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Functional Outcomes for Basilar Joint Arthroplasty with Meniscus Allograft Compared with Trapeziectomy Alone

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Abstract

Background: Advanced thumb carpometacarpal (CMC) joint arthritis is widely treated with trapeziectomy. To obviate the need for autologous tissue, maintain thumb length, and reduce the risk of scaphoid impingement, the senior author developed an interposition arthroplasty technique using meniscal allograft. We hypothesize that the use of meniscus improves outcomes and subsequent functionality compared with trapeziectomy alone. **Methods:** Twenty-three patients with Eaton stage III-IV CMC osteoarthritis underwent arthroplasty with meniscal allograft, and 7 patients underwent trapeziectomy alone. Preoperative Disabilities of the Arm, Shoulder, and Hand (DASH), pain, grip and pinch strength, and range of motion scores were compared with postoperative scores at 6 weeks, 6 months, and 1 year. **Results:** The study group consisted of 17 women and 6 men, and the control group consisted of 5 women and 2 men. The mean age was similar at 61.4 (48-72) years and 65.7 (56-78) years for the study and control groups, respectively. The DASH scores dropped by 61.8% in the study group compared with 38.8% in the control group (<0.01), whereas pain decreased 86.0% and 69.8%, respectively ($P < .01$). Strength and range of motion improvement was similar between the groups. Subsidence of the joint space was 1% in the study group compared with 18.4% in the control group. There were no surgical complications in either group. **Conclusions:** Joint resurfacing with meniscal allograft represents a viable joint salvage option in severe cases of CMC arthritis. Early results suggest that, compared with trapeziectomy alone, the approach results in greater reduction in subjective pain and disability scores, similar improvement in strength measures and range of motion, and less subsidence.

Keywords: arthroplasty, arthritis, diagnosis, allograft, basic science, CMC, outcomes, research and health outcomes, treatment

Introduction

The carpometacarpal (CMC) joint is commonly affected by osteoarthritis and frequently requires surgical intervention. Several different surgical treatments have been proposed, but it remains unclear which approach results in the best outcomes and highest patient satisfaction.[1-3] Arthrodesis was one of the first described approaches and has been shown to reduce pain, provide stability, and improve strength.[4,5] However, complications such as arthritis of adjacent joints, nonunion, and the potential need for removal of hardware, along with the loss of motion of the joint, have encouraged the development of motion-sparing approaches.[6,7] These procedures typically involve trapeziectomy. To avoid subsidence of the joint space and resultant recurrence of symptoms, many approaches additionally feature tissue interposition and/or ligamentoplasty with various autografts.[5,8-11]

Autograft procedures, however, necessitate a donor site that carries the risk of donor site morbidity. In a Cochrane review, Wajon et al[2] found those who had trapeziectomy with ligament reconstruction and tendon interposition (LRTI) had more complications, including scar tenderness, tendon adhesion or rupture, sensory change, or complex regional pain syndrome type 1, than patients who underwent trapeziectomy alone. Moreover, as the most common donors are the flexor carpi radialis (FCR) tendon and the abductor pollicus longus tendon, the wrist donor site may be subjected to functional problems such as decreased wrist flexion-extension torque ratio and flexion fatigue resistance.[12] The use of synthetic grafts, such as silicone implants, has also been plagued by high complication rates secondary to synovitis and mechanical failure.[13-15]

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Similarly, the use of Gore-Tex (W.L. Gore and Associates, Inc., Flagstaff, Arizona) has shown high rates of synovitis and poor patient outcomes.[16,17] Xenografts with porcine collagen have been attempted,[18-20] but have been found to have adverse immunologic reactions.[20] Various metal or polymer implants have also been developed, but these too are subject to high rates of mechanical failure.[21-23] Suture button suspensionplasty with mini-tightrope (Arthrex, Inc, Naples, Florida) avoids some of the complications of interposition grafts while still maintaining joint space, but carries with it the potential for metacarpal fracture, symptomatic hardware, and impingement of the metacarpal base if overtightened.[24,25]

