, and lateral displacement of the radius were calculated for both cotton and Gore-Tex groups. The rate of subsequent intervention and/or unacceptable results for each group was also analyzed.

Results: Seven hundred and twenty-two patients were treated with distal radius fractures at our hospital with 59 patients eligible for inclusion in our study. Thirty-six of our patients were treated with cotton-lined casts, and 23 patients were treated with Gore-Tex-lined cast. The mean maximum change in AP angulation, AP displacement, lateral angulation, and lateral displacement of the radius after initial reduction was 9.2 degrees, 6.9%, 13.9 degrees, and 13.6%, respectively, for the cotton-lined cast group and 7.7 degrees, 6.1%, 14.6 degrees, and 9.6%, respectively, for the Gore-Tex-lined cast group. There were no statistical differences between the means of the 4 measurements ($P = 0.33, 0.69, 0.73, \text{ and } 0.10$, respectively). There were also no significant differences between groups for final AP and lateral angulation and displacement. Subgroup analysis showed no significant differences in all measurements between cotton and Gore-Tex groups.

Conclusion: Gore-Tex and cotton-lined casts are equally effective in their ability to maintain the reduction of 100% displaced

distal forearm fractures. Thus, Gore-Tex-lined casts can be offered to pediatric patients immediately after closed reduction of distal radius fractures of any severity.

Level of Evidence: Therapeutic level II.

Key Words: pediatric forearm fracture, closed reduction, Gore-Tex cast, waterproof cast, pediatric distal radius fracture

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Distal forearm fractures are among the most common injuries sustained by children and are commonly treated by closed reduction and casting. This conservative treatment frequently leads to excellent functional results due to a child's capacity to correct residual deformity. In his study on the remodeling of pediatric distal forearm fractures, Friberg¹ reported that the residual angulation after closed reduction self-corrected at a rate of 0.9 degree/month in the dorsovolar plane and 0.8 degree/month in the radioulnar plane. However, not all patients treated with closed reduction will have successful results as up to 34% of distal radius fractures can show significant redisplacement after an acceptable initial closed reduction.²

Earlier distal forearm fracture studies have analyzed only patients treated with traditional cotton-lined casts. Recently, with the introduction of Gore-Tex cast liners, the care of patients wearing a cast has been greatly simplified. As these waterproof cast liners are designed to repel liquid and permit evaporation, patients with Gore-Tex casts can now shower, bathe, and even swim immediately after the application of their casts. There is also strong evidence that suggests Gore-Tex casts improve hygiene, comfort, and patient and physician satisfaction scores.^{3–8}

Currently, there are no published data evaluating the effectiveness of Gore-Tex cast liner in maintaining the reduction of pediatric distal forearm fractures when applied immediately after reduction. Many physicians have concerns about the ability of a Gore-Tex-lined cast to effectively maintain the reduction of a severely displaced distal forearm fracture. We designed a prospective study to compare cotton and Gore-Tex-lined casts for the treatment of pediatric displaced distal forearm fractures. Our hypothesis was that Gore-Tex-lined casts are as effective as cotton-lined casts in the treatment of these injuries.

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METHODS

After the approval of the study proposal by our institutional review board, all patients who presented at the Children's Hospital of Alabama with a radius fractures of the distal third forearm between February 2007 and July 2009 were evaluated for inclusion in our study. We included only 100% displaced distal radius fractures with and without associated ulna fractures. In addition, all patients must have received a minimum of 6 weeks of follow-up care to be included in the final analysis. We excluded any children more than 14 years of age and Salter-Harris type III-V injuries.

All patients presenting between February 2007 and July 2008 were casted with traditional cotton cast liner whereas all patients treated between August 2008 and July 2009 were casted with Gore-Tex cast liner (WL Gore & Associates, Flagstaff, AZ, USA). We used this method for its ease of implementation and to minimize confusion among the many residents who helped with the treatment of these pediatric fractures during this timeframe.

