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Radiographic and Functional Analysis of Movement Allowed by Four Wrist Immobilization Devices

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RADIOGRAPHIC AND FUNCTIONAL ANALYSIS OF MOVEMENT ALLOWED BY FOUR WRIST IMMOBILIZATION DEVICES

by

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CHAPTER I

INTRODUCTION

The need to splint or cast the wrist arises in treating a variety of conditions. Wrist fractures alone account for 1/6 of all fractures, most of which are treated with a cast or splint (Garcia-Elias & Folgar, 2006). Immobilization is part of the treatment for wrist fractures (Van Der Linden & Ericson, 1981), carpal fractures, and metacarpal fractures (Jones, 1995; Konradsen, Nielsen, & Albrecht-Beste, 1990) as well as carpal tunnel syndrome and tendonitis among other diagnoses (Barnum, Howard, London, & Rodriguez, 1998). The objective of applying a cast or splint, in these situations, is to immobilize the wrist. A large variety of wrist immobilization options exist. Short-arm casts, pre-fabricated wrist splints, and custom wrist splints are the main forms of wrist immobilization (Plint, Perry, Correll, Gaboury, & Lawton, 2006).

Biologically, the instinctive response to pain or discomfort is to protect and immobilize the painful body part. According to an historical review by Fess, Gettle, Philips, and Janson (2005), splints were used as early as 1500 B.C. to immobilize painful body parts. Ancient splint materials include copper, poppy leaves, leather, pulped fig, palm branches, bamboo, and wood. As medicine evolved, so did technology and splinting materials. Plaster casting became the standard of care by the mid 1800s; it was inexpensive and required little skill in application. The transition to plaster was due in large part to surgeons who did not have the skills to fabricate the highly technical metal and leather appliances, which were less attractive in a more competitive health care environment. With the advent of plaster, surgeons could get paid for their services rather than referring them elsewhere for treatment. Plaster casts remained the standard form of immobilization until the mid 1960s when fiberglass was introduced. Fess et al. also indicated that removal with a cast saw is still an issue for many patients because of the fear of being cut and the noise associated with the saw. Alternatives in thermoplastics and splint design are constantly being investigated (Fess et al., 2005; Harness & Meals, 2006).

Fess et al. (2005) noted that fiberglass casts resolved many of the issues with plaster; they are lightweight, durable, nontoxic, and resistant to chemicals. Low-temperature thermoplastics, which were introduced in the mid to late 1970s, had exceptional conformability, lightweight, ease of application, and were low profile. Since that time, occupational and physical therapists have been developing splint designs to maximize comfort, function, and effectiveness.

Statement of the Problem

Each wrist immobilization device limits motion and function to some extent, but data detailing exact limitations have not been collected. Establishing data that accurately describe the degree of mobility and functional ability allowed by each immobilization device will enable physicians and therapists to make an evidence-based decision each time they are confronted with the need to apply or order an orthosis.

The evolution of immobilization has been based on available technology and physician preference, not on the degree of immobilization or functional ability within the immobilization device. To date, no study examines the effectiveness of immobilization of custom and prefabricated splints as compared to casting. The American Hand Therapy

Foundation cites the study by MacDermid et al. (2002), which identified research priorities for the field of hand therapy. The panel of experts concluded that determining the effectiveness of therapeutic techniques and interventions was necessary. Because data regarding the degree of mobility allowed by immobilization devices have not been reported, identifying the effectiveness of wrist splints at immobilizing the wrist is necessary for evidence-based practice. Establishing criteria for choosing splints beyond the empirical evidence is critical.

Significance of the Research

Research that investigates the degree of immobilization a cast offers in comparison to thermoplastic splints is very limited. Although several studies suggest splints are subjectively more comfortable and provide increased function, the question regarding adequacy of wrist immobilization remains. It is important to integrate personal preference into clinical decisions, but it cannot be at the sacrifice of safety or healing. This investigation of the stability and protection of splints by means of precise radiographic and goniometric measures has the purpose of providing this evidence that is not currently available. Comparing the amount of range of motion that a cast allows to three common kinds of splints will add critical evidence to the knowledge base for clinicians utilizing wrist immobilization devices.

Purpose of the Study

The purpose of this repeated measures study is to identify if there is a difference in the amount of motion and function allowed among short-arm casts, pre-fabricated wrist splints, custom volar wrist splints, and custom circumferential wrist splints.

Research Questions

Two research questions emerge: (1) How do static wrist splints compare to short-arm casts in mobility reduction, defined by degrees of range of motion? (2) How do static wrist splints compare to short-arm casts in limiting function, defined by the TIME and Jebsen-Taylor test of hand function and perceived function, defined by the QuickDASH? It is hypothesized that all forms of wrist immobilization will allow some range of motion. Among these devices, it is hypothesized that the circumferential wrist splints will allow the best immobilization, and the pre-fabricated wrists splint will provide the least immobilization, which in turn will allow the most function and perceived function. Data from this study will allow clinicians to match the type of immobilization device to specific diagnoses with varying degrees of required support.

Definition of Terms

Thermoplastic: A lightweight material that can be heated quickly, making it highly moldable, then cools just as quickly, creating a highly conforming semi-rigid structure (Fess et al., 2005).

Short-arm cast: A wrist immobilization device formed with a padded liner and rolls of plaster or fiberglass wrapped circumferentially around the forearm and hand (Fess et al., 2005).

Hand function: A term used to describe the ability of someone to engage in activities of daily living with his or her hand.

Displacement: A term used to describe a fracture that is out of alignment.

Chapter Summary

Wrist immobilization devices are valuable tools in the treatment of many maladies. Selection of a specific device does not appear rooted in evidence, but rather convenience. Research designed to delineate differences in immobilization, functional allowance, and comfort of several immobilization devices is critical to the adoption of evidence-based practice.

CHAPTER II

LITERATURE REVIEW

Short-arm casts are a very common form of wrist immobilization, but they are not without problems. Casts can loosen because of excess padding and disuse atrophy (Azzopardi, Ehrendorfer, Coulton, & Abela, 2005; Bhatia & Housden, 2006). The literature details how casts interfere with dexterity, thumb prehension, and the ability to grip (Byl, Kohlhase, & Engel, 1999). Several studies have concluded that casts were inadequate at ensuring immobilization, causing subsequent surgeries and redisplacement of distal radius fractures (Moroni, Vannini, Faldini, Pegreffi, & Giannini, 2004; Solegaard, 1988; Zamzam & Khoshhal, 2005). Surgeries often result because of inadequate casts and the lack of literature to support splint immobilization (Mohler, Pedowitz, Byrne, & Gershuni, 1998). A detailed comparison between casts and splints may lead to improved outcomes for maladies requiring wrist immobilization. In addition, if excess swelling results during casting, compartment syndromes and chronic regional pain syndrome have been reported as resultants (Mohler et al., 1998; Smith, Hart, & Tsai, 2005).

Maintaining Fracture Alignment

Physicians agree that performing a closed manipulation to achieve anatomic reduction of a wrist fracture is the first step to achieving a successful outcome. Physicians do not have consensus on the most appropriate method of maintaining the fracture while it heals (Azzopardi et al., 2005). The study performed by Azzopardi, Ehrendorfer, Coulton, and Abela prospectively examined unstable distal radius fractures. They randomized 57 patients over the age of 60 to receive surgical percutaneous pinning or a short-arm cast. They gathered range of motion, radiographic, grip strength and perceived limitations on activities of daily living one year post-fracture. Greater ulnar deviation in the percutaneous pinning group was significant; otherwise no other data were statistically significant.

Another study examining distal radius fractures in children was a retrospective study of 183 children (Zamzam & Khoshhal, 2005). In this study, redisplacement or the repeated dislocation of the fracture occurred in 46 patients. Results indicated that initial complete displacement or fracture severity had an odds ratio of 24.7 with a confidence interval of 95%. Associated or additional fractures were also significant for redisplacement with an odds ratio of 22.5 with a confidence interval of 95%. While the study did not attempt to quantify causative factors, it was suggested that loss of cast fixation was a likely factor in these findings.

A high incidence of distal radius fracture redisplacement due to casting was the basis for a comparative study performed by Moroni, Vannini, Faldini, Pegreffi, and Giannini (2004). This study focused on elderly females with osteoporotic wrist fractures. The study compared 40 subjects who received an external fixator with those who received a plaster cast. None of the fractures redisplaced in the external fixator group, but four redisplaced in the cast group. Results of the *t* test, comparing radiographic changes, indicated that casts allowed significantly more displacements. While external fixators may carry the complication of pin-tract infections, the authors of this study concluded the risk of displacement was much higher and therefore the pin-tract infection rate was acceptable.

These studies indicate surgical intervention was superior to traditional casting methods at maintaining fracture alignment after reduction. Because of the invasive nature of these surgeries, it is important to continue to examine alternatives to both surgery and traditional casts.

Problems with Traditional Immobilization

In order to determine why surgical intervention may be superior to casting for the treatment of wrist fractures, it is important to identify how casts perform. Details of cast performance may provide a direction for identifying an alternative to traditional casting.

In a study performed by Bhatia and Housden (2006), casting inadequacies were further examined. They focused on the case records of 142 children. They examined the amount of padding used and the amount of cast material used measured through a lateral radiograph. They validated their study design through a reproducible pilot study. After determining a padding and casting index for each child they statistically compared the data to redisplacement rates. Results of the study indicated the more conforming the casting material and the smaller amount of padding, the less likely a child was to require a secondary procedure after fracture manipulation. This study concluded that better casting techniques are the key to preventing redisplacement. Minimizing the amount of padding was critical for maintaining fracture alignment.

Mell, Childress, and Hughes (2005) performed a study to investigate shoulder kinematics during object manipulation and the effects of wearing a wrist immobilization device. They discovered that increased humeral elevation and humeral axial rotation resulted from immobilizing the wrist during certain tasks. Poor posturing leaves an individual wearing any immobilization device prone to shoulder injury. The rate of shoulder maladies caused by wrist immobilization signifies the need to monitor shoulder symptoms during periods of wrist immobilization as well as the need to choose the most lightweight option for wrist immobilization to reduce the impact on the shoulder (Mell et al., 2005).

These studies indicate that a low profile and lightweight device, which has minimal amounts of padding, is key to maintaining fracture alignment during the healing phase. Concise and consistent application of an immobilization is also significant for maximizing outcomes.

Patient Satisfaction

Perception is an important aspect of patient care. It is important to understand the complexities of patient satisfaction, but it cannot be prioritized over safety. When immobilizing the wrist, there needs to be a balance between medical needs and individual perceptions of comfort and function.

A randomized controlled trial compared short-arm casts with removable splints for the treatment of radius and or ulna fractures in 113 children ranging in age from 6 to 15 (Plint et al., 2006). The study measured physical functioning with the Activities Scales for Kids (Plint et al., 2006), as well as radiographic analysis for bone healing. The groups were comparable in terms of age, gender, hand dominance, and pain levels. The study found that children who utilized removable splints had significantly better physical functioning and therefore less difficulty with activities than those with casts. This may indicate that children have better function in splints than in casts, but a question remains whether the splints offer as much stability and protection as required for optimal healing.