Meniscus allograft transplantation (MAT) with meniscus allograft has long been used in the knee to treat various forms of meniscus damage or degradation. The MAT yields fair to excellent results in almost 85% of patients with long-term improvements in pain and functional outcomes.[26,27] Complication rates are low,[27-29] with low reoperation and revision rates even in an athletic population.[28] While predominantly used in the lower extremity, Nanavati et al[30] first described the use of MAT for proximal carpectomy in the hand. More recently, Shapiro et al[31] described the use of MAT for interposition arthroplasty in CMC arthritis, and Hoang et al[32] described it for resurfacing of metacarpal phalangeal and proximal interphalangeal joints of the hand. However, further studies regarding clinical outcomes, including strength and range of motion measures, as well as patient-reported pain and disability scores, are lacking. We present a prospective, nonrandomized controlled trial comparing the use of meniscus for interposition arthroplasty with trapeziectomy alone for the treatment of basilar joint arthritis.

Methods

Patients

Thirty patients with Eaton stage III and IV CMC arthritis were enrolled in the study. Indications included persistent symptoms of pain, disability, and/or weakness despite conservative therapy (defined as either nonsteroidal anti-inflammatory medication and splinting or corticosteroid injections). Exclusion criteria included concurrent connective tissue disorder and conditions affecting wound healing, including uncontrolled diabetes, regional sympathetic dystrophy, pregnancy, or active infection at the time of surgery. Eligible patients were approached by a study administrator at the time of their preoperative visit for inclusion in the study. Discussion of the study occurred after consent for the procedure was signed to ensure that patients understood that their participation in the study would not affect their care. Approximately 40 patients were recruited with a 75% enrollment rate. Seven patients made up the control group of trapeziectomy alone, and 23 patients underwent interposition arthroplasty with meniscus to make up the study group. Two senior surgeons preformed the surgeries, with one preforming trapeziectomy alone and the other the meniscus interposition. Patients were assigned to groups based on their operating surgeon. The groups were frequency-matched for age, female-to-male ratio, Eaton stage, and prior intervention to ensure equal distribution of variables across the dissimilarly sized groups.

Operative Technique

In both the control and the study groups, an incision was made over the dorsal aspect of the CMC joint at the thenar eminence, approximately 1 cm distal to the tip of the radial styloid and extended distally for 4 to 5 cm. The dorsal sensory branches of the radial nerve and the dorsal branch of the radial artery were identified and protected, and the interval between abductor pollicis longus and extensor pollicis brevis tendons was identified. A longitudinal capsulotomy was performed in this interval to expose the joint. A synovectomy was then performed using a rongeur, and the trapezium was decorticated with a burr. Measurements of the debrided osteochondral defect were then taken and used to carve an appropriate-sized interposition graft from meniscal allograft (MTF Biologics, Edison, New Jersey) on the back table. The meniscus allograft was provided fresh-frozen and sterile after being aseptically processed with no terminal irradiation. Half of the width of the meniscus was used, making sure that the resultant graft was at least 2 to 3 mm thick, and the rough surface of the graft was placed against the decorticated bone to facilitate cellular repopulation. The allograft was then secured with extracapsular 4-0 Mersilene sutures (Ethicon, Somerville, New Jersey) and coated with fibrin sealant glue (Figure 1a-1c). Intraoperatively, the joint space was reduced and taken through a full range of passive motion to ensure smooth tendon gliding, adequate joint stability, and no bony contact. In the control group, an identical process for exposure was undertaken and a complete trapeziectomy was performed. In both groups, fluoroscopy was used to confirm the complete removal of the bone in the control group and to evaluate adequate positioning of the joint and implant in the study group.

In both groups, the joint capsule and skin were then closed, and the patient was placed in a short-arm thumb spica splint. The postoperative immobilization protocol and therapy protocol were the same in both groups. The operative splint was maintained for 3 weeks at which point it was exchanged for a removable thermoplastic thumb spica splint, and gentle range of motion exercises were initiated by a hand therapist. At 6 weeks, the splint was discontinued and progressive hand therapy continued until satisfactory range of motion and strength returned.