All of the fractures in this study were reduced under anesthesia by a second or third-year orthopaedic surgery resident from the University of Alabama at Birmingham Hospital System. A cast technician with Gore-Tex casting experience was present for assistance during all procedures. After fracture reduction, a long-arm fiberglass cast was applied to all patients by a cast technician and molded by an orthopaedic surgery resident. Two-layers of cast liner, either cotton or Gore-Tex, were circumferentially wrapped underneath the fiberglass cast. Extra padding was used over bony prominences. Postreduction anterior-posterior (AP) and lateral radiographs were taken to ensure acceptability of the reduction.

Initial follow-up visits for patients were performed approximately 1 week after initial reduction. Patients were evaluated clinically and received new AP and lateral distal forearm radiographs in their original casts. AP and lateral angulations and displacements were measured on the Syngo Imaging PACS system (by Siemens; Erlangen, Germany) with a built-in onscreen toolbar. Patients who still had acceptable alignment at this visit remained in their original cast. Acceptable alignment was defined by an angulation of less than 15 degrees on AP radiographs or less than 20 degrees on lateral radiographs in patients under the age of 10 years and an angulation of less than 10 degrees on AP radiographs or less than 15 degrees on lateral radiographs in patients of the age 10 years or older. Patients with unacceptable alignment were treated with a new cast mold application, repeat closed reduction with percutaneous pinning, or open reduction and internal fixation. For patients who remained in their original cast, further follow-up visits with new radiographs were performed at 2 and 3 weeks. Final angulation and displacement measurements were recorded in clinic between 6 and 8 weeks after injury. Figure 1 gives an example of the series of radiographical evaluations for a patient in our study.

Statistical Analysis

We defined " δ_{\max} " for AP angulation, AP displacement, lateral angulation, and lateral displacement as the maximum change in alignment from a follow-up radiograph compared with the initial postreduction alignment. After the first 36 patients (all treated with cotton cast liner) were included and analyzed in our study, the mean and standard deviation for δ_{\max} in AP angulation, AP displacement, lateral angulation, and lateral displacement were calculated. With the assumption of the same standard deviation for the Gore-Tex cast-liner group, a power analysis was performed which identified a requirement of 23 patients in the Gore-Tex group. This sample size allowed us to obtain a statistical power of 80% with an α value of 0.05 to detect a difference of 5 degrees or more in the mean δ_{\max} for AP and lateral angulation.

Student *t* tests and χ^2 tests were used to evaluate statistical significance in the descriptive statistics between the 2 study groups. The mean δ_{\max} for AP angulation, AP displacement, lateral angulation, and lateral displacement of the radius were compared using a Student *t* test. Similarly, the final averages for each of the 4 variables, excluding all patients who required intervention, were calculated and compared between groups also using a Student *t* test. The same variables were evaluated for significant difference in each subgroup analyzed. A *P* value of 0.05 or less was considered to be a statistically significant difference. All calculations were performed using the SPSS version 15 commercial software program (Chicago, IL).

RESULTS

The method and number of patients who were screened and included in our study is shown with the flow diagram in Figure 2. Seven hundred and twenty-two distal forearm fractures were evaluated and treated at the Children's Hospital of Alabama between February 2007 and July 2009. Thirty-six patients met the inclusion criteria in the cotton-lined group and 23 in the Gore-Tex-lined group.

Table 1 displays the descriptive statistics among the patients in each arm of the study. There were no significant differences with regard to age, sex, average follow-up time, proportion of right versus left arm injury, proportion of metaphyseal versus Salter-Harris fractures, and proportion of patients with associated ulna fracture. In addition, there were no significant differences with regard to AP angulation, AP displacement, lateral angulation, and lateral displacement of the radius after initial closed reduction (Table 1).

