Surgical Treatment of Thumb Carpometacarpal Joint Arthritis: A Single Institution Experience from 1995–2005

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Abstract There are numerous techniques for the surgical management of thumb carpometacarpal (CMC) joint arthritis. The four senior authors of this study employ three such techniques: trapeziectomy with hematoma distraction arthroplasty, hemitrapeziectomy with osteochondral allograft, and ligament reconstruction tendon interposition (LRTI). This study examines the three commonly utilized procedures at a single institution. This study examines the 10-year experience from 1995–2005 with a minimum 3-month follow-up. Disabilities of the arm, shoulder, and hand (DASH) scores, pre- and postoperative pinch strength, and operative time were examined. After approval from the institutional review board of our institution was obtained, all patients treated surgically by three of the senior authors were contacted via mail and phone. Each patient was asked to complete and return a DASH questionnaire. Of the 115 patients treated during that

period, 60 participated in this study. Each patient's final postoperative pinch measurement was obtained from occupational therapy and clinic records. This pinch strength was compared to the preoperative pinch and contralateral pinch strength. Lastly, the total operative time for each procedure was obtained from the operative record. The only significant finding in this study was a shorter mean operative time with the trapeziectomy group (76.90 min) and osteochondral allograft group (90.45 min) when compared to the LRTI group (139.00 min; $p=0.001$ and $p=0.001$, respectively). We found no significant difference between groups in terms of DASH score and pinch strength. There was no difference between the techniques in terms of postoperative pinch strength and patient satisfaction measured by DASH scores. The operative times for trapeziectomy and hematoma interposition as well as the osteochondral allograft were significantly shorter than that of the LRTI. This presents further evidence that potentially, "less is more" in the treatment of thumb CMC arthritis. We used a retrospective study design to evaluate potential differences between the three surgical techniques described above, therapeutic, levels III–IV.

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Introduction

Osteoarthritis of the thumb carpometacarpal (CMC) joint mostly affects older women. In one study, radiographic evidence of thumb CMC joint osteoarthritis is found in 28% of postmenopausal women. Of the patients with radiographic evidence of thumb CMC joint arthritis, 55%

experienced pain [1]. The condition is commonly bilateral with varying degree of symptoms. Most patients experience pain relief with conservative treatment options, such as activity modification, nonsteroidal anti-inflammatory medications, splints, or corticosteroid injections, but surgery is indicated in refractory cases.

There are many different surgical techniques described to treat the condition. Since simple trapeziectomy was described in the 1950s, there have been a number of authors advocating the technique for its predictable postoperative pain relief [19, 25, 26, 30, 33, 50, 56]. However, trapeziectomy alone is thought by some to be associated with a decrease in grip strength [14, 33]. Furthermore, the trapezial void created by the procedure is thought to cause the thumb metacarpal to subluxate, dislocate, migrate proximally into the void, or diverge laterally away from the second metacarpal [9, 14, 33, 36, 44]. Arthrodesis of the thumb CMC joint was described as an alternate procedure, but loss of range of motion at the thumb CMC joint has made many surgeons reluctant to adapt it as the first-line surgical method to treat refractory thumb CMC joint osteoarthritis, except in a young laborer [43]. Accordingly, many authors have devised procedures aimed to fill the trapezial void created by the trapeziectomy and/or recreate a suspensory ligament.

Ligament reconstruction and tendon interposition (LRTI) is one of the techniques that addresses the trapezial void created by the simple trapeziectomy technique [10, 20, 24, 38, 47, 54]. Although there are some authors reporting that postoperative patient satisfaction and functional outcome are similar in head-to-head comparison between the trapeziectomy technique and the LRTI technique, the latter has become increasingly popular among hand surgeons over the years [31]. The flexor carpi radialis (FCR), abductor pollicis longus (APL), or palmaris longus has been the tissue of choice for the tendon interposition to fill the trapezial void [10, 15, 18, 39]. Although there are subtle differences in surgical techniques, these procedures may be categorized as “tendon interposition” techniques, and postoperative results have not been significantly different among different variations [5, 13, 18, 22, 23, 51]. Because of the additional operative time and morbidity associated with the tendon harvesting portion of the techniques, there have been numerous attempts at finding other suitable spacers that may fill the trapezial void. One such spacer is an allograft costochondral interposition graft. The reported postoperative pain relief and functional improvement associated with the graft interposition is comparable to the results reported in the studies that investigated the efficacy of the tendon interposition techniques [55]. Currently, there are many synthetic spacers available as well. Although newer silicone materials show better results [37], silicone implants traditionally tend to be problematic because they