A prospective study by Byl, Kohlhase, and Engel (1999) examined functional limitations after cast immobilization. Researchers evaluated 16 adult subjects for upper extremity range of motion, grip strength, forearm circumference, two-point discrimination, and motor reaction times. Baseline data were gathered within 1 week of cast application on the uninvolved side, and follow-up data were gathered within 48 hours of cast removal following fracture healing on the involved side. Paired *t* tests revealed significant impairments in pronation and supination (40%), wrist range of motion (50%), grip strength (24%), and forearm circumference. The authors of this pilot study encourage clinical procedures to minimize dysfunction during immobilization to maximize restoration of function following distal radius fractures. While this study compared uninjured to injured arms of the same person, it did identify immediate limitations of function due to short-arm casts.

O'Connor, Mullet, Doyle, Mofidi, Kutty, and O'Sullivan (2003) performed a study that randomly assigned 66 patients to receive either a cast or removable splint for the treatment of distal radius fractures. Patients were compared for radiographic healing, pain, range of motion, grip strength, and functional abilities. *t* tests and the Mann–Whitney *U* tests were performed to detail these comparisons. At the 6-week mark, results indicated the splint group had higher satisfaction and comfort and scored higher on functional assessments (O'Connor et al., 2003). Range of motion was achieved faster in the splint group compared to the cast group, but equalized in both groups at long-term follow-up. Again, this identifies that splints provide higher patient satisfaction and increased function, but does not provide information about stability and protection. Some diagnoses require maximum immobilization to optimize healing. Therefore, decisions based solely on function and satisfaction may be detrimental to patients.

A study by emergency room physicians found the traditional plaster cast to be most appropriate initially because it accommodates the possibility of increased edema due to the injury (Smith et al., 2005). On the other hand, Smith et al. found that patient satisfaction with plaster casts is very low due to the mess and weight of the material. A new application design has allowed the use of fiberglass in the upper extremity despite issues with edema. The fiberglass eliminates the mess and is much lighter (Fess et al., 2005; Smith et al., 2005).

These studies identify the importance of patient satisfaction paired with compliance. The studies also indicate alternative materials to traditional casting that may provide a better balance between safety and satisfaction.

Maximizing Immobilization

White, Schuren and Konn (2003) report that cast immobilization is well proven for the treatment of fractures but is not without complications. Several studies are cited that indicate immobilization has detrimental effects on soft tissues that surround immobilized joints. They designed a study to compare rigid fiberglass casts to semi-rigid casts. White et al. argued for the use of semi-rigid materials because the properties permitted adaptation to the changing contours of the forearm during finger motion. They performed a biomechanical assessment of two different types of casting material. They utilized a single subject design with five different professionals applying the casts independently. They applied an electrogoniometer to evaluate motion within the device and pressure sensors to determine interface pressures between the material and the skin. Four out of five examiners discovered that the semi-rigid cast allowed significantly less mobility than the rigid cast and pressures were more uniformly spread in the semi-rigid cast. Subjects also reported more comfort in the semi-rigid material despite the heavy padding used in a rigid cast.

In another emergency room study, Jordan, Howell, Lauerman, and Butzin (1993) investigated the radiographic comparison of short-arm casts and fiberglass wrist splints. The study included 10 healthy male subjects with ages ranging from 18 to 35 years. Each subject had three different devices applied including the volar fiberglass wrist splint, the volar plaster wrist splint, and the plaster short-arm cast. Following statistical analysis with Tukey HSD of pairwise comparisons, results indicated that the plaster wrist splint limited wrist flexion, extension and radial deviation significantly better than the fiberglass splint. The short-arm cast limited only ulnar deviation better than the splint. The authors concluded that the properties of a splint were more moldable and conforming to the wrist, which was the basis for superior immobilization. (Jordan et al., 1993). This study, however, reported only differences and not actual range of motion allowances. Thermoplastic material was not investigated. Thermoplastic used in custom splinting is even lighter than fiberglass and can accommodate edema fluctuation much easier than fiberglass or plaster casts.

These studies support researching alternative materials used to immobilize the wrist. More must be understood to determine whether splinting options compare to casting. In the future, it may be valuable to determine if some splints may prevent fracture redisplacement comparable to surgical interventions.

Chapter Summary

Several studies have detailed the inadequacies of wrist immobilization, but have not quantified range of motion and functional inadequacies. The literature supports the need to quantify the mechanical and functional limitations of wrist immobilization devices. This information would have relevance by providing necessary evidence for clinical decision-making. The question remains about the stability of custom splints in comparison to traditional casting methods.

CHAPTER III

METHODOLOGY

The purpose of this repeated measures study is to identify if there is a difference in the amount of motion and function allowed among short-arm casts, pre-fabricated wrist splints, custom volar wrist splints, and custom circumferential wrist splints.

Research Design

The principal and co-principal investigators, to establish interrater reliability, measured the range of motion for the first five subjects. By using the standard evaluation technique of rounding range of motion measurements to the nearest five degrees, accuracy was confirmed with identical measurements between the two investigators. The co-principal investigator subsequently measured all of the radiographic images for range of motion data. Each investigator had separate data collection sheets to remain blind to the other investigator's measurements. This minimized the chance of a misclassification bias.

Graduate students in occupational therapy were trained by the principal investigator on how to perform all of the functional tests. Subsequently they performed all functional testing to minimize the bias of having the principal investigator gather the data. Senior staff therapists from the Michigan Hand Center alternated splint fabrication to avoid bias of having the principal investigator show bias during fabrication. It also avoids the notion of testing an individual therapist's ability to fabricate splints.

Procedure

Details of this protocol were consistently explained to subjects prior to signing the consent document.

Protocol Outline

The protocol outline (Figure 1) is a summary of the data collection procedure. This delineates the repeated measures nature of the study.

Protocol Outline for the Study

a. Gather demographic data
b. Gather baseline data for range of motion and functional testing
c. Wear first randomly assigned wrist immobilization device for 24 hours
d. Gather data for range of motion, functional testing and comfort
e. Wear second randomly assigned wrist immobilization device for 24 hours
f. Gather data for range of motion, functional testing and comfort
g. Wear third randomly assigned wrist immobilization device for 24 hours
h. Gather data for range of motion, functional testing and comfort
i. Wear final wrist immobilization device for 24 hours
j. Gather data for range of motion, functional testing, and comfort.

Note. Device application was approximately 1 week apart and all testing concluded in 4 weeks. Subjects wore a wrist immobilization device approximately 96 hours total. Approximately 4 hours of testing was performed.

Figure 1. Protocol outline.

Each device was worn for approximately 24 hours prior to performing functional testing. Depending on tester availability, splint or cast application specialists, time may have varied by 4 hours more or less than 24 hours. The functional testing was performed in a random order to minimize any perception bias. Subjects experienced a new immobilization device approximately 1 week apart from the previous device.

All subjects had each of the four devices applied. Within each device, the participant was asked to provide maximal effort in all planes of wrist motion under x-ray. The order of device application was randomized to minimize the perceived benefits of each device.

Each subject underwent range of motion evaluation without an immobilization device and then with each of the four immobilization devices. Details of the immobilization devices are below.

Prefabricated Wrist Splint

A standard high quality prefabricated wrist splint with a three d-ring design was utilized (see Figure 2). The manufacturer of the splint utilized is Bird and Cronin Premier Wrist Brace. The splint is circumferential in nature with aluminum stays imbedded in the volar and dorsal surface. The splint is pulled on over the hand and cinched to desired tightness by three d-ring straps.

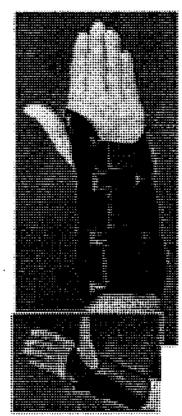

Figure 2. Prefabricated wrist splint.

Custom Volar Wrist Splint

A custom radial bar volar wrist splint constructed with 1/8 inch perforated TailorSplint™ was utilized (see Figure 3). The splint pre-cut was heated using a hot water bath, then conformed by a senior staff therapist on the volar surface of the individual's forearm. Thin cotton Stockinet was applied beneath the splint for comfort. The splint was secured with one 1-inch strap and two 2-inch straps.

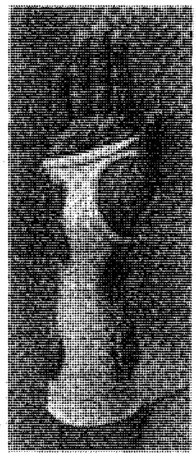

Figure 3. Custom volar wrist splint.

Custom Circumferential Wrist Splint

A custom circumferential wrist splint with ulnar opening, constructed with 3/16 inch Aquaplast-T® 42% superperforated was utilized (see Figure 4). The splint pre-cut was heated using a hot water bath, then conformed by a senior staff therapist circumferentially to the individual's forearm. Thin cotton Stockinet was applied beneath the splint for comfort. The splint was secured with one 1-inch strap and two 2-inch straps.

Splints in this study were fabricated using techniques as described by Schultz-Johnson (1996) in "Splinting the Wrist: Mobilization and Protection."

Figure 4. Custom circumferential wrist splint.

Short-Arm Cast

The cast was fabricated with 2-inch fiberglass tape applied in standard fashion (see Figure 5). Thin cotton Stockinet was first applied, followed by standard webril padding. Two 2-inch fiberglass tape rolls were applied circumferentially to the forearm and hand.

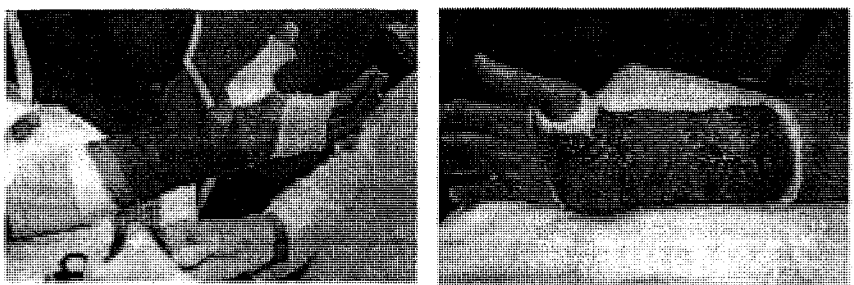

Figure 5. Short-arm cast application and completion.

All evaluation and subsequent intervention was performed at Michigan Hand Center. The facilities include the radiology suite needed to evaluate range of motion within the devices (see Figure 6), and equipment required to fabricate or apply each of the devices and evaluation tools. Once the radiographs were processed, they were printed so the necessary measurements could occur with a goniometer on these images.