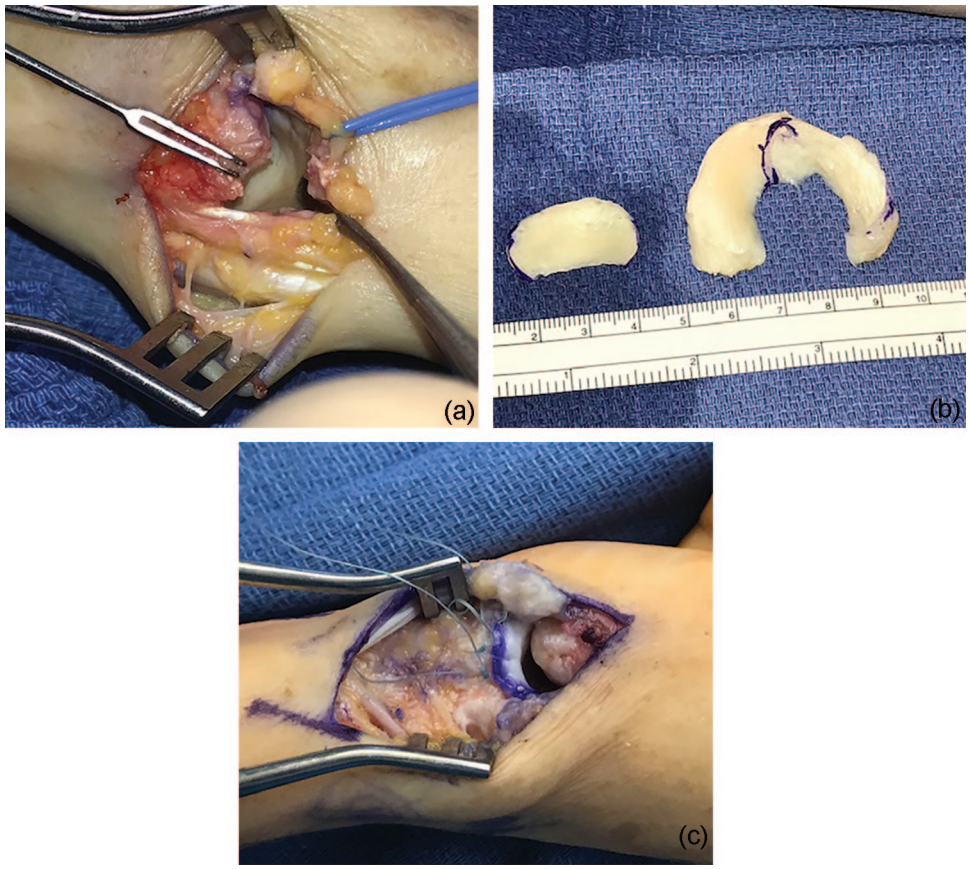

Figure 1. (a) Carpometacarpal joint space with abductor pollicis longus and extensor pollicis brevis tendons inferiorly and radial sensory nerve tagged with vessel loop. (b) Carving of the meniscus on the back table, demonstrating the size and thickness of the allograft. (c) Inset of meniscus with 4-0 Mersilene sutures.

Outcome Measures

Patients' Disabilities of the Arm, Shoulder, and Hand (DASH) and Wong-Baker pain scale scores were recorded with standardized, validated survey instruments.[33,34] These were completed by the patient at each visit and collected by a study administrator who was blinded to the patient group. Grip strength and pinch strength were recorded by the same blinded hand therapist at each session. Grip strength was measured with a JAMAR dynamometer (Sammons Preston, Bolingbrook, Illinois), and pinch strength was measured by a B&L pinch gauge (Baseline, Link, Germany). Standard arm positioning was used (patient seated with shoulder in neutral position and elbow at 90° of flexion). For each strength test, the scores of 3 successive trials were recorded, and the average value was used for analysis. Arthroplasty space was calculated by measuring the distance between the distal pole of the scaphoid and the proximal surface of the thumb metacarpal and dividing the scaphoid-metacarpal distance by the length of the thumb metacarpal, as described by Yang and Weiland.[35] Standard posteroanterior and oblique radiographs taken at each postoperative visit were used, and measurements of all patients were taken by the same researcher.