have the tendency to fracture and the fragments are known to cause synovitis, leading to osteolytic thumb joint destruction [7, 32, 34, 42, 49, 52, 53]. A similar inflammatory reaction is observed in various other synthetic or xenograft implants, and there has not been a good spacer implant that produced reliable long-term pain relief and thumb functionality [46].

Recent trends in CMC joint arthroplasty have evolved toward simple trapeziectomy with added precautions to prevent commonly known complications of the procedure mentioned above. Hematoma distraction arthroplasty (HDA) utilizes piecemeal excision of the entire trapezium and 5 weeks of K-wire immobilization of the first metacarpal in slight distraction and opposition [35]. The authors suggest that hematoma filling the trapezial void followed by fibrosis formation during the period of K-wire immobilization attributes to the stable CMC joint with postoperative findings comparable to other commonly utilized procedures [29]. Since most implant arthroplasty techniques also require some measure of immobilization for 5 to 18 weeks, some authors question the utility of spacer placement in CMC arthroplasty procedures [16, 21, 27, 29, 35].

With this study, we directly compared three senior surgeons utilizing three representative techniques from large popular categories of the CMC joint arthroplasty: hemitrapeziectomy with costochondral graft interposition (allograft interposition), LRTI, and HDA. With direct comparison of these techniques, we aim to elucidate any differences in intraoperative time, improvement in pinch strength, and patient satisfaction.

Methods

This study was approved by the institutional review board at our institution. A total of 115 patients underwent the CMC arthroplasty by three of the senior surgeons in this study during a 10-year period from 1995 to 2005. All of the procedures included in this study were performed at the same institution. The patients were contacted via mail and phone for consent and distribution of the DASH questionnaire. Of the 115 identified patients, 60 (53%) patients responded and participated in this study. The operative time and preoperative pinch strength for each patient was obtained from surgical records. Each patient's final postoperative pinch measurement was obtained from occupational therapy and clinic records. Postoperative pinch strength was compared to the preoperative and contralateral pinch strength.

The *p* value given for each measure of surgical outcome comparing the three techniques was generated using analysis of variance (ANOVA). This method uses the null hypothesis that the three surgical techniques are similar

with respect to the outcomes and tests for differences. If the p value is significant, it indicates that all groups are not the same, but does not identify which one is different. Therefore, we utilized the Tukey–Kramer method to evaluate each type of surgery with the other. This method was used because we wanted to compare each group head-to-head and still ensure an overall level of significance of $\alpha=0.05$. The Tukey–Kramer method is a conservative method, which allows for multiple comparisons and unequal sample sizes in each surgical group.

Operative Procedures

Costochondral Allograft Interposition Arthroplasty

The surgery is performed using a standard volar approach to the base of the thumb. The branches of the superficial radial nerve are identified and protected. The CMC joint is exposed by reflecting the abductor pollicis brevis muscle medially, protecting the insertion of the APL. A longitudinal capsulotomy is made in the capsule, and radial flaps are elevated to expose the thumb trapeziometacarpal joint. The distal half of the trapezium is subperiosteally dissected. In addition, a small arthrotomy is made in the scapho–trapeio–trapezoidal joint to confirm that the joint is free of degenerative changes before proceeding with partial excision of the trapezium. A small oscillating saw is used to remove the distal half of the trapezium while protecting the FCR tendon. A costochondral allograft is carved into a disk for interposition into the joint. A good press fit is obtained. A distally attached 3–4 mm×4 cm slip of APL tendon is created and passed into the joint via a tunnel drilled into the base of the trapezium, then passed through a hole made in the cartilage graft and finally through a tunnel drilled in the remaining trapezium. The end of the tendon slip is anchored under mild tension to its origin at the base of the metacarpal, recreating the course of the normal anterior oblique ligament. The capsule is then closed with non-absorbable sutures. Postoperative immobilization in a thumb spica cast is followed at 4 weeks by gentle range of motion exercises and a removable splint that immobilizes the thumb. At 8 weeks, unrestricted thumb motion is allowed, and the splint is discontinued.

