Efficient Construction of Volar Wrist Splints: A Biomechanical Study Comparing Splints of Different Material, Thickness, and Design

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Abstract

Background: The aim was to test the null hypothesis that splint material, thickness, or longitudinal ridging does not affect the strength of a wrist splint. **Methods:** Ten splints were made according to each of 7 different splint designs (resulting in 7 groups of 10 splints each). All splints were the same length and were molded to approximate the contour of the volar hand, wrist, and forearm with the wrist in neutral. Three groups consisted of plaster splints of different thicknesses (8, 10, and 12 ply). Three additional groups included splints of the same thicknesses but with a longitudinal ridge. A single group was constructed from prefabricated fiberglass splinting material and did not involve a longitudinal ridge. Five splints in each group were subjected to 3-point bending mimicking flexion of the wrist and 5 were subjected to a 3-point bend mimicking wrist extension. Splints were loaded to failure using a servohydraulic load frame. Analysis of variance was used to compare splints. **Results:** Among the plaster splints, more layers of material and longitudinal ridging increased splint strength. Ridged 8-ply plaster splints exceeded the strength of nonridged 10-ply plaster splints. Ridged 8-ply plaster splints were similar in strength to fiberglass splints. **Conclusions:** The 8-ply ridged plaster splints may be a lighter, effective, and cheaper alternative to more common splint designs.

Keywords: splint, hand, wrist, cost

Introduction

Splints are used to treat a variety of chronic conditions affecting the hand and wrist, and may also be used to temporize acute injury and to promote comfort and healing postoperatively. Although variations in technique exist, orthopedists commonly construct wrist splints from 10 layers of plaster-bandage splinting material.¹ Maximizing the integrity of wrist splints, the creation of less cumbersome orthoses, and efficient use of splinting materials are of interest to orthopedists and might benefit the health care system in general.

We have observed, like other authors, that wrist splints may weaken with time.^{2–5} Splints that initially hold the wrist in a desirable position may weaken over days, allowing the wrist to move and/or to assume an unsafe position. This process may predispose the patient to stiffness, loss of reduction, wound breakdown, pressure sores, and noncompliance with splint wear.

Wrist splints are frequently constructed from fiberglass or plaster in different thicknesses. The placement of a longitudinal

ridge in plaster splints is a simple way of increasing splint strength without using additional splint material.^{2–5} Several authors have investigated modifications in splinting technique designed to increase splint durability and/or to affect efficient use of splinting materials.^{3–5} We sought to expand on this work by using larger experimental groups, a greater number of tested variables, more realistic models, and more precise technique. Our null hypothesis was that strength would not be affected by splint material, thickness, or ridging.

Materials and Methods

Ten splints were created according to each of 7 different splint designs (resulting in 7 groups of 10 splints each;

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Table 1. Experimental Groups.

Group	1	2	3	4	5	6	7
Material	Plaster	Plaster	Plaster	Plaster	Plaster	Plaster	Fiberglass
Layers	8	10	12	8	10	12	NA
Shape	No ridge	No ridge	No ridge	Ridge	Ridge	Ridge	No ridge

Note. NA, not available.

Figure 1. Plaster splints approximating the contour of the volar upper limb from the mid-palm to forearm are shown (distal on left).

Note. A nonridged splint is shown in the foreground. A ridged splint is shown in the background. Note that the ridge has been raised and then flattened by folding in the direction of the viewer to simulate the effect of overlying splint material.

Table 1). All splints were made by the same researcher (C.M.). All splints were approximately 25 cm long and were placed while still flexible over a form approximating the sagittal contour of the volar upper limb from mid-palm to forearm with the forearm in neutral rotation and the wrist in neutral flexion/extension. All splints were allowed to dry for 12 hours or more prior to testing.

The plaster splints were prepared with warm (50°C–55°C) water and dried by manual compression of the plaster-bandage material (BSN Medical, Hamburg, Germany) followed by wringing between the extended index and middle fingers. Plaster splints were made in different thicknesses and both with and without a central longitudinal ridge approximately 1 cm in height. Where present, the ridge was flattened prior to drying to simulate the effect of overlying bandage material (Figure 1).

Fiberglass splints were made from prefabricated fiberglass splinting material (BSN Medical), using room temperature (20°C–22°C) water and did not involve a longitudinal ridge.