Statistical Analysis

Preoperative scores were compared with postoperative scores at 6 weeks, 6 months, and 1 year. All patients from the control group completed full 1-year follow-up, whereas 6 patients from the study group did not. Given the descriptive nature of the statistics, no imputation of missing data was performed. Descriptive summaries were based on the observations available within each of the time points. SPSS software V.22.0 (IBM SPSS, Armonk, New York) was used for all analyses. Paired *t* test were used to evaluate statistical significance from preoperative measures to each of the designated follow-up measures within each group. Significance was set at α of 0.05, and confidence intervals were set at 95%. Where there were bilateral surgeries, each hand was separately recorded. The study was approved by our institution's institutional review board, and informed consent was obtained from all patients.

Results

The study group with meniscal allograft consisted of 17 women and 6 men, and the control group consisted of 5 women and 2 men. Two patients in the study group underwent bilateral basilar joint arthroplasty with meniscus to make a total of 25 joints studied. The mean age was similar between the groups at 61.4 (48-72) years for the study group and 65.7 (56-78) years for the control group. All cases in the control group were primary interventions, whereas 1 case in the study group had previously undergone a CMC arthroplasty with acellular dermal matrix (FlexHD; MTF Biologics).

The mean DASH score decreased by 61.8% and 38.8% for the meniscus and control groups, respectively, from preoperatively to 1 year postoperatively. This reduction reached statistical significance ($P < .01$) in both groups; however, the study group improved more quickly and to a lower absolute value than the control. Reduction in Wong-Baker pain scores was statistically significant in both groups ($P < .01$). Strength measures improved in both groups, reaching statistical significance in grip, tip pinch, and key pinch. Grip improvement was equal between the groups at 29.1% and 29.4% for the study and control groups, respectively, but both tip and key pinch showed greater improvement in the control group (147.6% compared with 100% for tip pinch and 51.7% compared with 20.7% for key pinch). The range of motion improvement was also slightly greater in the control group, but failed to reach statistical significance in either group for either radial or palmar abduction. Finally, subsidence, as represented by the arthroplasty index, was nonsignificant in both groups, but was greater in the control group than in the study group (18.4% compared with 0.7%). The mean preoperative and postoperative measures with standard deviation, percentage change, and associated *P* values with confidence intervals are summarized in Table 1. Trends at each of the time points in DASH scores, Wong-Baker pain scale scores, strength measures, range of motion, and arthroplasty index are shown in Figure 2a-2e.

At the last follow-up, arthroplasty space was maintained in all patients with no evidence of impingement of the thumb metacarpal against the scaphoid. Figure 3a-3c demonstrates maintenance of the arthroplasty space in a patient with meniscus interposition, showing preoperative, 6-week, and 1-year follow-up radiographs in the same patient. There were no complications or adverse reactions associated with meniscus and no operative revisions in either group. Two patients in the study group went on to have the procedure in their contralateral basilar joint 6 months postoperatively.

Discussion

Meniscal tissue has unique properties that contribute to its potential application for CMC arthritis. It combines the strength of a native autograft without the necessity of a donor site. The composition of the tissue allows it to behave as a fiber-reinforced, porous, permeable composite material similar to articular cartilage. Type I collagen fibers maintain significant tensile strength (100-300 MPa), whereas high friction drag caused by low permeability of the matrix (which is one-sixth that of articular cartilage) allows for more energy dissipation.[36] The decellularization process of the meniscal allograft maintains the native scaffold, allowing it to maintain its intrinsic strength while simultaneously allowing repopulation with host cells once placed over the decorticated bone. Debeer et al[37] demonstrated that 1 year after MAT, the DNA of the meniscal allograft was 95% identical to that of the human recipient, showing that the allograft is nearly completely repopulated by host cells. As it is a foreign tissue, a concern for a foreign body reaction exists; however, Rodeo et al[38] compared histological and immunohistochemistry characteristics to assess the immune response elicited against MAT to a control group of unimplanted allografts, and at a mean of 16 months after transplantation found a minimal, and clinically insignificant, immune response.

