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Static versus Dynamic Splinting for PIP Joint Pyrocarbon Implant Arthroplasty: A Comparison of Current and Historical Cohorts

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Abstract

Study Design—Non-randomized mixed current and historical cohort follow-up study.

Introduction—Dynamic splinting is recommended following proximal interphalangeal (PIP) joint pyrocarbon implant arthroplasty; however, static splinting may be more feasible to deliver.

Purpose—To test the effectiveness of static splinting following arthroplasty in patients with osteoarthritis.

Methods—Nine consecutive patients received static splinting. These patients were compared to a historical control group ($n = 10$) who received dynamic splinting. Function and performance variables were measured preoperatively and 3 months following surgery. All patients underwent surgery by the same hand surgeon and the majority of patients were treated by the same certified hand therapist.

Results—Both static and dynamic groups showed improvement on several function and performance measures. Compared to the dynamic group, the static group showed greater improvements in the Michigan Hand Questionnaire (MHQ) subset of work performance (21.00 ± 14.75 versus 3.13 ± 14.13 , $p < 0.05$) and Jebsen-Taylor test (-11.58 ± 5.44 versus -2.81 ± 3.23 , $p < 0.03$).

Conclusions—Patients who received static splinting had similar outcomes to those who received the dynamic splinting. Static splinting requires less therapist training and offers greater patient convenience and is a promising protocol that should be evaluated in a larger study.

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Keywords

Therapy protocol; Outcomes; MHQ; Pyrocarbon Implant; PIP Joint

Introduction

Hand osteoarthritis (OA) is prevalent and is associated with functional limitations and joint pain [1, 2] that tends to increase in severity with age [1]. Of the hand joints, proximal interphalangeal joints (PIP) are commonly affected, but are difficult to treat. Medication and arthrodesis of the PIP joint are treatment options; however these treatments may not adequately control pain or may hinder hand function. Silicone arthroplasty has been widely used since the early 1970s; however, joint failure has been reported to be 20% at 10 years and 51% at 16 years [3].

Recently, pyrocarbon implant arthroplasty has been used as a treatment for OA of the PIP joint given its potential to reduce pain and help preserve hand function. Pyrocarbon implant arthroplasty uses pyrolytic carbon that is reported to be wear-resistant and biocompatible, making it especially useful for small joint arthroplasty. After undergoing this surgery, splinting is used to preserve surgical outcomes and increase hand function. Both the static and dynamic splinting approaches are used to facilitate digital ROM while protecting the joint. Short-term outcomes following surgery in studies by one of the authors (KCC), and others have shown positive results in patient satisfaction and pain relief [4] as well as hand function [5]. However, little is known about the optimal postoperative splinting approach.

Following pyrocarbon implant arthroplasty, dynamic splinting has been recommended for daytime with static splinting used only at night [6]. Using a dynamic splinting protocol, Bravo et al. [6] found that patients had improved pain relief, pinch strength and overall patient satisfaction without statistically significant gains in arc of motion or grip strength in their minimum two-year follow-up evaluation. In a study of 14 patients, Chung et al. followed patients over a one year period and reported outcomes of dynamically splinted patients using the Michigan Hand Outcomes Questionnaire (MHQ) as well as objective measures, including active arc of motion (AAM), grip and pinch strength and the Jebsen-Taylor test [4]. Scores on the pain, satisfaction, and Activities of Daily Living (ADL) domains of the MHQ improved, with the domains of pain, satisfaction and aesthetics showing the largest effect sizes whereas AAM and grip strength did not improve. Despite positive patient-reported outcomes, one downside of the dynamic splinting approach is the potential for implant migration. Hyperextension of the joint can lead to dorsal dislocation of the implant, an aspect of dynamic splinting that is more easily controlled with a static splint. Both of these studies [4, 6] report complications including squeaking, dislocations, and delayed wound healing when using a dynamic splinting rehabilitation approach.