Five splints in each group were subjected to a 3-point bend mimicking flexion of the wrist and 5 were subjected to a 3-point bend mimicking extension (Figure 2). Failure strength was measured using a MTS electromechanical

Figure 2. Three point bends mimicking wrist flexion (a) and extension (b) are represented.

tensile tester (MTS, Eden Prairie, Minnesota) and a LabVIEW data acquisition system (National Instruments, Austin, Texas). Initially, a load cell with a ± 100 N capacity was used and samples were loaded at 5 mm/min. The majority of samples were tested, however, using a load cell with a ± 1 kN capacity and at a rate of 30 mm/min to capture loads to failure in excess of 100 N and to expedite testing, respectively. Five splints in each group were subjected to a 3-point bend mimicking flexion of the wrist and 5 were subjected to a 3-point bend mimicking extension (Figure 2).

Statistical Analysis

Load at failure was evaluated in a 3-way analysis of variance (ANOVA) with thickness, ridge presence, and flexion versus extension as the main factors. The smallest number of observations in a main effects ANOVA group was 20. Assuming a standard deviation of 20 N, this would have an

Figure 3. Loads to failure of the various splints in different configurations are shown.

Note. The 8-ply ridged plaster splints exceeded the strength of “standard” 10-ply, nonridged plaster splints and compared favorably with splints made of more expensive fiberglass material.

80% power to detect an 18 N difference at the .05 two-sided significance level. Interactions between main factors were also tested. Fiberglass splints were compared with the various ply groups with and without ridging in a separate ANOVA. For this final analysis, flexion and extension data were combined.

Results

Results are illustrated in Figure 3. The main effects were as follows: Increasing the layers of material in the plaster splints resulted in increased splint strength ($P < .001$) as measured by load to failure. The addition of a longitudinal ridge resulted in increased splint strength regardless of the number of layers ($P < .001$). The following interaction was found and a subsequent t test was performed to describe the interaction: load to failure was higher in the flexion position, but only significantly so in the splints with ridges. Ridged 8-ply plaster splints exceeded the strength of nonridged 10-ply plaster splints ($P = .001$).

Differences were found comparing the fiberglass and plaster splints ($P < .001$) as follows: The fiberglass splint had a load to failure that was greater than the nonridged 8-ply and nonridged 10-ply plaster splints. The ridged 10-ply and ridged 12-ply plaster splints had load to failures greater than the fiberglass splint. No differences in strengths were found between the fiberglass and either the nonridged 12-ply plaster splints or the ridged 8-ply plaster splints.

Discussion

Previous investigations have suggested methods to increase the strength of wrist splints and have specifically noted the

value of longitudinal splint ridging.³⁻⁵ We sought to expand on and validate this work by using larger experimental groups, a greater number of tested variables, more realistic models, and more precise technique.

We observed clear effects of splint material, thickness, and longitudinal ridging on splint strength and therefore reject our null hypothesis. Notably, we observed that a longitudinal ridge nearly doubled the strength of plaster splints made with a given number of layers. The 8-ply plaster splints exceeded the strength of nonridged 10-ply plaster splints. Ridged 8-ply plaster splints were similar in strength to fiberglass splints.

We paid \$0.16 for each 4 × 15 inch plaster sheet used in this study and \$6.16 for each prefabricated fiberglass splint. Therefore, each 8-ply plaster splint was nearly 5 times less expensive than each fiberglass splint and 20% cheaper than each 10-ply plaster splint. Although the absolute savings we observed between individual splints was small, large-scale savings based on the multitude of these splints produced across the country on a daily basis are likely to be significant.

We acknowledge that our cost-savings calculations serve only as a guide: The cost of medical materials is frequently negotiated, and the absolute cost of a wrist splint relies not only on the core material but also potentially on cast padding, elastic bandages, and so forth. We also recognize that, empirically, splints are likely subjected to low-amplitude cyclic loading, rotational forces, changes in position against the skin, changes in pressure of underlying tissue, as well as changes in moisture and temperature. These conditions are difficult to simulate in the laboratory, and we therefore relied, as other authors have,³⁻⁵ on load-to-failure testing as an expedient, albeit non-physiologic way of comparing splint strength. Although the studied splints would be relatively easy to reproduce, we did

not account for differences in the experience or technique of splint makers.

Acknowledging these weaknesses, our finding that a less expensive and lighter 8-ply ridged plaster wrist splint can be made to exceed the strength of a “standard” 10-ply, non-ridged plaster splint, may be of particular interest to orthopedists. The 8-ply ridged plaster splints also compared favorably with splints made of more expensive prefabricated fiberglass material.

Acknowledgments

Norman Dubin, PhD, contributed to the statistical analysis portion of this investigation. Mark Wagner contributed to the testing portion of this investigation.

Ethical Approval

Ethical approval was not necessary for this biomechanical study.

Statement of Human and Animal Rights

This article does not contain any studies with human or animal subjects (biomechanical study).

Statement of Informed Consent

Informed consent is not applicable (biomechanical study).

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study received \$5000 grant from the Sibley Memorial Hospital Foundation.

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