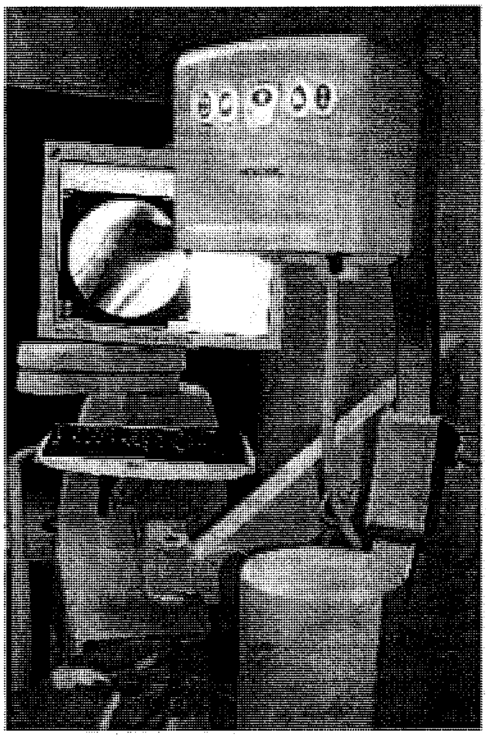

Figure 6. Fluoroscan suite used for radiography.

In this study the independent variables are the different forms of wrist immobilization. These include a short-arm cast, custom volar wrist splint, custom circumferential wrist splint, and a prefabricated wrist splint. The dependent variables in this study are the measurement devices repeatedly measured. These include active range of motion in two planes, Jebsen-Taylor Test of Hand Function, a comfort rating, the QuickDASH, and the Timed In-hand Manipulation Exam (see Table 1).

Table 1

Table of Independent and Dependent Variables

Independent Variables	Dependent Variables
• Short-Arm Cast • Prefab Wrist Splint • Volar Wrist Splint • Circumferential Splint	• Active Range of Motion (2 planes of motion) • Jebsen-Taylor (7 subtests of Function) • Comfort Rating • Modified QuickDASH (perceived function) • Timed In-hand Manipulation Exam

Data Source

Subjects were selected from Orthopaedic Associates of Michigan/Michigan Hand Center. All subjects were employees of the hand center performing clerical, administrative, or clinical tasks. A convenience sample of 24 participants was recruited from this population, ranging in age from 18 to 99, with equal numbers of men and women who were volunteers from a normal healthy adult population. Participants were excluded if they had any pre-existing conditions or wrist injuries that might impair normal wrist motion or strength. They were also excluded if they were or thought they may become pregnant during the 4-week data collection period. All participants selected were employed in "white-collar" jobs because of easy access to this population for investigation. The first individuals to respond to the recruitment e-mail that also qualified for the study were enrolled. Western Michigan University Human Subjects Institutional Review Board (HSIRB) and Spectrum Health Institutional Review Board approval was acquired. See Appendix A for HSIRB approval letter.

Hypothesis

It is hypothesized that all forms of wrist immobilization will allow some range of motion. Among these devices, it is hypothesized that the circumferential wrist splints will allow the best immobilization, and the pre-fabricated wrists splint will provide the least immobilization, which in turn will allow the most function and perceived function.

Measures

Range of Motion

Range of motion measurements were gathered for the wrist in all planes including extension, flexion, radial deviation, and ulnar deviation. These measurements were made on radiographic images taken of each subject without and with each of the immobilization devices. These measurements are degrees of motion from midline, as recommended by the American Society of Hand Therapists (Cassanova, 1992) rounded to the nearest five degrees using a standard 6-inch goniometer to maximize reliability and validity. See Figure 7 for range of motion evaluation images. Measurements were recorded as Total Active Motion (TAM) for wrist flexion and extension and wrist radial and ulnar deviation. Figure 7 also shows a sample radiograph taken with someone in a cast as well as a standard 6-inch goniometer.

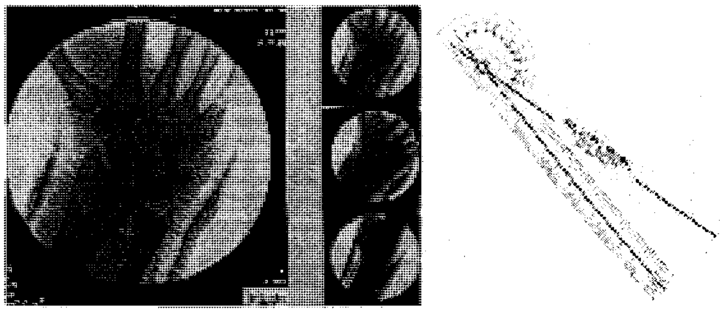

Figure 7. Sample radiograph and 6-inch goniometer used to measure range of motion.

QuickDASH

The QuickDASH is a shortened version of the original disability of the arm, shoulder, and hand (DASH); it contains nine survey items. It has been reported that the QuickDASH is a more efficient version of the original DASH questionnaire while it upholds the full measurement qualities of the original (Beaton, Wright, & Katz, 2005). The DASH was developed by the Institute for Work and Health and the American Academy of Orthopaedic Surgeons and was first described in the literature in 1996 and was designed as a self-report questionnaire aimed to identify a patient's perception of upper extremity function (Changulani, Okonkwo, Keswani, & Kalairajah, 2007). The literature supports its use for a variety of arm disorders and it has been deemed to be a reliable and valid tool (Gummesson, Ward, & Atroshi, 2006). The version administered in this research utilized the optional work module to gain a clearer understanding of all aspects of activities of daily living. Questions related to pain were eliminated from this questionnaire as subjects were from a normal healthy population. See Appendix D for QuickDASH questionnaire.

Timed In-Hand Manipulation Exam (TIME)

Exner standardized a test that identifies the speed and quality of in-hand manipulation. Ten in-hand manipulation tasks were evaluated. TIME assesses skills of finger-to-palm translation, palm-to-finger-translation, shift and rotation with and without stabilization (Exner, 1992, 1997). The test has been evaluated for reliability and validity in children (Exner, 1993; Miles Breslin & Exner, 1998). While this test was designed for children, it examines the qualities needed to understand how a wrist immobilization device can impair hand function. Identifying effective hand function is important to understand how an immobilization device can physically block in-hand manipulation. See Figure 8 for an example of in-hand manipulation with a cast in place. See Appendix E for the TIME instrument.

Figure 8. Example of the TIME with a cast in place.

Jebsen-Taylor Test of Hand Function

The Jebsen-Taylor Test of Hand Function was designed to evaluate hand disability. This standardized test has seven subtests of individual commonly performed functional tasks that were deemed representative of activities of daily living. The tasks include writing, turning, manipulation of small objects, simulated eating, and moving objects. The tool has been evaluated to be a valid and reliable tool to evaluate hand function (Jebsen, Taylor, Trieschmann, Trotter, & Howard, 1969). This test is also frequently referenced in hand surgery and therapy literature. See Figure 9 for an example of a subject performing the eating subtest of the Jebsen-Taylor Test of Hand Function while wearing a custom volar wrist splint. See Appendix F for the Jebsen-Taylor Test of Hand Function.

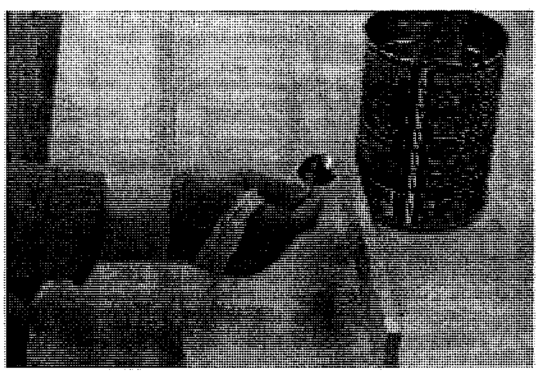

Figure 9. Example of the Jebsen-Taylor performing the simulated eating task while wearing a custom volar wrist splint.

A data collection form (Appendix G) was designed to compile data elements from each of the instruments including participant number, age, gender, height, weight, range-of-motion measurements, QuickDASH score, comfort rating, TIME score, and Jebsen-Taylor scores.

Data Analysis and Strategy

Descriptive statistical analyses were performed on the data including demographic information. Data were entered twice to compare frequencies with 100% accuracy. Stem and leaf plots were performed to analyze frequencies and skewness of data and validate equal variances prior to analyses. Levene's Test of Equality of Error Variances was performed. The error of variance of the dependent variable was equal across groups.

Repeated measures MANOVA was utilized for inferential data analysis to identify significant differences among the variables. Subsequent post hoc testing was performed when statistical significance was determined with the MANOVA in an effort to determine which comparisons were statistically significant.

Research Question 1

How do static wrist splints compare to short-arm casts in mobility reduction, defined by degrees of range of motion?

Research Question 2

How do static wrist splints compare to short-arm casts in limiting function, defined by the TIME and Jebsen-Taylor Test of Hand Function and perceived function, defined by the QuickDASH?

Chapter Summary

For each splint, the exact range of motion in wrist flexion, wrist extension, wrist radial deviation, and wrist ulnar deviation was explored through radiographic analysis. In addition, the QuickDASH, a standardized evaluation to determine perceived arm, shoulder, and hand disability; Timed In-Hand Manipulation Exam (TIME), the standardized test of in-hand manipulation to determine general fine motor skills; and the Jebsen-Taylor Test of Hand Function, a standardized test to determine level of function on standard hand related activities of daily living were performed.

A convenience sample of 24 participants was recruited. All subjects wore each of the four different immobilization devices for 24 hours and then were evaluated for range of motion and functional abilities. MANOVA and post hoc testing were performed on the data to identify significant differences among the different wrist immobilization devices.

CHAPTER IV

RESULTS

This study utilized data collected prospectively to investigate the differences in allowed range of motion and functional testing among four different forms of wrist immobilization. Data were analyzed in phases in order to determine statistical significance. First, descriptive analysis was performed to understand the study population and determine normality within the subject data. Second, MANOVA was performed to identify relationships that are significant and require further examination with post hoc testing. All testing had significance levels set at .05. Finally, results of the research questions and hypothesis will be described. Findings in this chapter will be subsequently summarized.

Descriptive Analysis of Data

Four categories of independent variables and 12 categories of dependent variables were selected for use in this study. The independent variables, or types of wrist immobilization devices, were chosen because of their common frequency of use. The dependent variables were chosen to describe mobility and functional differences among the four wrist immobilization devices. These variables include total active range of motion in flexion and extension, total active range of motion in radial and ulnar deviation, comfort, QuickDASH score, TIME score, and the seven subtests of the Jebsen-Taylor Test of Hand Function.

Independent Variables

Each subject wore each of the four immobilization devices: short-arm cast, prefabricated wrist splint, custom volar wrist splint, and custom circumferential wrist splint.

Demographic Factors

Twenty-four subjects participated in this study with equal numbers of men and women. Subjects ranged in age from 21 to 63 years with the mean being 40 years old (*SD* = 11.2). Males had a mean age of 41 years and females had a mean age of 40 years. Subjects ranged in height from 60 inches tall to 75 inches tall with a mean height of 68 inches or 5 feet 7 inches tall (*SD* = 3.6). Subjects ranged in weight from 105 pounds to 300 pounds with a mean weight of 188 pounds (*SD* = 49.2). Ninety-two percent of the participants or 22 were right-hand dominant, while the other 2 were left-hand dominant. This is a typical distribution of hand dominance in the general population. See Table 2 for a summary of the demographic data.

Table 2

Demographic Factors Regarding Participants in the Wrist Immobilization Study

Factor	Range	Mean	*SD*
Age (years)	21–63	40	11.2
Height (inches)	60–75	68	3.6
Weight (pounds)	105–300	188	49.2

Dependent Variables

Each of the dependent variables will be detailed in individual sections below.