To help prevent hyperextension of the implant, several authors describe modifications in postoperative splinting either by using a static extension block of 15–20 degrees within the dynamic PIP extension splint [7] or by using static template exercise splints in addition to the static resting splint and foregoing dynamic splinting altogether [8, 9]. Herren et al. [10] have tested early motion using a static splint, without dynamic splinting or restrictions to the allowable arc of motion at the implant, and used the same postoperative rehabilitation protocol as for silicone PIP joint replacement. This splinting approach did not involve the use of dynamic splinting and resulted in nonsignificant gains in ROM yet there were significant improvements in both grip strength and pain relief with an average follow-up of 19 (range 12–27) months. However, because of the rate of complications that occurred

(involving migration of the implants), the authors suggested that this approach to postoperative management may affect the stability of the prostheses.

To our knowledge, no study has compared the use of static splinting alone versus a daytime dynamic and nighttime static splinting combined approach (hereafter referred to as the static group and dynamic group). There are important reasons to examine treatment outcomes of static splinting. Dynamic splinting requires training in the fabrication of a complex dynamic PIP extension splint. Further dynamic splinting must be adjusted weekly as improvements are seen in the patient's edema and their allowable joint arc of motion. In addition, patients elect to get their rehabilitation in locations other than the surgical center and there is a challenge in providing a continuity of care which includes modifications in the dynamic splint. Static splinting, specifically a hand-based static gutter splint, is an alternative to the dynamic splint, and could be worn between prescribed exercises during the day and at night. Compared to a dynamic splint, a static splint offers greater protection from lateral stress, is fabricated in less time, and is typically quicker to adjust than a dynamic splint. A static splint is also typically easier for patients to don and doff compared to a dynamic splint.

The purpose of this paper is to examine the effect of a postoperative approach that uses static splinting alone versus an approach that utilizes a dynamic splint during the day and a static splint at night. We hypothesize that patient-reported outcomes (MHQ) including pain, and objective hand function will be clinically similar between the splinting approaches.

Methods

Participants

Participants in both treatment groups received PIP joint arthroplasty from the same surgeon (KCC) who used a dorsal surgical approach with a central slip longitudinal splitting technique [4]. All participants were eligible for surgery if they were deemed medically stable, were found to be capable of performing postoperative self-care, and in the case of other major health disorders, were cleared for surgery by the appropriate specialist. To be eligible for this study, participants needed to be cognitively able to complete questionnaires and to be able to read and write in English. This study was approved by the University of Michigan Medical School Institutional Review Board. Informed consent was obtained for each participant and their rights as human subjects were protected.

Table 1 shows the patient demographic data. Participants in the static group had a mean age of 62 (range 53 – 78 years) and participants in the dynamic group had a mean age of 59 (range 52 – 72 years). This group of OA patients was comprised of primarily Caucasian women who underwent surgery on their right hand more often than their left (15 versus 10) and varied in the digits involved. The majority of digits included the radial two digits rather than the ulnar two digits (17 versus 8).

Static Splinting Group

Consecutive candidates for proximal interphalangeal joint arthroplasty with the pyrocarbon implant (Ascension Orthopedics, Austin, TX) were included because of OA of the PIP joint and were approached by a research associate regarding study participation following their decision to undergo the surgical procedure. Patients with diagnoses of psoriatic arthritis or posttraumatic arthritis were excluded from analysis. The static splinting group was evaluated prospectively.

Dynamic Splinting Group

Ten individuals who received dynamic splinting postoperatively from December 2004 through June 2008 as part of a previous study [4] served as a historical comparison group and were included if they received arthroplasty due to pain and OA of the PIP joint. This dynamic splinting group was evaluated retrospectively.