Shapiro et al[31] were the first to report on the use of meniscal allograft in basilar joint arthroplasty in 2015. In their study of 23 patients and 25 joint reconstructions, they found statistically significant improvement in DASH and pain scale scores at 2-year follow-up. Grip strength and tip strength also increased, although they did not reach statistical significance. Oppositional range of motion decreased by 7.7%, although they note that all patients were able to touch the thumb to the base of the small finger. The authors also report a 5.5% subsidence rate compared with our 1%, although their follow-up period was longer which may account for further subsidence at the final follow-up. Notably, they included less severe cases of only Eaton stage II and III osteoarthritis, and while they demonstrate the feasibility of the approach, it is a single series report without a control group for comparison. In addition, we believe there are several advantageous technical distinctions within our own approach. Although we initially decorticated and resurfaced both the proximal and distal aspect of the joint, by the time of this study our technique had transitioned to only resurfacing the proximal, trapezial side. This reduces operative time to an average of 1 hour, results in less distortion of the native joint architecture, and allows for the use of less meniscal tissue.

Several trends in our results warrant further discussion. Pain was markedly improved in both groups, although again to a greater degree and more rapidly in the study group. Improvement in DASH scores similarly was greater overall and more rapid in the study group, but notably both the control and the study group had a transient increase in disability at the 6-week mark. This finding is likely due to the period of postoperative immobilization as strength measures in

Table 1. Mean Preoperative and 1-Year Follow-up Measures, Including Standard Deviation, % Change, and *P* Value With 95% Confidence Intervals.

	Preoperative		1 year		% change		*P* value	
Outcome Measure	Meniscus	Control	Meniscus	Control	Meniscus	Control	Meniscus	Control
DASH	40.4 (±21.5)	39.1 (±20.2)	15.4 (±16.8)	23.9 (±26.5)	61.8	38.8	**.002** 10.2 to 35.8	**.002** 19.5 to 37.5
Pain	6.3 (±2.4)	6.6 (±1.6)	0.88 (±2.7)	2.0 (±1.4)	86.0	69.6	**.001** 3.2 to 7.5	**.004** 2.3 to 6.4
Grip	38.8 (±24.8)	39.1 (±18.2)	50.1 (±24.1)	50.6 (±25.2)	29.1	29.4	**.041** −23.1 to 0.5	**.009** −18.2 to 4.7
Tip pinch	4.4 (±4.3)	4.2 (±2.0)	8.8 (±5.0)	10.4 (±4.8)	100	147.6	**.006** −7.7 to 1.7	**.019** −10.7 to 1.6
Key pinch	10.1 (±5.6)	8.7 (±4.2)	12.2 (±5.2)	13.2 (±6.4)	20.7	51.7	**.007** −5.5 to 1.1	**.006** −7.7 to 2.4
Palmar abduction	45.1 (±8.9)	42.1 (±9.5)	48.3 (±8.1)	54. 0 (±12.4)	7.1	28.2	.471 −11.9 to 0.08	.227 −23.5 to 7.5
Radial abduction	44.7 (±9.0)	45. 7 (±12.1)	51.0 (±12.0)	55. 0 (±15. 9)	14.1%	20.3%	.142 −13.3 to 2.2	.235 −53.8 to 17.8
Arthroplasty index	0.262 (±0.022)	0.228 (±0.0228)	0.260 (±0.025)	0.186 (±0.048)	0.7	18.4	.702 −0.02 to 0.11	.168 −0.01 to 0.01

Note. Bold type indicates statistical significance. DASH = Disabilities of the Arm, Shoulder, and Hand.