Ligament Reconstruction and Tendon Interposition

A curvilinear incision is made along the palmar radial border of the thumb metacarpal base, starting 2 cm distally to the distal wrist crease and ending 5 cm proximally to the proximal wrist crease between the radial artery and FCR tendon. After the thenar muscles are reflected distally, the trapeziometacarpal joint is exposed. The trapezium is

excised en bloc or in pieces with all osteophytes using an osteotome. The FCR tendon is exposed through a single longitudinal incision at the junction of the distal and medial thirds of the forearm. The proximal tendon is cut halfway across its width. Half of the tendon is stripped free of the remaining portion of the FCR (10 cm in length) and brought out through the distal incision. A drill hole is made into the base of the metacarpal and connected with a drill hole made in the dorsal radial aspect of the thumb metacarpal base. The FCR is then passed through the tunnel, around the APL, and back around the intact half of the FCR tendon in a figure of eight fashion. The Pulvertaft weave is repeated four times and sutured under minimal tension. Advancement of the APL tendon from a point proximal to the suspension sling to the proximal metacarpal periosteum is then performed. The tendon is sutured securely just distally to its insertion at the base of the thumb metacarpal. The capsule and soft tissue closure was followed. The thumb is immobilized in a short-arm thumb spica case for 5 weeks. The patients began active and passive range of motion exercises after the immobilization.

Hematoma Distraction Arthroplasty

The surgical protocol consists of a standard dorsal approach to the CMC joint. A curved dorsal-radial incision over the trapezium is made. Blunt longitudinal scissor dissection in the subcutaneous tissue locates and protects the radial sensory nerve, radial artery, extensor pollicis longus, extensor pollicis brevis, and APL tendon. After retracting these structures, the capsule of CMC joint is visualized. A longitudinal incision is made in the capsule, and this is sharply reflected off the trapezium. A 10-mm osteotome is then used to make two longitudinal fractures in the trapezium. These fragments of trapezium are removed with a rongeur. A stout elevator is useful in maneuvering deep bone fragments into the field for removal with the rongeur. Care is taken during this part of the procedure not to injure the FCR tendon, which crosses the surgical field obliquely just ulnar to the trapezium. After the extraction of the trapezium, the thumb is held in slight distraction and opposition, and a 0.062-inch Kirschner wire is inserted through the base of the thumb metacarpal in a dorso-ulnar direction into the base of the index metacarpal or the trapezoid. After the K-wire placement, the thumb is examined in the operating room to ensure that the K-wire is supporting the thumb in a distracted and opposed position. The wire is cut short, leaving a short stump for the ease of removal postoperatively. The wound is then irrigated, and the capsule and skin are closed. A short arm thumb spica splint is placed. The pin is removed 5 weeks postoperatively and gentle range of motion exercises is initiated.

Results

For our statistical analysis, we utilized the Tukey's method for the purpose of head-to-head comparison of the result from each technique because each group contained different total number of patients. The ANOVA was utilized for the overall comparison.

The average age of the HDA group was 59.70 ± 7.07 years. For the costochondral graft group, the average patient age was 57.06 ± 12.98 . The LRTI patient group has the average age of 55.50 ± 13.33 (Fig. 1).

We found no significant differences between the mean DASH scores in all surgery groups (ANOVA p value=0.92). When individual comparisons were made between each type of surgery using the Tukey's method, we found that each surgery demonstrated no significant difference to each other in terms of the DASH scores (LRTI, 19.26 mean ± 12.84 SD; HDA 23.49 mean ± 17.16 SD; costochondral allograft 19.04 mean ± 21.91 SD, Fig. 2).

The ANOVA p value for the pinch strength improvement was 0.08 (LRTI, -4.00 mean ± 11.31 SD; HDA 2.83 mean ± 2.32 SD; costochondral allograft 2.22 mean ± 3.00 SD, Fig. 3). The ANOVA p value for the pinch strength of the operative thumb as a percentage of the contralateral thumb was 0.19 (LRTI, 53.00 mean ± 14.17 SD; HDA 76.63 mean ± 20.15 SD; costochondral allograft 62.17 mean ± 21.66 SD, Fig. 4). No measure of the pinch strength showed statistically significant differences in direct comparison utilizing the Tukey method.