Range of Motion—Flexion/Extension Total Active Motion. Range of motion was evaluated under x-ray to determine the amount of mobility each device allowed. The mean combined flexion and extension for the subjects while not immobilized was 134.2 degrees. The short-arm cast allowed a mean of 31.3 degrees of combined flexion-extension ($SD = 9.12$). The custom volar wrist splint allowed a mean of 48.3 degrees of combined flexion–extension ($SD = 18.57$). The custom circumferential wrist splint allowed a mean 54.8 degrees of combine flexion-extension ($SD = 25.3$). The prefabricated wrist splint allowed a mean of 88.5 degrees of combined flexion-extension ($SD = 20.67$). The cast allowed a mean of 23.3% of baseline or unimmobilized range of motion. The custom volar wrist splint allowed a mean of 36.0% of baseline range of motion. The circumferential wrist splint allowed a mean of 40.8% of baseline range of motion. The prefabricated wrist splint allowed a mean of 66% of baseline range of motion. Table 3 summarizes combined flexion and extension total active range of motion allowed by each immobilization device and compares it to baseline data. Figure 10 illustrates the mean combined flexion and extension for all immobilization devices compared to baseline data.

Table 3

Combined Flexion and Extension Total Active Range of Motion Allowed by the Different Immobilization Devices Compared to Baseline

Immobilization Device	Mean AP-TAM	*SD*	Mean/Baseline
Short-Arm Cast	31.3°	9.12	23.3%
Volar Splint	48.3°	18.57	36%
Circumferential	54.8°	25.3	40.8%
Prefabricated	88.5°	20.67	66%

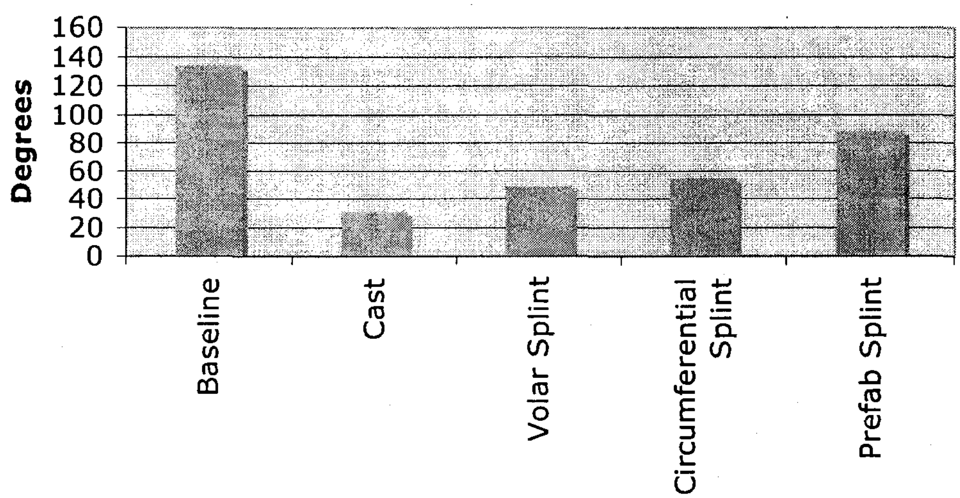

Figure 10. Mean AP-TAM comparing baseline to all wrist immobilization devices.

Range of Motion—Radial and Ulnar Deviation Total Active Motion. The mean combined radial and ulnar deviation for the subjects while not immobilized was 64.0 degrees. The short-arm cast allowed a mean of 27.7 degrees of combined radial and ulnar deviation (SD = 8.47) and 43.3% of baseline or unimmobilized range of motion. The custom volar wrist splint allowed a mean of 36.7 degrees of combined radial and ulnar deviation (*SD* = 9.74) and 57.3% of baseline or unimmobilized range of motion. The custom circumferential wrist splint allowed a mean of 35.4 degrees of combined radial and ulnar deviation (*SD* = 9.88) and 55.4% of baseline or unimmobilized range of motion. The prefabricated splint allowed a mean of 51.7 degrees of combined radial and ulnar deviation (*SD* = 10.6) and 80.8% of baseline or unimmobilized range of motion. Table 4 summarizes the combined radial and ulnar deviation range of motion allowed by each immobilization device and compares it to baseline data. Figure 11 illustrates the mean combined radial and ulnar deviation for all immobilization devices compared to baseline data.

Table 4

Combined Radial and Ulnar Deviation Total Active Range of Motion Allowed by the Different Immobilization Devices Compared to Baseline

Immobilization Device	Mean LAT-TAM	*SD*	Mean/Baseline
Short-Arm Cast	27.7°	8.47	43.3%
Volar Splint	36.7°	9.74	57.3%
Circumferential	35.4°	9.88	55.4%
Prefabricated	51.7°	10.6	80.8%

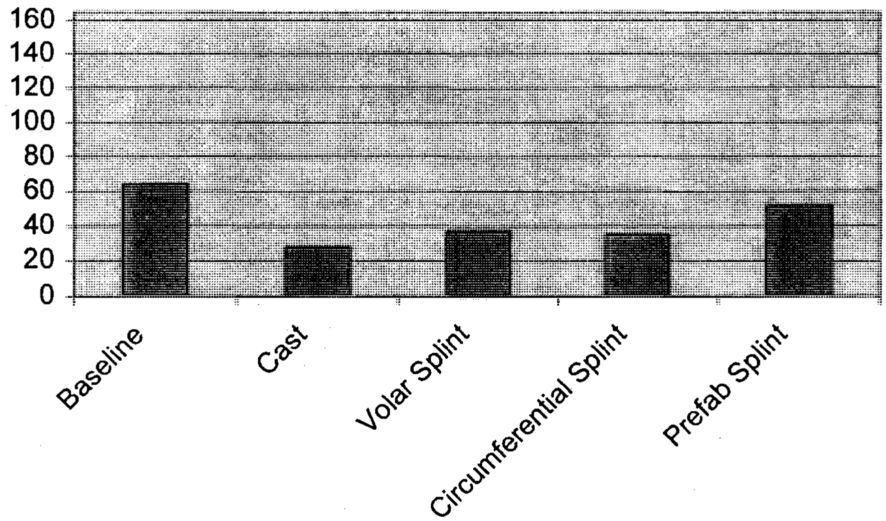

Figure 11. Mean Lat-TAM comparing baseline to wrist immobilization devices.

Comfort. Comfort is scored on a scale of 0 to 10, where 0 is the most comfortable and 10 is the least comfortable. The mean comfort rating for the short-arm cast was 4.7/10. The mean comfort rating for the custom volar wrist splint was 4/10. The mean comfort rating for the custom circumferential wrist splint was 5/10. The mean comfort rating for the prefabricated wrist splint was 3.2/10. Figure 12 illustrates the mean comfort ratings for all immobilization devices.

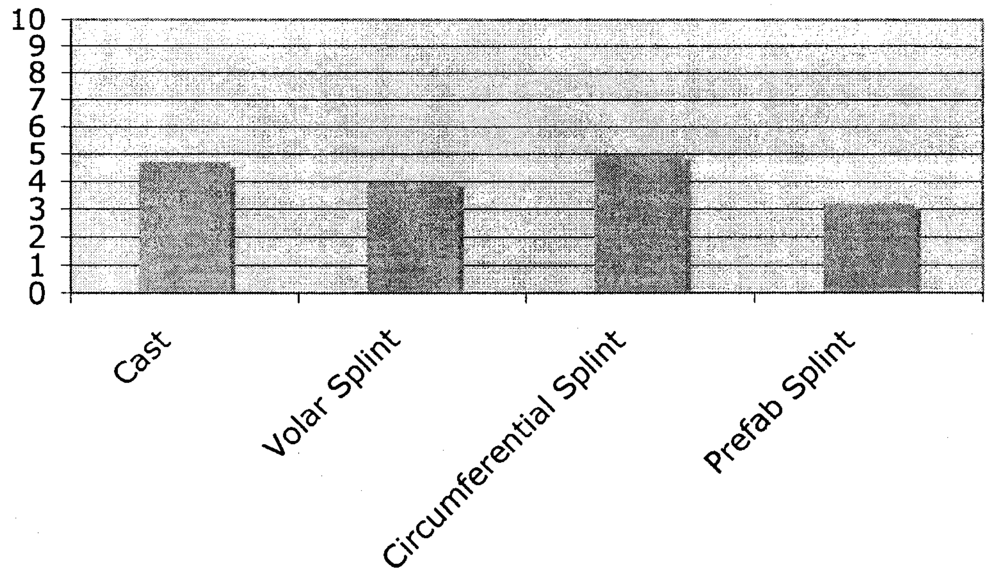

Figure 12. Mean comfort ratings for each of the wrist immobilization devices.

Jebsen-Taylor Test of Hand Function. Table 5 details the subtests of the Jebsen-Taylor Test of Hand Function. In this table, the control, or no immobilization device, is compared, on the basis of range, mean, and standard deviation, to short-arm cast, volar wrist splint, circumferential wrist splint, and prefabricated wrist splint scores. Figure 13 illustrates the comparison of mean timed scores on the Jebsen-Taylor eating subtest.

QuickDASH. The QuickDASH is scored on a scale of 0 to 100, where 0 indicates no perceived functional limitations, while 100 means perceived full disability considering upper extremity function. The mean QuickDASH score for the subjects while not immobilized was 1.39. The mean QuickDASH score for the short-arm cast group was 54.6 (*SD* = 13.22). The mean QuickDASH score for the custom volar wrist splint was41.0 (*SD* = 15.69). The mean QuickDASH score for the custom

Table 5

Descriptions of All Subtests of the Jebsen-Taylor Test of Hand Function Compared to Immobilization Device

Variable	Range (seconds)	Mean (seconds)	*SD*
JTTHF–Writing			
Control	4.48–22.83	10.6	3.7
Cast	7.19–22.71	12.2	3.6
Volar	5.52–17.18	11.3	2.8
Circum	6.43–20.3	11.5	3.3
Prefab	6.63–18.02	10.6	2.4
JTTHF–Cards			
Control	2.36–5.16	3.5	0.7
Cast	2.92–5.92	4.2	0.9
Volar	2.92–7.51	4.0	1.0
Circum	2.67–6.91	4.3	1.1
Prefab	2.61–7.07	4.1	1.1
JTTHF–Small Obj			
Control	4.47–10.0	6.1	1.3
Cast	2.33–9.46	6.8	1.5
Volar	5.21–9.06	6.4	1.0
Circum	4.82–12.27	6.9	1.1
Prefab	5.30–7.73	6.4	0.8
JTTHF–Eating			
Control	5.40–11.69	7.6	1.5
Cast	6.11–14.42	9.7	2.1
Volar	5.68–13.60	9.0	2.3
Circum	6.29–15.56	9.3	2.4
Prefab	5.42–14.22	7.8	1.9
JTTHF–Checkers			
Control	2.09–7.95	3.7	1.2
Cast	3.13–6.24	4.5	0.9
Volar	2.53–7.04	4.1	1.2
Circum	3.10–7.34	4.7	1.2
Prefab	2.58–6.84	4.2	1.1
JTTHF–Lt Obj			
Control	2.25–4.08	3.1	0.6
Cast	2.41–9.17	3.6	1.3
Volar	2.49–4.69	3.4	0.7
Circum	2.34–5.21	3.5	0.7
Prefab	2.22–4.41	3.3	0.7
JTTHF–Heavy Obj			
Control	2.41–4.37	3.1	0.5
Cast	2.19–4.63	3.5	0.6
Volar	2.61–4.70	3.5	0.6
Circum	2.28–4.63	3.5	0.6
Prefab	2.50–4.25	3.4	0.5