Intervention

Specific details of each splinting approach, static versus dynamic, are in Table 2. Briefly, patients in the static splint group wore their splint when not exercising and those in the dynamic group wore the splint throughout the day (even while exercising) and they wore a static splint at night. The goal of postoperative therapy for both groups is to facilitate digital range of motion while protecting the joint. Treatment in each group involved a home exercise program (HEP), splint adjustment, edema control, scar remodeling, moist heat modalities, and patient education. The static and dynamic splinting approaches (see photographs of static and dynamic splints) were equivalent in terms of postoperative treatment time and attention. The postoperative hand therapy involved 6–8 treatment sessions each lasting 1 hour. It began 4–7 days after surgery and extended through the 8th postoperative week. Participants were instructed in the HEP involving ROM exercises every 1–2 hours using goniometer's readings as feedback while they performed the allowable flexion arc and practiced this task in clinic. Both groups were also instructed to perform scar massage twice a day. For the static group, participants were asked to complete a daily log to examine adherence to the HEP, splinting regime, and scar management. Logs were reviewed by the treating therapist (JMR) at each session and were used to facilitate discussion on the importance of the HEP and of the participant's role and responsibility in his or her own functional outcome. Four subjects in the static group were initially splinted and treated by the first author and subsequently treated closer to home by hand therapists who communicated with the referring therapist (JMR) and followed the study protocol. Two subjects in the dynamic group were also treated and splinted initially by the first author and then transferred to receive therapy closer to home. Three therapists from one of these treatment centers received training by the first author in dynamic splint fabrication and modification as well as in the therapy protocol prior to treating the study subject.

Measurement

Preoperative data were collected in the weeks prior to undergoing the joint arthroplasty (range of 1–20 weeks) and at three months post surgery. For the static group, a non-treating hand therapist blinded to the study hypotheses performed the ROM measurements to reduce the possibility of treatment bias; the treating therapist (JMR) performed ROM assessments of participants in the dynamic splinting group. Hand performance was examined using several objective and standardized measures. The Jebsen-Taylor functional assessment is an objective and standardized test of hand function, specifically measuring dexterity and hand function related to ADLs. It is a series of timed tests measured in seconds [11] and was administered by a trained research assistant. Grip and key pinch strength were assessed using a Jamar dynamometer (Sammons Preston, Bolingbrook, IL) and pinch meter (B&L Engineering, Tustin, CA), respectively. Active arc of motion of the involved joint, defined as active flexion of the PIP joint minus any active extension lag, was measured using a goniometer (Richardson Products Inc., Frankfort, IL) and was documented in degrees. The MHQ measures several important patient outcomes and includes subscales on overall hand function, activities of daily living, work, pain, aesthetics, and satisfaction with function. This is a tool that is capable of measuring health status domains that are important to patients with hand dysfunction [12]. Raw scores are normalized and presented on a 0–100 scale, where 100 indicates no disability (the exception is the pain domain, where 0 indicates no pain).

Data Analysis

Data were analyzed using PASW v18.0 (formerly the Statistical Package for Social Sciences, SPSS). Because of the small sample size, we opted for a non-parametric approach for our statistical analyses. Non-parametric tests do not require that the data conform to any particular distribution and are useful in cases where the n is small and the sample distribution is not normal; the only requirement is that the data are continuous [13].

Our primary interest revolved around the within-group changes from baseline to 3-months follow-up. These analyses involved the change scores for each participant, using the Wilcoxon Signed Rank test which is the non-parametric analog to the paired t -test. The individual differences were ranked according to their absolute value, and then only the positive ranks were summed yielding the Wilcoxon Signed Rank statistic, W^+ . The test statistic was analyzed using a table of critical values: if the test statistic is less than or equal to the critical value based on the sample size, then the null hypothesis is rejected for the alternative hypothesis. Otherwise, the null hypothesis is not rejected.[13].