The ANOVA p value of the operative time was 0.0009 (LRTI, 139.00 mean ± 40.72 SD; HDA 76.90 mean ± 15.28 SD; costochondral allograft 90.45 mean ± 34.20 SD, Fig. 5). The head-to-head analysis utilizing the Tukey method demonstrated that the LRTI procedure took significantly longer compared to the HDA or the costochondral allograft arthroplasty. The comparison between the HDA procedure and costochondral allograft technique did not show a significant difference.

Figure 1 The average age of patients in each group.

Figure 2 The average postoperative DASH score of the patients treated by each technique.

Discussion

With the current study, we demonstrated postoperative results similar to that published previously for each of the CMC arthroplasty techniques. The LRTI procedure did show an overall decrease in pinch strength compared to preoperative values, but there was no statistically significant difference when compared to the pinch strength improvement observed in the HDA technique and the costochondral allograft arthroplasty. The pinch strength compared to the contralateral thumb confirmed that there is no difference with regards to pinch strength among the three techniques performed.

The only significant difference observed in the current study was the operative time between the LRTI technique and the other two techniques. The tendon grafting portion of the LRTI technique is known to be primarily responsible for additional operative time compared to the HDA and the costochondral arthroplasty technique. Patient satisfaction measured by the DASH score and the pinch strength analysis demonstrated no difference in surgical outcome among the three techniques. The benefit of the shortened operative time would be a decrease in costs for operating room time and less tourniquet and anesthesia exposure for patients.

There is a possibility that the current study is not powered enough to show the differences in clinical outcome measures.

Figure 3 The average of the change in pinch strength postoperatively for the patients who were treated with each technique.

Figure 4 The average of the pinch strength as a percentage of the contralateral thumb for each technique.

However, if a higher powered study is required to detect the differences in the clinical outcome among the patients who underwent the three surgical techniques, we believe that the difference in outcome measure would be clinically insignificant. The number of patients participating in our study is comparable to that of previously published studies. The response rate of our initial patient selection was 53%. Because of the retrospective nature of the data collection, the patients were not seen in person, and full physical exam could not be performed for the purpose of the study. However, all the patient data collected were from our regular postoperative follow-up visits with minimum follow-up period of 1 year.

Patients who undergo the LRTI procedure are known to have decreased pinch strength [31, 54]. One study reported that their patients lost from 1 to 2 kg in pinch strength, but the authors state that such loss does not impair the patients' quality of life [11]. There are reports that support good functional outcomes of the patients treated with the LRTI procedure [15]. Tendon interposition or ligament reconstruction in addition to simple trapeziectomy does not improve functional outcome, at least in short term [16]. Simple trapeziectomy seems to produce weakness in pinch strength, similar to the LRTI technique. Reported pinch

strength as compared to the patients' contralateral thumb was 84%, and grip strength was 79% [19]. In another study, the authors once again confirm the fact that the patients do equally well postoperatively, comparing the simple trapeziectomy technique to the LRTI technique. However, they noted that the LRTI patient group had better preserved trapezoidal height, and this correlated positively with the patients' pinch strength [17]. This relationship between trapezoidal height and pinch strength has been questioned a number of times. In one study, K-wire fixation was applied for 4 weeks postoperatively, regardless of whether there was a ligament reconstruction and/or tendon interposition [21]. The authors did not find any correlation between trapezoidal height and thumb strength. Furthermore, there have been doubts about the role of the spacers to preserve the carpal height. Many authors suspect that trapezoidal height is not well maintained even with spacers in place, and the trapezoidal space ratio does not seem to correlate with thumb strength [21, 46]. The creation of a suspensory ligament or tendon interposition does not seem to demonstrate much benefit in terms of preserving trapezoidal height under stress at long-term follow-up [8]. Nonetheless, there has been continued interest in the use of spacer material in the CMC arthroplasty, and newer biodegradable materials, such as polyurethaneurea (Artelon™), showed very promising results in terms of the postoperative key pinch strength and biocompatibility [45].