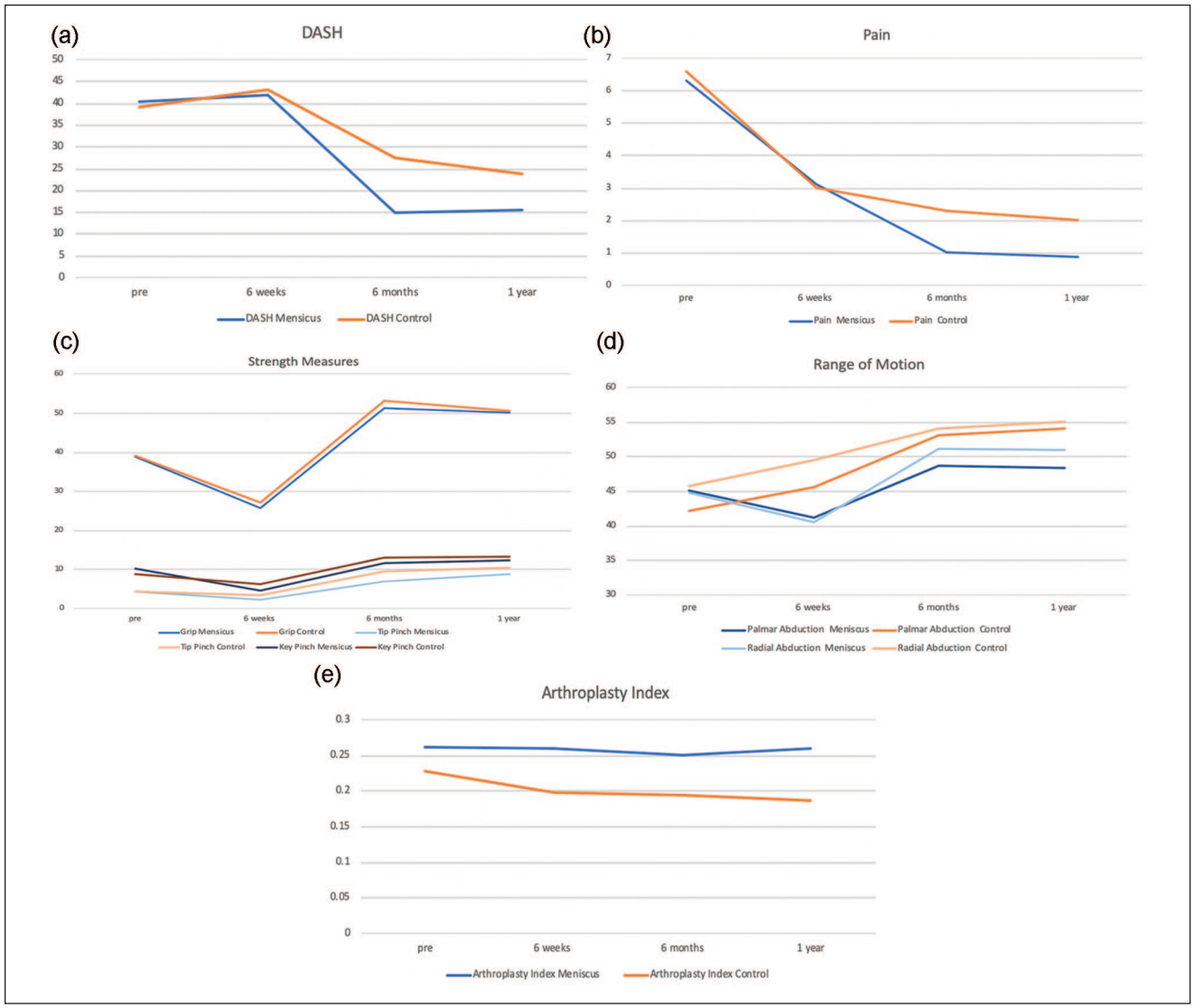

Figure 2. Trends in outcomes measures at each study time point: (a) DASH scores, (b) pain scale scores, (c) strength measures, (d) range of motion, and (e) arthroplasty index.
Note. DASH = Disabilities of the Arm, Shoulder, and Hand.

both groups followed a similar trend. Interestingly, range of motion scores showed a similar transient decrease in the study group at 6 weeks, whereas the control group showed a steady improvement throughout as well as a slightly higher end point. Although this may represent a motion limitation secondary to the interposition material, these trends should be interpreted with caution given the overall low study size.

Strength measures including palmar grip, tip pinch, and key pinch strength increased statistically significantly in both groups from preoperative to postoperative measures, but the increase was markedly greater in the control group, particularly for tip pinch strength (147% compared with 100%). Again, interpretation of this finding is limited as the very small sample size for the control group, 7 patients, and lower baseline average may have skewed the improvement. The lesser improvement in strength is also somewhat counterintuitive given the greater improvement in functionality in the study group. The improvement in DASH scores, however, does mirror a greater improvement in Wong-Baker pain scores, suggesting that patients' perceptions of disability were more affected by their pain level than by their strength. Studies have shown a strong correlation between pain and disability in CMC arthritis[39] and found that pain correlates more strongly than strength measures with respect to DASH scores.[40] Finally, neither group reached statistical significance in arthroplasty index, indicating adequate maintenance of arthroplasty space in both groups, but subsidence was found to be higher in the control group. This is to be somewhat expected as in the study group the trapezium was