Our secondary interest was examining whether there were significant differences in self-reported outcomes and functional performance between the dynamic and static splinting groups at 3-months after surgery. This time frame was targeted as a period when objective measures begin to plateau and patients are typically discharged from therapy and using their hand without restrictions. First, we computed change scores for each participant ($\Delta = 3\text{-mos follow-up} - \text{baseline}$). We then used the Wilcoxon Rank Sum test to evaluate differences in outcomes between the two groups. The Wilcoxon Rank Sum, analogous to the independent samples t -test, assigns a rank (i.e. first, second, third...) to each change score; the ranks are then summed by group. Outcomes of two different treatments can be compared by evaluating the sum of the ranks relative to the the mean of the rank sums [13].

Results

This study examined the feasibility and preliminary outcomes of using a static splinting approach postoperatively for adults with hand OA who underwent PIP joint arthroplasty. Our results demonstratesimilarity among the two treatment groups. Both the static and dynamic splinting groups had similar reductions in pain and increases in satisfaction from baseline to 3 months follow-up. In addition, the static group had better outcomes in MHQ work performance and Jebsen-Taylor test, while non-significant improvements were found on the other functional performance tests of grip and pinch strength and arc of motion.

Within-group analyses

Figure 1 displays the within-group changes from baseline to 3-months on the MHQ. Both groups showed improvement on all of the subscales with varying degrees of statistical significance. The static splinting group reported significant improvements over baseline in all subscales ($\Delta=16\text{--}32$, $p=.04$) except for satisfaction which showed a non-significant trend ($\Delta=30$, $p=.07$).

The dynamic splinting group reported statistically significant improvements in the pain, satisfaction and aesthetics subscales ($\Delta=22\text{--}28$, $p<.04$). Both the function ($\Delta=13$, $p=.09$) and ADL ($\Delta=9$, $p=.16$) subscales showed a trend toward statistical significance, while the work subscale showed no improvement statistically($\Delta=3$, $p=.46$).

Figure 2 displays the within-group changes from baseline in the functional performance measures. The static splinting group demonstrated statistically significant improvements in their performance on the Jebsen-Taylor test ($\Delta=11.58$ seconds, $n=5$, $p=.04$). The grip

strength ($\Delta=2.17\text{kg}$), key pinch ($\Delta=.75\text{kg}$) and arc of motion ($\Delta=8.25^\circ$) changes did not reach statistical significance ($n=8$, $p=.16-.33$).

In the dynamic splinting group, no changes in functional performance reached statistical significance. The time to complete the Jebsen-Taylor test demonstrated an improvement ($\Delta=2.76$ seconds, $n=7$, $p=.06$), however changes in the remaining tests of grip and pinch strength and arc of motion were non-significant ($p=.44-1.0$).

Between-group analyses

Tables 3 and 4 show the between-group differences on both the patient-reported outcomes and the performance tests. With respect to the MHQ (Table 3), there were no significant differences between the static and dynamic splinting groups except on the “work” subscale. Specifically, in the dynamic group, two of the 10 patients reported a decrease in work performance at three months which did not occur in the static group. Similarly, there were no significant differences among any of the performance measures (Table 4) except for the Jebsen-Taylor hand function test in which the static group displayed a greater improvement relative to the dynamic splinting group.

Discussion

Although a larger trial on static versus dynamic splinting is needed, these preliminary findings suggest that static splinting alone may be an appropriate alternative treatment approach to dynamic splinting. In clinical settings, therapists have been modifying the implant manufacturer’s recommended protocol to exclude dynamic splinting and include various static splinting designs as well as template exercise splints. Although the study by Herren et al. [10] reported on the use of a static splinting protocol, the early range of motion and lack of restriction to the allowable arc of motion likely contributed to complications with the implants. In this study, a more conservative approach was taken to control range of motion and as a result, may have reduced these complications.