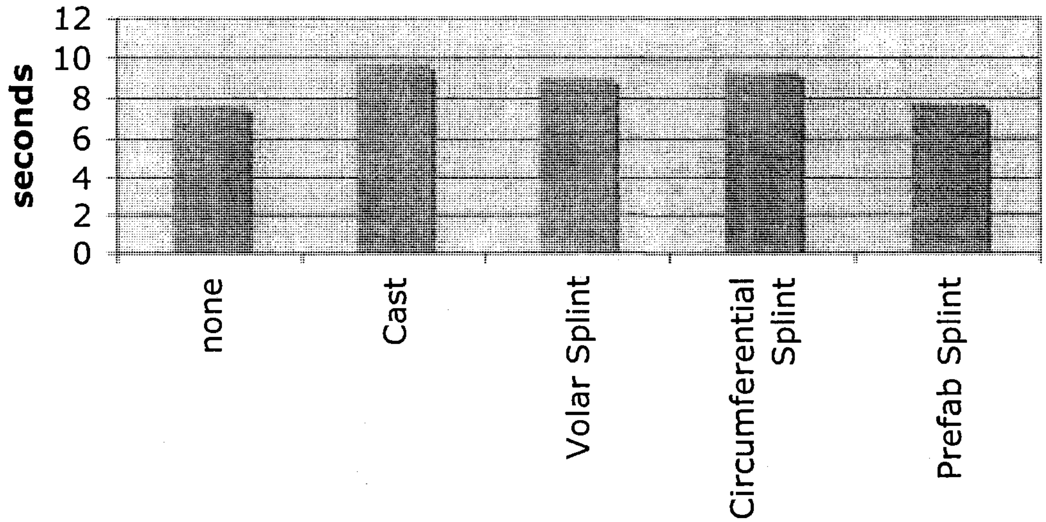

Figure 13. Comparison of mean timed scores on the Jebsen-Taylor eating subtest.

circumferential wrist splint group was 43.9 (*SD* = 15.71). The mean QuickDASH score for the prefabricated wrist splint group was 28.24 (*SD* = 10.51). Table 6 summarizes the descriptive results of the QuickDASH comparing all forms of immobilization. Figure 14 illustrates the mean QuickDASH scores comparing baseline to individual immobilization devices.

Table 6

Descriptive Results of the QuickDASH Comparing All Forms of Wrist Immobilization to No Immobilization

Variable	Range	Mean	*SD*
Control	0–13.89	1.4	3.3
Cast	13.89–75	54.6	13.2
Volar	16.82–69.44	41.0	15.7
Circumferential	22.22–88.89	43.89	15.7
Prefabricated	8.33–47.22	28.2	10.5

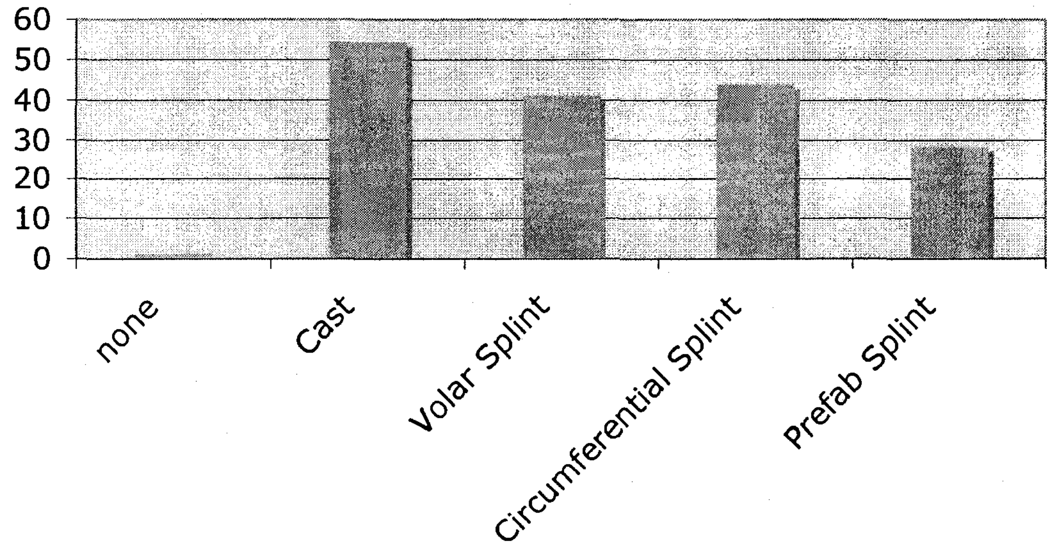

Figure 14. Mean QuickDASH scores comparing baseline to individual immobilization devices.

Timed In-Hand Manipulation Exam. The mean TIME score for the subjects while not immobilized was 12.3 seconds. The mean scored time on the TIME for the short-arm cast was 19.03 seconds, which is 6.69 seconds slower than baseline or the unimmobilized group. The mean scored time on the TIME for the custom volar wrist splint was 17.62 seconds, which is 5.28 seconds slower than baseline or the unimmobilized group. The mean scored time on the TIME for the custom circumferential wrist splint was 16.10 seconds, which is 3.76 seconds slower than baseline or the unimmobilized group. The mean scored time on the TIME for the prefabricated wrist splint was 13.88 seconds, which is 1.54 seconds slower than baseline or the unimmobilized group. Table 7 summarizes the descriptive results data of the TIME comparing all forms of immobilization to baseline data. Figure 15 illustrates the comparison of mean times on the Timed In-Hand Manipulation Exam.

Table 7

Descriptive Results of the TIME Comparing All Forms of Wrist Immobilization to No Immobilization

Variable	Range	Mean	*SD*
Control	2.89–17.70	12.3	3.5
Cast	12.77–32.41	19.0	5.5
Volar	9.68–41.67	17.6	7.0
Circumferential	8.83–25.4	16.1	3.8
Prefabricated	9.73–23.19	13.9	3.2

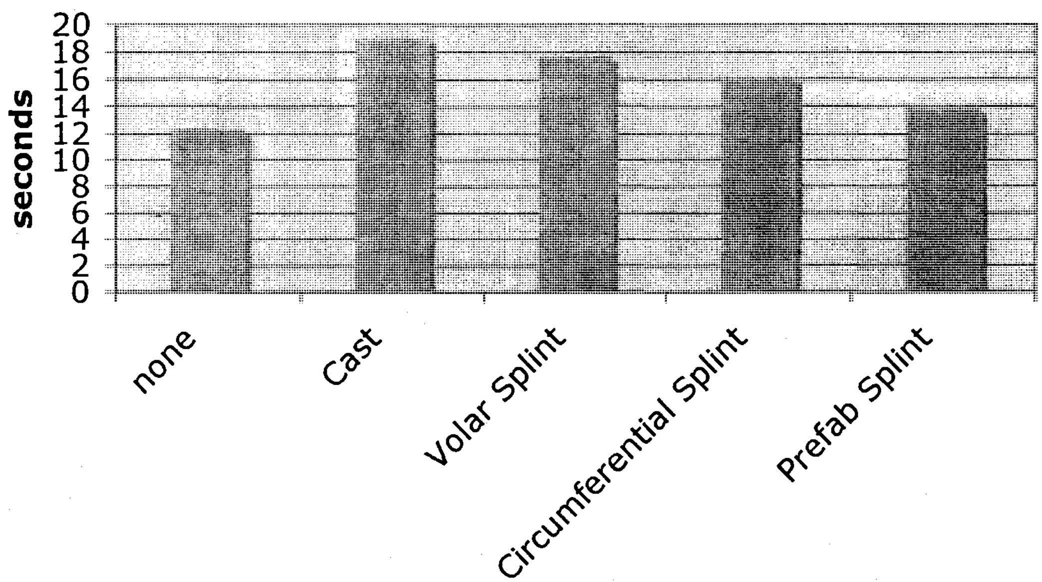

Figure 15. Comparison of mean times on the Timed In-Hand Manipulation Exam.

Inferential Analysis of Research Questions

Using multiple analysis of variance (MANOVA) to assess the main effects of wrist immobilization types with anterior-posterior total active range of motion, lateral total active motion, comfort, QuickDASH, TIME, and the subtest scores on the Jebsen-Taylor Test of Hand Function, significant relationships were identified. Wilks' Lambda testing was performed to determine significance (see Table 8).

Table 8

Wilks' Lambda Significance Testing

Effect		Value	*F*	Hypothesis *df*	Error *df*	Sig.	Partial Eta Squared	Observed Power
Splint	Wilks' Lambda	.095	8.663	40.000	403.79	.000	.444	1.000

Table 9 identifies the results from the MANOVA tests of between-subjects effects. Anterior-posterior ($F = 37.11$) and lateral ($F = 25.58$) total active range of motion measures both indicate a statistically significant difference ($p = .00$). A difference between the forms of wrist immobilization was also identified for comfort rating ($F = 2.9$) ($p = .04$), results on the QuickDASH test of perceived function ($F = 14.53$) ($p = .00$), the eating subtest on the Jebsen-Taylor Test of Hand Function ($F = 3.48$) ($p = .02$), and the TIME ($F = 4.51$) ($p = .01$).

Analysis was performed on the data to examine potential interactions of age, gender, height, weight, and hand dominance. Significance remained unchanged for range of motion, comfort, the eating subtest of the Jebsen-Taylor, and TIME. The demographic data do not interfere the results of this MANOVA.

Table 9

MANOVA Test of Between-Subjects Main Effects

Dependent Variable	Type III sum of squares	*df*	Mean Square	*F*	Sig.
AP-TAM	4155.21	3	13851.74	37.11	.00
LAT-TAM	7225.78	3	2408.6	25.58	.00
Comfort	45.62	3	15.21	2.90	.04
QuickDASH	8480.17	3	2826.73	14.53	.00
JT-Writing	32.16	3	10.72	1.13	.34
JT-Cards	1.40	3	.47	.45	.72
JT-Sm Objects	5.92	3	1.97	1.25	.30
JT-Eating	49.36	3	16.45	3.48	.02
JT-Checkers	6.19	3	2.06	1.74	.16
JT-lt. Objects	2.05	3	.68	.91	.44
JT-Hvy Objects	.14	3	.05	.13	.94
TIME	350.55	3	116.85	4.51	.01

Table 10 details Box's Test of Equality of Covariance Matrices. It was performed to test the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups. The variance ($F = 1.020$) was calculated with a significance of $p = .406$. Therefore, the null hypothesis failed to reject indicating the groups were equal. Table 10 details this significance. Therefore, MANOVA with subsequent post-hoc testing was performed on the variables with significance.