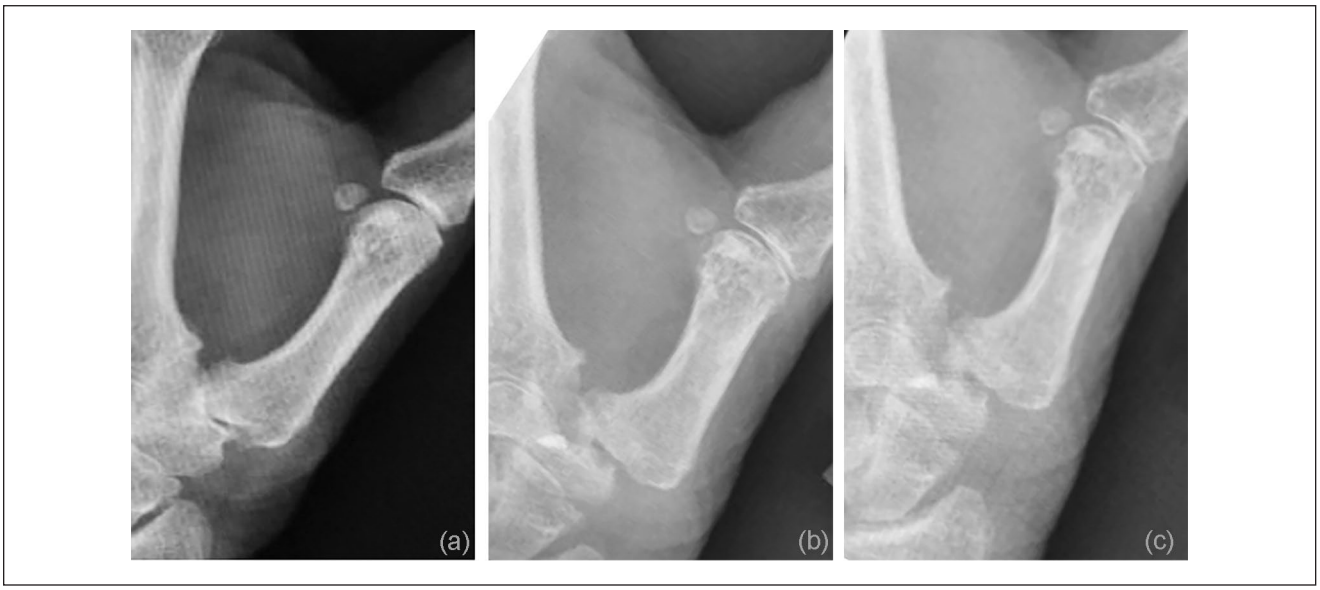

Figure 3. (a) Preoperative radiograph demonstrating joint space destruction. (b) Postoperative radiograph at 6 weeks after arthroplasty with meniscal allograft. (c) Postoperative radiograph at 1 year demonstrating maintenance of the arthroplasty space.

retained and resurfaced, compared with its complete removal in the control group. Nonetheless, we believe that the retained and resurfaced trapezium helps to maintain joint architecture and arthroplasty space, representing a distinct advantage of the meniscal allograft approach.

Prior meta-analyses have failed to show definitive proof of the superiority of any particular surgical approach over another for CMC arthritis,[1-3] and our own study is unable to demonstrate clear superiority of either technique examined. Nonetheless our findings show meniscus interposition arthroplasty to be at least comparable to trapeziectomy. Direct outcomes comparisons to other approaches are difficult given the multitude of outcomes measures and variability of follow-up in the literature, but the results in the study group were at least as good or better than established historical controls for a range of procedures encompassing arthrodesis, trapeziectomy alone, trapeziectomy with LRTI with FCR tendon, LRTI with fascia lata, costochondral grafts, silicone implants, human acellular dermal matrix interposition arthroplasty, pyrocarbon spacers, and button suspensionplasty.[5,9,10,11,13,18,19,22,24,31] Table 2 demonstrates direct outcomes comparisons where applicable. The control group also compared favorably, establishing trapeziectomy alone as a reliable baseline for prospective comparison.