We found that the static splinting was feasible to deliver and easy for the participant. Overall compliance with the HEP and daytime splinting recommendations was high with 76% of patients performing their exercises at least 6 times a day and 94% of the patients wearing their splint at least 5 hours per day. In addition, this protocol may facilitate patient compliance in hand therapy attendance by allowing the patient to be treated closer to home than the surgeon’s hand therapy clinic. Often it is difficult to find a certified hand therapist (CHT) to treat a patient with dynamic splinting, which requires advanced skills to assess proper fit and adjust appropriately the angle of pull and tension. Therapists from outlying communities have visited our clinic for training prior to treating this population with dynamic splinting. Dynamic splinting requires advanced skills. The use of static splinting rather than dynamic splinting may make it more convenient for patients to be followed closer to home by less specialized therapists.

There are several differences between using a static splint and using a dynamic splint for this population. A static splint offers lateral support the entire length of the digit, offering greater protection during the day from lateral stress to the implant than provided by a dynamic splint. In addition, donning and doffing a static splint requires fewer steps than a dynamic splint. In contrast, a dynamic splint provides tension which needs to be monitored closely, to prevent hyperextension of the implant, and potential for dorsal dislocation. Tension that falls short of the desired amount can result in a flexed resting position of the joint that can promote an extensor lag. It has been reported that hyperextension, with the PIP joint locking at the flexion initiation, is regarded by patients as troublesome and cause for an inferior

outcome [7]. Full PIP extension can actually allow hyperextension of the implant, which can be difficult to control with dynamic splinting.

A main limitation to this study is the small sample size. This fact limits the ability to generalize our findings. Although every patient invited to participate in the study was included, the low numbers are due to the fact that this is an elective procedure, which relies on patients seeking treatment. By examining the change in each group individually from baseline to 3 month followup, we found improvements in both groups. However, our low sample size contributed to the high likelihood of a Type II error when examining differences *between* groups. We performed a post-hoc power analysis to examine this likelihood using data from our current MHQ pain and patient satisfaction subscales. Indeed, our data suggests that in order to detect a significant group difference ($\alpha = 0.05$) at 80% power we would need 453 and 906 subjects respectively. Despite the small sample size, our ongoing long-term assessments (at one and two years post procedure) may provide further evidence to enhance this study.

Although not formally documented, efforts were made in the early phase of this study to ensure similar measuring techniques between the blinded CHT who measured the static splinting group and the author who measured the dynamic splinting group. Both CHTs used the same type of goniometer.

A possible confounding issue when interpreting the results is that both groups received a static splint so it is impossible to determine if the outcomes were solely due to splint approach differences. Further the differences in the protocols regarding active extension could also have influenced the outcomes. As the dynamic group begins active extension within the dynamic splint at 3 weeks, they are getting assistance from the dynamic extension splint, whereas the static group is actively extending out of a splint.

Strengths of this study include the fact that all subjects in both the static and dynamic splinting groups underwent joint replacement surgery by one of the authors (KCC), and the majority of subjects were treated exclusively by the first author (JMR). A separate blinded CHT evaluated ROM and a research assistant evaluated patients in the Jebsen-Taylor test, grip strength, pinch strength and issued the self-assessment MHQ.

In conclusion, this study provides preliminary evidence that a static splinting approach is feasible, efficacious and at least equivalent to a dynamic splinting approach after PIP arthroplasty. Given that static splinting offers greater protection postoperatively, is easier to don and doff, requires less skilled care in adjusting for fit and generally offers the patient more convenience than dynamic splinting, future studies with larger samples and evaluation of long term effects are needed.

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Figure 1.

Within-group changes in MHQ scores from baseline to 3-months follow-up

*Statistically significant change from baseline to 3-months in the static splinting group ($p < .05$); \$Statistically significant change from baseline to 3-months in the dynamic splinting

group ($P < .05$).

Figure 2.