The mean δ_{\max} in AP angulation, AP displacement, lateral angulation, and lateral displacement of the radius were 9.22 degrees, 6.94%, 13.86 degrees, and 13.58%, respectively, for the cotton-lined cast group and 7.70 degrees, 6.09%, 14.57 degrees, and 9.57%, respectively, for the Gore-Tex-lined cast group (Fig. 3). There were no significant differences in the mean δ_{\max} of each of the 4 measurements (*P* = 0.33, 0.69, 0.73, and 0.10,



FIGURE 1. Radiographs showing the progression in treatment of a patient included in the study. A, Anterior-posterior wrist radiograph of the initial injury. B, Lateral wrist radiograph of the initial injury. C, Lateral wrist radiograph immediately after reduction with measurement of angulation. D, Lateral wrist radiograph after 3 weeks in cast, which shows a 16 degrees progression in angulation (5 degrees of apex volar to 21 degrees of apex volar). This fracture required remanipulation.

respectively). The final average AP angulation, AP displacement, lateral angulation, and lateral displacement, with the exclusion of all patients who received intervention, were 7.26 degrees, 6.74%, 7.57 degrees, and 15.83%, respectively, for the cotton-lined cast group and 6.28 degrees, 6.67%, 11.56 degrees, and 16.94%, respectively, for the Gore-Tex-lined cast group (Fig. 3). No significant differences were observed ($P = 0.69, 0.98, 0.21,$ and $0.87,$ respectively). Thirty-six percent of the patients in the cotton-lined cast group required some type of subsequent intervention versus 22% of patients in the Gore-Tex-lined cast group. With exclusion of all patients who received intervention, 30% of the cotton-lined cast group had unacceptable final alignment versus 28% of the Gore-Tex-lined cast group.

Subgroup analysis of mean δ_{\max} in AP angulation, AP displacement, lateral angulation, and lateral displacement of the radius continued to show no significant differences. Patients were divided into 4 subgroups: those only with isolated distal radius fractures, with concurrent distal radius and ulna fractures, with Salter-Harris fractures, and with metaphyseal fractures. The same comparisons between cotton and Gore-Tex were then individually performed for each of the 4 subsets of patients. The average δ_{\max} in AP angulation, AP displacement, lateral angulation, and lateral displacement of the

cotton and Gore-Tex groups within these subgroups, along with the P values, are displayed in Table 2.

DISCUSSION

The success of treating distal forearm fractures with closed reduction and casting varies significantly among studies. Rates of remanipulation have ranged from 2.5% to 39%.^{9,10} Proctor et al² identified 2 factors, the presence of initial complete displacement and the failure to achieve a perfect reduction, that increase the chance of redisplacement in a pediatric distal forearm fracture. Bohm et al¹¹ concluded that combined radial and ulnar fractures and residual angulation of the fracture increased the risk for loss of reduction. The question of whether the type of cast liner can be a significant independent predictor of outcome has not been reported. From the results of our study, choosing between cotton and Gore-Tex as cast liner will not have a statistically significant impact on the ability of the cast to maintain the reduction of the fracture.

Mani et al¹² found a significant discrepancy in the probability of cast failure between severe fractures with translation of the radius of more than half the diameter of the radius and milder fractures with displacement of the radius by less than 50%. By incorporating only 100% displaced fractures in our study, we avoid confounding