Table 10

Box's Test of Equality of Covariance

Box's M	277.126
F	1.020
*df*1	220
*df*2	23562.376
Sig.	.406

Paired samples testing were performed to statistically compare the means and confirm the MANOVA results. Statistical significance is supported by this comparison. See Table 11 for details of the results.

Table 11

Paired Samples Test of Significant Differences Identified by MANOVA

	Paired Differences					*t*	*df*	Sig.
	Mean	*SD*	Std. Error Mean	95% Confidence Interval of the Difference				
Splint Comparison				Lower	Upper			
AP-TAM	−69.41667	41.65173	3.80227	−76.94553	−61.88780	−18.257	119	.000
Lat-TAM	−41.08333	16.49017	1.50534	−44.06406	−38.10261	−27.292	119	.000
Comfort	−1.73958	2.77676	.28340	−2.30221	−1.17696	−6.138	95	.000
QuickDASH	−31.82008	21.76300	1.98668	−35.75391	−27.88626	−16.017	119	.000
JTTHF: eating	−6.65942	2.62234	.23939	−7.13342	−6.18541	−27.819	119	.000
TIME	−13.79450	5.50693	.50271	−14.78992	−12.79908	−27.440	119	.000

Post Hoc Testing

Paired samples testing was performed to determine confirm the significant relationships of the MANOVA. Post hoc analysis utilizing Bonferroni's correction was performed on the data to determine which means were significantly different from each other. Data are used to answer the research questions below:

Research Question 1

How do static wrist splints compare to short-arm casts in mobility reduction, defined by degrees of range of motion?

Table 12 details the post hoc results for significant comparisons for anterior-posterior total active motion or combined wrist flexion and extension comparing each device. Data suggest the short-arm cast that allowed a mean range of motion of only 31.3 degrees of motion was significantly different from the volar splint that allowed a mean of 48.3 degrees ($p = .03$), the circumferential splint that allowed a mean of 54.8 degrees ($p = .00$), and the prefabricated splint that allowed a mean of 88.5 degrees ($p = .00$). Data also suggest the volar splint that allowed a mean of 48.3 degrees of motion was significantly different from the prefabricated wrist splint that allowed 88.5 degrees ($p = .00$). In addition, findings indicate the circumferential wrist splint that allowed 54.8 degrees of motion was significantly different from the prefabricated wrist splint that allowed 88.5 degrees of motion ($p = .00$). Table 12 compares range of motion by device and the significance of comparison.

Table 12

Post Hoc Testing for Range of Motion Variables

Dependent Variable	(I) splint	(J) splint	Mean Difference (I–J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
AP-TAM	Cast	Volar	–17.0833(*)	5.60002	.028	–33.1117	–1.0549
	Cast	Circum	–23.5417(*)	5.60002	.001	–39.5701	–7.5133
	Cast	Prefab	–57.2917(*)	5.60002	.000	–73.3201	–41.2633
	Volar	Prefab	–40.2083(*)	5.60002	.000	–56.2367	–24.1799
	Circum	Prefab	–33.7500(*)	5.60002	.000	–49.7784	–17.7216
Lat-TAM	Cast	Volar	23.9583(*)	2.82463	.000	15.8737	32.0430
	Cast	Circum	15.0000(*)	2.82463	.000	6.9153	23.0847
	Cast	Prefab	16.2500(*)	2.82463	.000	8.1653	24.3347
	Volar	Prefab	53.2400(*)	3.62655	.000	43.1889	63.2911
	Circum	Prefab	39.5896(*)	3.62655	.000	29.5385	49.6407

Table 12 details the post hoc results for significant comparisons for lateral total active motion or combined wrist radial and ulnar deviation comparing each device. Data indicate the short-arm cast that allowed a mean range of motion of 27.7 degrees of motion was significantly different from the volar splint that allowed a mean of 36.7 degrees (p = .00), the circumferential splint that allowed a mean of 35.4 degrees (p = .00), and the prefabricated splint that allowed a mean of 51.7 degrees (p = .00). Data also suggest the volar splint that allowed a mean of 36.7 degrees of motion was significantly different from the prefabricated wrist splint that allowed 51.7 degrees (p = .00). In addition, findings indicate the circumferential wrist splint that allowed 35.4 degrees of motion was significantly different from the prefabricated wrist splint that allowed 51.7 degrees of motion ($p = .00$). Table 13 compares range of motion by device and the significance of comparison.

Table 13

Significant Range of Motion Pairwise Comparisons for Each Immobilization Device

ROM	Device 1 (mean ROM)	Device 2 (mean ROM)	Sig.
AP-TAM	Cast (31.3)	Volar Splint (48.3)	.03
	Cast (31.3)	Circum. Splint (54.8)	.00
	Cast (31.3)	Prefab Splint (88.5)	.00
	Volar Splint (48.3)	Prefab Splint (88.5)	.00
	Circum. Splint (54.8)	Prefab Splint (88.5)	.00
LAT-TAM	Cast (27.7)	Volar Splint (36.7)	.00
	Cast (27.7)	Circum. Splint (35.4)	.01
	Cast (27.7)	Prefab Splint (51.7)	.00
	Volar Splint (36.7)	Prefab Splint (51.7)	.00
	Circum. Splint (35.4)	Prefab Splint (51.7)	.00

It was hypothesized that all forms of wrist immobilization would allow some range of motion. Among these devices, it was hypothesized that the circumferential wrist splints would allow the least mobility and the prefabricated wrists splint would allow the most mobility. Clearly the prefabricated wrist splint allowed the most mobility. Each of the other devices had lower mean degrees of range of motion with significant difference to the prefabricated splint. The circumferential splint did not perform as well as expected. The short-arm cast performed with lower mean range of motion measures significantly different to each of the other devices in anterior-posterior planes as well as lateral planes of motion. The circumferential splint performed comparable to the volar wrist splint, but was not significantly different.

Research Question 2

How do static wrist splints compare to short-arm casts in limiting function, defined by the TIME and Jebsen-Taylor Test of Hand Function and perceived function, defined by the QuickDASH?

Table 14 details the post hoc testing for the QuickDASH comparing the different devices. The mean QuickDASH score for the prefabricated wrist splint group was 28.24, which is statistically significantly different from the cast group that had a mean score of 54.6 (p = .00), the volar splint group that had a mean score of 41 (p = .01), and the circumferential splint group that had a mean score of 43.9 (p = .00). The volar splint group that had a mean score of 41 was significantly different from the cast group that had a mean score of 54.6 (p = .00). Finally, data identify the circumferential splint group that had a mean score of 43.9 was significantly different from the cast group that had a score of 54.6 (p = .04) (see Table 18 for summary).

It was hypothesized that the prefabricated wrist splints would allow the most perceived function. Data suggest that the prefabricated wrist splint group had the lowest perception of disability indicated by the mean score of 28.24 that is significantly different from the cast, volar splint, and circumferential splint. Data support the hypothesis that prefabricated splints allow the most perceived function.

Table 14

Post Hoc Significance for the QuickDASH Comparing the Different Immobilization Devices

Dependent Variable	(I) splint	(J) splint	Mean Difference (I–J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
QuickDASH	Cast	Volar	13.6504(*)	3.62655	.003	3.2705	24.0303
	Cast	Circum	10.7654(*)	3.62655	.036	.3855	21.1453
	Cast	Prefab	26.3896(*)	3.62655	.000	16.0097	36.7695
	Volar	Circum	–2.8850	3.62655	1.00	–13.2649	7.4949
	Volar	Prefab	12.7392(*)	3.62655	.006	2.3592	23.1191
	Circum	Prefab	15.6242(*)	3.62655	.000	5.2442	26.0041

Post hoc testing was performed on the means of the TIME compared to each immobilization device. The prefabricated splint that had a mean score of 13.9 seconds was significantly different from the cast that had a mean score of 19.0 seconds (p = .00). No other relationship was significant. See Table 15 as well as Table 18 for the pairwise comparison summary.

It was hypothesized that the prefabricated wrist splints would allow the most function of all devices. While mean scores were the fastest on the TIME for the prefabricated wrist splint, it was only significantly different from the short-arm cast. In-hand manipulation is a key concept for functional use. The mean scores for the volar and circumferential wrist splints were not significantly different from the prefabricated splint. These data do not conclusively support the hypothesis.

Table 15

Post Hoc Testing Comparing the TIME to All Immobilization Devices

Dependent Variable	(I) splint	(J) splint	Mean Difference (I–J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
TIME	Cast	Volar	1.4096	1.39014	1.000	–2.5693	5.3885
	Cast	Circum	2.9317	1.39014	.371	–1.0472	6.9105
	Cast	Prefab	5.1542(*)	1.39014	.003	1.1753	9.1330
	Volar	Circum	1.5221	1.39014	1.000	–2.4568	5.5010
	Volar	Prefab	3.7446	1.39014	.081	–.2343	7.7235
	Circum	Prefab	2.2225	1.39014	1.000	–1.7564	6.2014

Post hoc testing was performed on the means of the subtests of the Jebsen-Taylor test compared to each immobilization device. For the eating subtest, the prefabricated splint had a mean score of 7.76 seconds that was significantly different from the cast that had a mean score of 9.69 seconds ($p = .02$). No other relationship was significant. See Table 16 as well as Table 18 for the pairwise comparison summary.

It was hypothesized that the prefabricated wrist splints would allow the most function of all devices. While mean scores were the fastest on the eating subtest of the Jebsen-Taylor for the prefabricated wrist splint, it was only significantly different from the short-arm cast. The mean scores for the volar and circumferential wrist splints were not significantly different from the prefabricated splint. In addition, the other subtests of the Jebsen-Taylor, which are representative of functional activities of daily living,

Table 16

Post Hoc Testing Comparing the Jebsen-Taylor Eating Subtest to All Immobilization Devices

Dependent Variable	(I) splint	(J) splint	Mean Difference (I–J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
JTTHF-Eating	Cast	Volar	.7133	.59526	1.00	–.9904	2.4171
	Cast	Circum	.4354	.59526	1.00	–1.2683	2.1392
	Cast	Prefab	1.9313(*)	.59526	.015	.2275	3.6350
	Volar	Circum	–.2779	.59526	1.00	–1.9817	1.4258
	Volar	Prefab	1.2179	.59526	.430	–.4858	2.9217
	Circum	Prefab	1.4958	.59526	.134	–.2079	3.1996

did not indicate significant differences. These data do not conclusively support the hypothesis.

Finally, the comfort rating that is tangentially related to function was examined with the post hoc testing. The prefabricated wrist splint group that had a mean rating of 3.2/10 was significantly different from the circumferential wrist splint group that had a mean score of 4.8/10 (p = .05) (see Table 17). Again, the prefabricated wrist splint group had the lowest comfort rating compared to the other devices, but it was only significantly different from the circumferential splint. While this study only investigated short-term comfort, long-term comfort can impact function, so it is an important characteristic to consider when determining function. These data cannot completely support the hypothesis.