Several limitations to this study exist, including its small sample size and shorter follow-up period. Importantly, limited statistical power because of the modest sample size, particularly in the control group, may have played a role in limiting the significance of some of the statistical comparisons conducted. A post hoc power analysis revealed that on the basis of the mean, the sample size of 5 was adequate to observe a statistical power of at least 0.80 for strength, pain, and disability measures, but fell below this level for range of motion measures. Those same range of motion measures did not reach statistical significance; nonetheless, trends should be interpreted with caution. In addition, the nonblinded, nonrandomized design based on operating surgeon may have introduced a patient selection bias. Despite a standardized protocol, the difference in operative surgeon may have resulted in slight variation in operative technique, beyond the main differentiating trapezial resection versus resurfacing, or postoperative management. Cost of the meniscus is another limitation to the approach as the product used for the interposition costs approximately US $1200 for a full meniscus. Tailored smaller MAT sizes specific to the hand and small digit joint space may further reduce the cost of the meniscus allograft and maximize the use of the donated human tissue. However, this is comparable to other currently used implants such as the pyrocarbon spacer, PI2 (Tornier Bioprofile, Grenoble, France), at approximately €930, FlexHD (MTF Biologics) at approximately US $1000,[19] Arthrex mini-tightrope (Arthrex, Inc) at approximately US $1000, GraftJacket acellular dermal matrix (Wright Medical Group, Memphis, Tennessee) between US $1000 and US $3000, and the titanium hemiarthroplasty implant at approximately US $2000 (Wright Medical Group).[31]

Conclusion

Basilar joint arthroplasty with meniscal allograft can be used safely and effectively to treat CMC arthritis, preserving motion compared with arthrodesis, providing an alternative material to avoid autograft donor site morbidity, and avoiding many of the complications inherent to synthetic

Table 2. Outcomes Comparison to Historical Controls.

	Arthroplasty space subsidence, %	DASH score, %	Wong-Baker score, %	Grip strength. %
Trapeziectomy alone (control)[a]	18	39	69	29
Meniscus interposition arthroplasty[a]	1	62	86	29
Meniscus interposition arthroplasty[31]	5.5	42	*	29
Arthrodesis[5]	*	36	*	17
LRTI with FCR[5]	*	55	*	8
LRTI with FCR[9]	*	55	76	35
LRTI with Fascia lata[10]	45	*	80	26
Costochondral graft[11]	21	*	*	51
Silicone implant[13]	50	*	*	4
ADM arthroplasty[18]	31	*	89	16
ADM arthroplasty[19]	12	74	78	24
Pyrocarbon implant[22]	*	*	85	*
Pyrocarbon implant[23]	*	84	86	40
Button suspensionplasty[24]	20	*	83	44

Note. DASH = Disabilities of the Arm, Shoulder, and Hand; LRTI = ligament reconstruction and tendon interposition; FCR = flexor carpi radialis; ADM = acellular dermal matrix.
[a]Described herein.
*Not measured.

interposition alternatives. To our knowledge, this is the only prospective study comparing trapeziectomy alone with interposition arthroplasty with meniscus, and early results suggest that it can result in a more rapid return to painless, functional use; comparable improvement in strength and range of motion measures; and less subsidence at 1 year. By retaining and resurfacing the trapezium, it effectively maintains the joint space and preserves the option for any number of potential revisional approaches should a secondary surgery be required. Further long-term follow up is ongoing to evaluate the durability of the method over time and to determine whether higher long-term functionality might justify the initial cost investment of the allograft.

Authors' Note

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Ethical Approval

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. The institutional review board at our institution approved this study (CR00001079).

Statement of Human and Animal Rights

This article does not contain any studies with human or animal subjects.

Statement of Informed Consent

Informed consent was obtained from all patients for being included in the study.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: D.K. serves on the board of the Musculoskeletal Transplant Foundation but receives no remuneration with respect to the products discussed. All other authors have no disclosures.

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