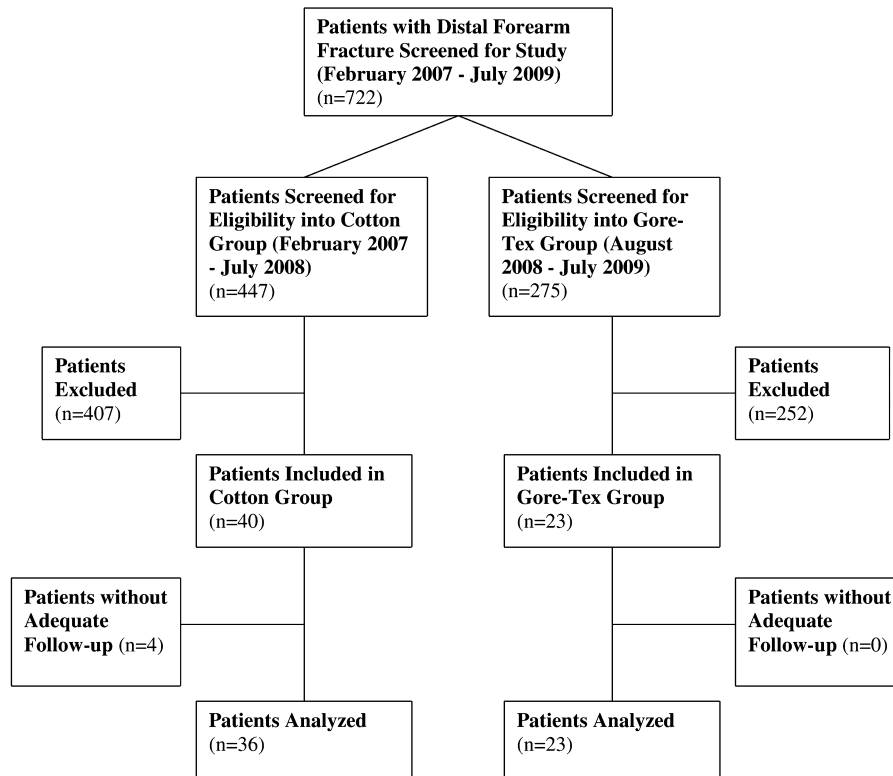


FIGURE 2. Flow diagram of patients' progress throughout the study.

TABLE 1. Descriptive Statistics

	Cotton	Gore-Tex	P
Age (y)	8.97	9.61	0.46
±	3.23	3.23	
Sex			
Male	25	14	0.58
Female	11	9	
Wrist			
Right	19	13	0.80
Left	17	10	
Fracture type			
SH	13	6	0.57
Met	23	17	
Ulna fx			
Yes	19	15	0.42
No	17	8	
Postreduction AP angulation			
Degrees	2.56	1.22	0.14
±	3.84	2.49	
Postreduction AP displacement			
Percentage	7.08	3.91	0.15
±	9.13	6.02	
Postreduction lateral angulation			
Degrees	3.72	2.91	0.58
±	6.50	2.98	
Postreduction lateral displacement			
Percentage	12.64	9.35	0.44
±	16.28	14.95	

AP indicates anterior-posterior; M, metaphyseal; SH, Salter Harris.

our results with minimally displaced stable fractures that would heal well regardless of the type of cast used. Our overall rate of intervention was 30%, which is consistent with the high rate of failure in other studies that have examined nonoperative management of 100% displaced distal radius fractures.^{10,12} We also report a high rate (29%) of unacceptable final alignment as measured on radiographs between 6 and 8 weeks after initial reduction and casting. However, we believe all of these patients have sufficient remodeling potential remaining to ultimately achieve adequate alignment and function without the need for intervention.

The advantages of waterproof casting are clear to orthopaedic surgeons and patients. Kruse et al³ found improved patient hygiene and decreased incidences of skin irritation in patients treated with lower extremity waterproof casts. Selesnick and Griffiths⁵ reported only a 5.9% minor skin complication rate and minimal complaints of odor, itching, and drying difficulties from the cast. In a randomized prospective study, Haley et al⁶ confirmed the advantages of Gore-Tex by showing superior scores for itch, discomfort, irritation, overall patient satisfaction score, and overall physician satisfaction score as compared to the cotton group.

Selesnick conducted a prospective study with 140 patients with nondisplaced fractures, stable fractures, or severe sprains who were treated with waterproof casting

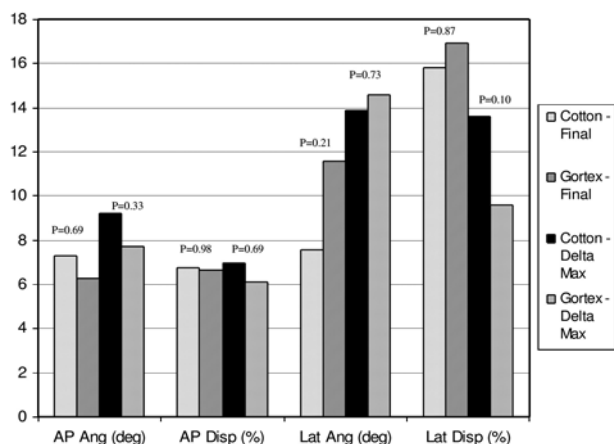


FIGURE 3. Comparison of average final alignment and average δ_{max} between cotton and Gore-Tex-lined casts. AP indicates anterior-posterior.