Table 17

Post Hoc Testing Comparing Comfort Ratings to All Forms of Immobilization

Dependent Variable	(I) splint	(J) splint	Mean Difference (I–J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Comfort	Cast	Volar	.6667	.66067	1.000	–1.1148	2.4482
	Cast	Circum	–.2917	.66067	1.000	–2.0732	1.4898
	Cast	Prefab	1.5000	.66067	.153	–.2815	3.2815
	Volar	Circum	–.9583	.66067	.902	–2.7398	.8232
	Volar	Prefab	.8333	.66067	1.000	–.9482	2.6148
	Circum	Prefab	1.7917(*)	.66067	.048	.0102	3.5732

Table 18

Significant Pairwise Comparisons for Individual Devices

ROM	Device 1 (mean)	Device 2 (mean)	Sig.
Comfort	Prefab Splint (3.2)	Circum. Splint (4.8)	.05
QuickDASH	Prefab Splint (28.2)	Cast (54.6)	.00
	Volar Splint (28.2)	Circum. Splint (43.9)	.00
	Volar Splint (50.0)	Cast (54.6)	.00
	Circum. Splint (43.9)	Cast (54.6)	.01
JT-Eating	Prefab Splint (7.8)	Cast (9.7)	.00
TIME	Prefab Splint (13.9)	Cast (19.0)	.00

Chapter Summary

Results of this 24 subject repeated measures prospective study were evaluated with MANOVA and subsequent Bonferroni test post hoc testing. Data indicate that the cast allowed the least amount of motion and differed significantly from the volar, circumferential, and prefabricated wrist splints. The null hypothesis for the first research question was accepted and the notion that the circumferential wrist splint would better limit range of motion in all planes of motion was rejected.

While evaluating the functional component of this research, the prefabricated wrist splint had superior mean scores over the other immobilization devices, but post hoc testing supported only some components. The prefabricated splint was significantly different from the circumferential splint for comfort ratings. The prefabricated splint was significantly different from the short-arm cast on perceived function scores of the QuickDASH, the TIME, and the Jebsen-Taylor subtest of eating. In addition, significant differences were found for the volar splint compared to the circumferential splint and the cast, which indicates the volar splint group had lower perceived disability.

The hypothesis that the prefabricated splint would allow more function than the others was only partially supported.

CHAPTER V

DISCUSSION

Chapter Overview

Details of this chapter are broken down to discuss the results as they apply to the research questions. Subsequently, the results will be related to the literature. This chapter will also examine limitations to this study as well as implications to practice. Finally, recommendations for future research will be discussed.

Discussion of Results

The literature suggests short-arm casts are inadequate in many circumstances of fracture maintenance (White et al., 2003). Research has concluded that a wrist immobilization device should be highly conforming, with the least amount of padding to allow the most function while not losing device stability (Bhatia & Housden, 2006; Jordan et al., 1993). The design of this study focused on these comparisons, utilizing three of the most common splints and a standard fiberglass cast. It was hypothesized that the custom circumferential wrist splint would significantly allow the least amount of motion, while the prefabricated wrist splint would allow the most and allow for the highest amount of function and perceived function. This research focused on two primary research questions including identifying the amount of mobility, function, and perceived function each wrist immobilization device allowed.

Descriptive Data for the Sample

The subjects nearly mirrored the general population, from equal numbers of men and women to the 8% of left-hand dominant individuals. In addition to very similar qualities to the general population, statistical analysis indicated that age, gender, hand dominance, height, and weight did not impact the outcomes of this research.

Range of Motion

The results of this research identified the details associated with four different forms of wrist immobilization. While the cast group had the lowest amount of mobility within the device, it still allowed a mean range of 31.3 degrees of flexion-extension and a mean range of 27.7 degrees of combined radial-ulnar deviation. This is consistent with research that suggests casts were often inadequate and led to surgery (Mohler et al., 1998). Previous research suggested that a highly conforming immobilization device with minimal padding was key to wrist immobilization (Bhatia & Housden, 2006; Jordan et al., 1993). It was hypothesized that the properties of a circumferential thermoplastic wrist splint would be superior to a short-arm cast. This was not observed in this study. While this does not indicate custom splinting is inadequate at immobilizing the wrist, it does highlight the differences.

The prefabricated wrist brace proved to be significantly inadequate to immobilize the wrist in combined flexion-extension and radial and ulnar deviation compared to the short-arm cast, custom volar wrist splint, and the custom circumferential wrist splint. Clinically, this information should be strongly considered when prescribing a prefabricated wrist splint for any diagnoses.

Mohler et al. (1998) detail the needs for an immobilization device that is conforming yet not circumferentially rigid as with casts. Two common complications from a cast that is too tight are compartment syndrome and chronic regional pain syndrome, both of which can have devastating results. Researchers have called for a device that immobilizes well, but can be adjusted to accommodate fluctuations in edema. This concept was not researched in this study as it was assumed a splint that has a Velcro closure was inherently superior at preventing unnecessary restrictions.

The data indicate the short-arm cast allowed the least amount of mobility not the circumferential wrist splint. The literature suggests further research on materials should be performed (White et al., 2003). The materials and or design of the circumferential wrist splint did not allow it to immobilize as well as hypothesized.

Function and Perceived Function

Perceived function, identified through the QuickDASH, ranked the short-arm cast as the lowest scoring immobilization device. These scores were significantly different for all three of the other immobilization devices. The prefabricated wrist splint maintained the significantly highest perceived function of all the devices. The two custom splints performed similarly, with only significant improvements in functional scores over the short-arm cast. It was hypothesized that the prefabricated wrist splint would allow the most motion and therefore allow the most function and perceived function. The results indicate that the prefabricated wrist splint allowed the most perceived function.

In-hand manipulation, as tested with the TIME, identified the fastest score/time was performed while wearing the prefabricated wrist splint. This difference was significantly different from the short-arm cast. This is likely attributable to bulk in the palm interfering with object manipulation as well as wrist immobilization. The short-arm cast seems to maintain the largest amount of material in the palm, mechanically blocking in-hand manipulation. The prefabricated splint had the fastest mean time score on the TIME, but it was not significantly different from the volar and circumferential splints. It was hypothesized that the results would be significantly different for all devices; therefore, the hypothesis is only partially supported. This is consistent with the literature. Research designed to examine functional use comparing casts to splints has consistently favored splint designs (Byl et al., 1999; O'Connor et al., 2003; Plint et al., 2006).

Comfort is a major concern when immobilizing the wrist; it can ultimately lead to functional deficits. Data indicated a significant difference between the reported comfort for the prefabricated splint (3.2/10) and the short-arm cast that had a mean score of 4.8/10. It is likely that comfort levels rise for both devices as padding compresses and more rigid structure comes in contact with the skin. In turn, function may decrease. This is consistent with a study performed by White et al. (2003). They identified patient satisfaction and increased function with splints when compared to casts. If immobilization is needed for a diagnosis, comfort may need to be sacrificed for safety and healing. Again, the hypothesis is only partially supported because the prefabricated splint was only significantly different from the short-arm cast.

The Jebsen-Taylor Test of Hand Function was designed to simulate several tasks synonymous with many key activities of daily living. As previously stated, the eating subtest of the Jebsen-Taylor test identified the prefabricated wrist splint as having a significantly lower score than the short-arm cast. While not significant over the custom splints, it appears in the case of functional eating, the prefabricated wrist splint allowed for the fastest or closest to unimmobilized times. Again, it was hypothesized that the prefabricated splint would allow the most function of all forms of wrist immobilization. Out of the seven subtests, only the eating subtest indicated significance and only the prefabricated wrist splint had significant difference to a short-arm cast. While differences existed, none of them were significant. A possible explanation is the scoring of the test maintains scores for individual subtests rather than a single combined score. Many of the individual time scores were below 3 seconds, making differences more difficult to identify.

Again, research supports splinting over casting for function and perceived function. A case can be made that the prefabricated wrist splint may consistently allow significantly more function than a cast, but data are inconclusive about the custom fabricated splints. The literature indicated a highly conforming, low-profile splint with minimal padding should be superior to functional allowances of a short-arm cast. These data cannot entirely confirm this hypothesis.

Limitations of the Study

The methodology of this study controlled for each anticipated limitation. While the sample size was only 24 subjects, the repeated measures design used the subjects as their own control. This improves the validity of the data, but decreases the ability to generalize to the public. This includes data from the control, the short-arm cast, the volar splint, the circumferential splint, and the prefabricated splint. If the study had a larger sample size, a linear relationship may be identified between range of motion and function, as well as a larger delineation between immobilization devices.

The primary limitation to this study is the duration of wrist immobilization. It is common for casts and or splints to be worn an average of 4 to 6 weeks for injury or illness healing. In this amount of time, disuse atrophy can be significant. Casts will loosen, but often splint designs allow for Velcro tightening, which maintain conformity. While this study identifies casts as better at initial immobilization, splints may prove to immobilize more after disuse atrophy occurs.

This study does not take into account the amount of self-bracing that may occur following injury or surgery due to pain or fear of further injury, even within an immobilization device. This again suggests longer term immobilization may be of benefit.

The subjects in this study all came from a white-collar work environment because of convenience. Manual laborers may have a different perception of function or possibly be more functionally adept, but it is not likely that blue-collar workers would impact the significance of this study. For this study, it is important to note the difference from the general population.

This study does not examine children, so data cannot be generalized from the adult population. Children have a high rate of wrist injuries requiring splinting or casting. So it would be important to study the differences among various wrist immobilization devices with a younger population.

The results from the Jebsen-Taylor test were not conclusive, even for the prefabricated splint that allowed near normal motion. Perhaps another test of hand function or activities of daily living checklist could be utilized in the future. The literature suggests wrist immobilization has a significant impact on functional activities and quantifying it remains important (Byl et al., 1999; O'Connor et al., 2003; Plint et al., 2006). In retrospect, a comprehensive activity of daily living checklist may identify function deficits more completely.

Several limitations certainly weaken this study, but the design remains strong. Significance gathered from the data has identified some inconclusive information about custom splints as they relate to immobilization and function. Further investigation is necessary.

Implications for Practice

This study has intentionally avoided diagnosis specific treatments. The knowledge gained from this study may be applied to diagnosis specific treatments, but the foundational work performed in this study was intended to give clinicians the evidence needed to make individual decisions about individual patients. It became very apparent that follow-up studies should be performed to address some of these limitations.

The biggest implication this study identified was the inability of the prefabricated wrist splint to immobilize the wrist. By allowing near-normal motion, healing may be limited depending on the diagnosis. Immediate efforts should be made to deter the use of prefabricated wrist splints for diagnoses that require immobilization, not just positioning.

It also became apparent that custom splints performed in the middle when analyzing range of motion as well as function. Efforts should be made to explore new materials and designs to maximize immobilization and function. A better balance between form and function needs to be identified. Occupational and physical therapists are at a critical time to provide treatments that are supported by evidence. Enhancing current splints or developing new splints that strike that balance is critical.

Recommendations for Further Research

It was expected that custom splints would provide superior immobilization based on results from previous research. Clearly, circumferential wrist splints did not perform as expected, indicating a need to develop a better splint. Several more wrist immobilization devices exist including ulnar gutter wrist splints and clamshell wrist splints. Different thermoplastic material thicknesses could also be examined to increase the rigidity and potentially limit more wrist range of motion. There may also be ways to improve the performance of casts. New more flexible and conforming fiberglass exists as well as new lining materials that may provide less bulk that in turn limit loosening.