Within-group changes on functional performance from baseline to 3-months follow-up
 kg=kilograms; sec=seconds, ROM=range of motion; *Statistically significant change from
 baseline to 3-months in the static splinting group (p<.05)

Table 1

Demographic Data

	Static Splinting Group (n=9)	Dynamic Splinting Group (n=10)
Age (years)	62 (53–78)	59(52–72)
Sex F/M	8/1	9/1
No. of procedures	9	16
Laterality of procedure R/L	5/4	10/6
Involved digit		
• Index	4	4
• Middle	2	7
• Ring	3	4
• Small	0	1

Table 2**Static and Dynamic Splinting Approaches**

Post-operative period	Static Splinting Approach	Dynamic Splinting Approach
4–7 days	Fabricate hand-based volarstatic extension gutter splint with PIP in slight flexion worn between exercises during the day and at night. Gradually adjust goniometer or cardboard template to allow for a 30° arc initially and progress to 45° by 3-wks post-op. If hyperextension exists, fit in a dorsal blocking splint with PIP at 30° worn during the day. Initiate active flexion and passive extension hourly using goniometer to MCP/PIP/DIP.	Fabricate hand-based clamshell dynamic PIP extension splint allowing 30° arc with precaution not to hyperextend implant worn during the day and gradually adjusting to allow for 45° by 3-wks post-op. If hyperextension exists, add PIP extension block at 30°. Fabricate hand-based (originally forearm-based) volar static extension gutter splint with PIP in slight flexion worn at night. Initiate AROM hourly within splint to PIP and DIP.
10–14 days	Scar management initiated following suture removal	Scar management initiated following suture removal
3-weeks	Goal: 45° of PIP flexion Active extension initiated	Goal: 45° of PIP flexion Active-assisted extension initiated in dynamic splint
4-weeks	Goal: 60° of PIP flexion May reduce static splinting during the day and replace with buddy strap to radial border digit or hinged PIP splint for index. A blocking splint may be fabricated to enhance PIP flexion as well as reverse blocking.	Goal: 60° of PIP flexion May discontinue dynamic splint and replace with buddy strap to radial border digit or hinged PIP splint for index.
6-weeks	Goal: 15/75° at PIP Replace with buddy straps to a radial border digit if not already done. Gentle passive range of motion initiated. Encourage light use of digit using joint protection principles and avoiding lateral pressure to digit.	Goal: 0/75° at PIP Gentle passive range of motion initiated. Encourage light use of digit using joint protection principles and avoiding lateral pressure to digit.
8-weeks	Gentle strengthening initiated Encourage continued use of night splint for 3+ months.	Gentle strengthening initiated Encourage continued use of night splint for 3+ months.

Table 3Between group differences^{\$} on change in MHQ scores

	Static (n=5)	Dynamic (n=8)	P
Change Scores			
Pain	-32.00 ± 13.96	-28.75 ± 20.31	0.94
Satisfaction	29.67 ^{\$} ± 27.23	31.19 ± 19.43	0.83
Aesthetics	26.15 ± 22.35	22.34 ± 22.87	0.94
Work	21.00 ± 14.75	3.13 ± 14.13	0.05*
ADL	19.16 ± 11.47	9.29 ± 18.87	0.44
Function	16.00 ± 9.62	13.13 ± 17.92	0.72

^{\$} Positive number indicates improvement on all scales, except for pain where a negative number indicates decreased reported pain.

* Statistically significant *W* statistic from Rank Sum Test, $p < 0.05$;

Table 4Between group differences[§] on change in functional performance

	Static Splinting	(n)	Dynamic Splinting	(n)	p
Grip strength (kg)	2.17 ± 3.47	(8)	-0.11 ± 4.96	(6)	0.28
Key pinch (kg)	0.75 ± 1.18	(8)	-0.0006 ± 0.61	(6)	0.35
Jebsen-Taylor	-11.58 ± 5.44	(5)	-2.81 ± 3.23	(7)	0.03 *
Arc of Motion (°)	8.25 ± 22.75	(8)	4.78 ± 20.54	(9)	0.96

* Statistically significant *W* statistic from Rank Sum Test, $p < .05$;[§] Positive numbers indicate improvement, except in the Jebsen-Taylor test where a negative number indicates improved hand function