and found that all fractures healed without complication.⁴ Selesnick and Griffiths⁵ then repeated the study on 337 patients and verified the effectiveness of waterproof casts. Shannon et al⁷ studied 165 waterproof lined casts and determined that waterproof casts allow acceptable immobilization with no significant associated unusual risks. These three studies were performed only on stable fracture patterns and sprains. Our study verifies that it is also appropriate to use waterproof casts on unstable distal forearm fracture patterns with similar results at sustaining fracture immobilization.

We acknowledge that there are several disadvantages using Gore-Tex casts. The primary disadvantages of waterproof casts are increased difficulty with application and increased expenses. Gore-Tex cast liners are more expensive than a regular cast, currently costing approximately \$30 to 50 more per cast.⁷ However, some patients

may be willing to cover this cost as it will allow their children increased range of activities. In addition, Gore-Tex casts decrease the likelihood that a patient returns to the hospital for an unscheduled cast change due to water damage. Wolff and James⁸ found the incidence of unscheduled cast changes was 14% in the non-waterproof group versus 2.9% in the waterproof group in their study of hip spica casts. Similarly, Haley et al⁶ found that 33% of cotton casts required an unscheduled change without a major adverse reaction (defined as a necessary rereduction or operative fixation) versus only a 10% unscheduled cast change rate with Gore-Tex casts.

Since Chess et al⁹ first proposed the cast index, defined as the ratio of the sagittal cast width over the coronal cast width, some researchers have suggested that this value is a significant predictor of redisplacement in distal radius fractures treated with closed reduction. We did not evaluate the cast index between our 2 groups of patients because the cast index is measured on the basis of inner cast dimensions and would be affected by the amount of padding used. As cotton and Gore-Tex cast liner differ in material consistency and volume occupancy, we believe that the cast index cannot be suitably compared for the 2 groups of treatment. Furthermore, as all casts were applied by the same group of cast technicians, we believe that the consistency in casting technique was preserved throughout the study. In addition, other studies have reported that the cast index value was not a significant predictor of outcome.^{11,13}

Our prospective study showed no difference between cotton and Gore-Tex cast liner in the radiographical outcome of the treatment of completely displaced distal third radius and ulna fractures in children. As long as physicians are able to obtain near-anatomical alignment with their reductions, they should expect good results with either cotton or Gore-Tex cast padding for even the most unstable fracture. Although we do not believe Gore-Tex is

TABLE 2. Subgroup Analysis of Cotton Versus Gore-Tex Cast Liner

Patient Subgroup	No. Patients	δ_{max} AP Angulation (Deg)	δ_{max} AP Displacement (%)	δ_{max} Lateral Angulation (Deg)	δ_{max} Lateral Displacement (%)
Radius + ulna fractures					
Cotton	19	11.16	8.42	15.42	14.74
Gore-Tex	15	9.27	7.00	16.80	13.00
P-value		0.39	0.69	0.61	0.63
Radius without ulna fractures					
Cotton	17	7.06	5.29	12.12	12.29
Gore-Tex	8	4.75	4.38	10.38	7.13
P-value		0.26	0.62	0.56	0.07
Salter-Harris fractures					
Cotton	13	2.38	3.85	7.23	11.54
Gore-Tex	6	4.00	1.67	8.00	5.83
P-value		0.40	0.35	0.78	0.12
Metaphyseal fractures					
Cotton	23	13.09	8.70	17.61	14.74
Gore-Tex	17	10.17	7.65	16.88	11.47
P-value		0.10	0.75	0.78	0.36

AP indicates anterior-posterior.

necessary for all patients, its use would be recommended in patients who are highly active or who may lack adequate supervision at home.

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