The Jebsen-Taylor test could be examined to see if a combined score had the same validity as individual subtest scores through a pilot study. Though the TIME may have provided adequate data regarding function, it may not answer the activities of daily living tasks. Perhaps a task checklist may be incorporated instead of the Jebsen-Taylor test and the study replicated. If the study were to be replicated, it would be ideal to increase the sample size.

Future studies should take the data from this study and apply them to diagnosis specific treatments and attempt to identify differences noted after longer durations of immobilization. Understanding how wrist immobilization devices perform after long-term use is the next step in understanding how well wrist immobilization impacts range of motion and function. It is essential to maintain an interdisciplinary approach to this research to maximize the evidence for quality clinical approaches.

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Appendix A

Human Subjects Institutional Review Board
Letter of Approval

WESTERN MICHIGAN UNIVERSITY

Human Subjects Institutional Review Board

Date: December 19, 2007

To: Ben Atchison, Principal Investigator
Timothy Mullen, Student Investigator for dissertation

From: Amy Naugle, Ph.D., Chair Amy Naugle

Re: HSIRB Project Number: 07-11-05

This letter will serve as confirmation that your research project entitled "Radiographic and Functional Analysis of Movement Allowed by Four Wrist Immobilization Devices" has been **approved** under the **full** category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note that you may **only** conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: November 21, 2008

Walwood Hall, Kalamazoo, MI 49008-5456
PHONE: (269) 387-8293 FAX: (269) 387-8276

Appendix B

Subject Recruitment Email

RE: Volunteers Needed

A research study is being performed to examine wrist immobilization devices. Participants will be asked to undergo three tests of hand function and evaluate their wrist range of motion under x-ray (approximately 45 - 60 minutes). They will then wear four different wrist immobilization devices for twenty-four hours each with about seven days off rest between each of the four devices. At the end of the twenty-four hours of immobilization, participants will perform a range of motion exam under x-ray, as well as the same three tests of hand function (approximately 45 - 60 minutes each time). You will not be allowed to participate if you have had previous wrist injuries that limit your motion or if you are or may become pregnant in the next eight weeks. Participation is voluntary and you may quit at any time. Your participation in the study enters you in a drawing for a new Apple iPod.

If you have any questions please feel free to call, e-mail, or talk to me about participating in this study.

Appendix C

Informed Consent Document

WESTERN MICHIGAN UNIVERSITY
H. S. I. R. B.
Approved for use for one year from this date:

NOV 2 1 2007

x
HSIRB Chair

MICHIGAN HAND CENTER
Center of excellence in hand and arm surgery, therapy and research

12/1/2007

Dear potential participant,

You are invited to participate in the research project: Radiographic and Functional Analysis of Movement Allowed by Four Wrist Immobilization Devices. Your participation will last for approximately four weeks. The study is being conducted by Ben Atchison, Ph.D., OTR, FAOTA from Western Michigan University Department of Occupational Therapy and Timothy M. Mullen, MS, OTR, CHT from Western Michigan University, Interdisciplinary Health Studies. This research is being conducted as part of the Ph.D. dissertation requirements for Timothy M. Mullen, MS, OTR, CHT.

Procedure and Participant Involvement
You will be asked to give general information about yourself, including age, gender and hand dominance. You will be asked to perform three different tests of hand function five separate times over four weeks. You will have your wrist motion tested under x-ray five separate times over four weeks. You will be asked to wear four different types of wrist immobilization devices for twenty-four hours each, with about a week between each. The order in which you wear the immobilization will be random.

Twenty-four people will be tested during this research project over the next several months. You will not be allowed to participate if you are or may become pregnant in the next 8 weeks. You will not be allowed to participate if you have an old injury to your wrist or arm that limits your motion or use.

Your participation in this study is completely voluntary, you may quit at any time without worry of penalty of any sort.

Possible Risks and Benefits
During this research you will be exposed to radiation. We will be using low-level fluoroscopy which is a fraction of a normal x-ray. You will also be shielded with lead protective wear covering your body except the wrist to be examined.

Hot water is used to make two of the wrist splints, your exposure to being burned is extremely low and precautions will be taken to let the material dry and cool to appropriate temperatures before being applied to you. In addition, a cast saw is used to remove the cast; it is possible for a burn to occur during this process. Technicians will apply the plastic guard beneath the cast to prevent direct contact of the vibrating blade with your skin.

You may have difficulty with some daily tasks while wearing the wrist immobilization devices. This may cause some frustration. Your job at Michigan Hand Center will not be impacted by working slower.

As in all research, there may be unforeseen risks to the participant. If an accidental injury occurs, appropriate emergency measures will be taken; however, no compensation or treatment will be made available to me except as otherwise specified in this consent form.

There are no direct benefits for participation in this study.

Costs and Compensation
If you complete the research, your name will be entered in a drawing to win an Apple iPod as an incentive to participate.

Confidentiality
All of the information collected from you is confidential. That means that your name will not appear on any papers on which this information is recorded. The forms will all be coded, and Timothy Mullen will keep a separate master list with the names of participants and the corresponding code numbers. Once the data are collected and analyzed, the master list will be destroyed. All other forms will be retained for at least three years in a locked file in the principal investigator's office. This remaining data will not include your name, but will still remain locked. If information from this study gets published, it will contain only combined information like average age or average test scores.

Contact Information
You may choose to quit or not participate at any time. If you have any questions, you may contact Ben Atchison, PhD at (269) 387-7270, or Timothy M. Mullen at 616-956-1201. The participant may also contact any or all of the following if questions or problems about the study arise during the course of the study:

Michigan Hand Center
Julian Kuz, MD (616) 957-4263
Western Michigan University
Chair, Human Subjects Institutional Review Board (269-387-8293)
Vice President for research (269-387-8298).

This consent document has been approved for use for one year by the Human Subjects Institutional Review Board as indicated by the stamped date and signature of the board chair in the upper right corner. Do not participate in this project if the stamped date is more than one year old.

Western Michigan University
H. S. I. R. B.
Approved for use for one year from this date:
NOV 2 1 2007
x Amy Naugle
HSIRB Chair

Your signature below indicates that you have read and/or had explained to you the purpose and requirements of the study and that you agree to participate.

Printed Name: ______________________________

Signature: _________________________________

Date: _____________

Consent obtained by: _____________ Date: __________

Appendix D

QuickDASH Data Collection Form

Modified QuickDASH

Participant #: _______ Immobilization Device: ____________

	No Difficulty	Mild Difficulty	Moderate Difficulty	Severe Difficulty	Unable
1. Open a tight jar?	1	2	3	4	5
2. Do heavy household chores?	1	2	3	4	5
3. Carry a shopping bag or briefcase?	1	2	3	4	5
4. Wash your back?	1	2	3	4	5
5. Use a knife to cut food?	1	2	3	4	5
6. Recreational activities in which you take some force or impact through your arm, shoulder, or hand?	1	2	3	4	5
7. Using your usual techniques for your work?	1	2	3	4	5
8. Doing your work as well as you would like?	1	2	3	4	5
9. Spending your usual time doing your work?	1	2	3	4	5

((sum of responses/9)-1)x25

QuickDASH Score _____

Appendix E

TIME Data Collection Form

TIME

Participant #: _______ Immobilization Device: _______

Finger-to-palm translation Time ______

Pick up a quarter and close it in a fist

Finger-to-palm translation with stabilization Time ______

While holding 2 quarters in one hand, pick up a third quarter and close them in a fist

Palm-to-finger translation Time ______

Start with a cube in the palm with the palm up, move it to the finger tips and stack on top of another block in front of them

Palm-to-finger translation with stabilization Time ______

Start with 2 small cubes in the palm with the palm up, move one cube to the finger tips and stack on top of another block in front of them

Shift Time ______

Hold a marker at the end and maneuver it to the writing position

Shift with stabilization Time ______

With palm up, place one key in the palm and another key on P2 of the ring and small finger, have them maneuver the key to a standard key pinch as if inserting in a lock

Simple rotation Time ______

Palm is placed flat on the table; marker is place horizontally in front of the finger tips with the point on the ulnar side of the hand. Have them pick up the marker and put it into writing position

Simple Rotation with Stabilization Time ______

With palm up, place 2 keys in the palm pointing toward the thumb. Have them manipulate one key to the key pinch position as if inserting in a lock

Complex Rotation Time ______

Palm is placed flat on the table; marker is place horizontally in front of the finger tips with the point on the radial side of the hand. Have them pick up the marker and put it into writing position

Complex Rotation with stabilization Time ______

With palm up, place 2 pegs "sideways" in palm, have them rotate one peg and put it in a pegboard

Total Time: ______

Appendix F

Jebsen-Taylor Test of Hand Function
Data Collection Form

Jebsen-Taylor Test of Hand Function

Participant #: _______ **Immobilization Device:** ____________

Writing	_______
Cards	_______
Small Objects	_______
Eating	_______
Checkers	_______
Large Light Obj	_______
Large Heavy Obj	_______

Appendix G

Data Summary Form

Participant # _____ Age ________ Gender *M / F* Hand Dominance *R / L*
Height ____________ Weight __________ JEK / TMM Measurements

(1) No Immobilization
Dom Wrist Extension _________
Flexion _________
Rad Dev _________
Ulnar Dev _________
( )Subjective Comfort ____/10
( )Modified QuickDASH _______
( )Jebsen-Taylor
Writing _______
Cards _______
Small Objects _______
Eating _______
Checkers _______
Large Light Obj _______
Large Heavy Obj _______
TIME _______

( )Short-Arm Cast (applied by ______)
Dom Wrist Extension _________
Flexion _________
Rad Dev _________
Ulnar Dev _________
( )Modified QuickDASH _______
( )Jebsen-Taylor
Writing _______
Cards _______
Small Objects _______
Eating _______
Checkers_______
Large Light Obj _______
Large Heavy Obj _______
TIME _______

( )Volar Wrist Splint (applied by ______)
Dom Wrist Extension _________
Flexion _________
Rad Dev _________
Ulnar Dev _________
( )Subjective Comfort ____/10
( )Modified QuickDASH _______
( )Jebsen-Taylor
Writing _______
Cards _______
Small Objects _______
Eating _______
Checkers_______
Large Light Obj _______
Large Heavy Obj _______
TIME _______

( ) Circum. Splint (applied by ______)
Dom Wrist Extension _________
Flexion _________
Rad Dev _________
Ulnar Dev _________
( )Subjective Comfort ____/10
( )Modified QuickDASH _______
( )Jebsen-Taylor
Writing _______
Cards _______
Small Objects _______
Eating _______
Checkers_______
Large Light Obj _______
Large Heavy Obj _______
TIME _______

( ) Prefab Wrist Splint (applied by ______)
Dom Wrist Extension _________
Flexion _________
Rad Dev _________
Ulnar Dev _________
( )Subjective Comfort ____/10
( )Modified QuickDASH _______
( )Jebsen-Taylor
Writing _______
Cards _______
Small Objects _______
Eating _______
Checkers_______
Large Light Obj _______
Large Heavy Obj _______
TIME _______