In patients treated with costochondral allograft interposition, reported postoperative grip strength and pinch strength were 95% and 85% of contralateral limb. The grip strength and pinch strength improved 31% and 35%, respectively, compared to the preoperative values [55]. With the LRTI procedure, patients gained 34% in pinch strength and 93% in grip strength after the surgery [54]. With HDA, both grip strength and pinch strength improved 22% compared to the values obtained before the surgery [29].

As demonstrated by the results of the current study and previously published data, there is no clear treatment of choice when it comes to CMC osteoarthritis. Further adding to the complexity of the treatment modality of the CMC osteoarthritis is the recent development of arthroscopic treatment option. For years, many authors discussed indications for CMC joint arthroscopy and developed safer portals [3, 6, 12, 28, 40, 41, 48, 57]. It is already shown that arthroscopic techniques may enable surgeons to perform therapeutic procedures in treating wrist arthritis [58], and there is a previously published algorithm to incorporate therapeutic arthroscopy in treatment of the CMC arthritis [2]. A combined arthroscopic debridement and metacarpal osteotomy as a treatment of early CMC arthritis is introduced [4].

There is no doubt that the debate over the treatment choice for the CMC arthroplasty will continue. Many surgeons are still working on developing a better spacer to

Figure 5 The average operative time of each technique.

fill the trapezial void, while the LRTI continues to be a widely popular procedure. The recent trend toward the HDA and the development of arthroscopic technique will give even more options to hand surgeons. The best treatment for the CMC osteoarthritis will likely be very patient and surgeon specific. The techniques that the surgeons are most familiar with will undoubtedly produce the most reliable result. The future development of the surgical technique will likely involve variations on the trapeziectomy portion of the procedure, which is shared in most of the currently available techniques. With the current study, we demonstrated that the LRTI technique, HDA, and costochondral allograft arthroplasty are three different techniques with similar efficacy and patient satisfaction.

References

1. Armstrong AL, Hunter JB, Davis TR. The prevalence of degenerative arthritis of the base of the thumb in post-menopausal women. *J Hand Surg (Br)* 1994;19:340–1.
2. Badia A. Trapeziometacarpal arthroscopy: a classification and treatment algorithm. *Hand Clin* 2006;22:153–63.
3. Badia A. Arthroscopy of the trapeziometacarpal and metacarpophalangeal joints. *J Hand Surg (Am)* 2007;32:707–24.
4. Badia A, Khanchandani P. Treatment of early basal joint arthritis using a combined arthroscopic debridement and metacarpal osteotomy. *Tech Hand Up Extrem Surg* 2007;11:168–73.
5. Barron OA, Glickel SZ, Eaton RG. Basal joint arthritis of the thumb. *J Am Acad Orthop Surg* 2000;8:314–23.
6. Berger RA. A technique for arthroscopic evaluation of the first carpometacarpal joint. *J Hand Surg (Am)* 1997;22:1077–80.
7. Bezwada HP, Sauer ST, Hankins ST, Webber JB. Long-term results of trapeziometacarpal silicone arthroplasty. *J Hand Surg (Am)* 2002;27:409–17.
8. Bhat M, Davis TR, Bannerjee A. Trapezial space height measurement after trapeziectomy: a comparison of the use of standard and stress radiographs. *J Hand Surg (Am)* 2003;28:390–6.
9. Burton RI. Basal joint arthritis. Fusion, implant, or soft tissue reconstruction? *Orthop Clin North Am* 1986;17:493–503.
10. Burton RI, Pellegrini VD Jr. Surgical management of basal joint arthritis of the thumb. Part II. Ligament reconstruction with tendon interposition arthroplasty. *J Hand Surg (Am)* 1986;11:324–32.
11. Camus E, Farez E, Rtaimate M, Millot F, Bouretz JC. Surgical treatment of carpometacarpal joint osteoarthritis of the thumb by trapeziectomy-interposition-ligamentoplasty. *Chir Main* 2000;19:36–43.
12. Carro LP, Golano P, Vega J, Cabestany JM. Innovations in arthroscopic management of Basal joint arthritis of the thumb. *Arthroscopy* 2006;22:1361 e1–4.
13. Carroll RE. Long-term review of fascial replacement after excision of the carpal lunate bone. *Clin Orthop Relat Res.* 1997:59–63.
14. Conolly WB, Rath S. Revision procedures for complications of surgery for osteoarthritis of the carpometacarpal joint of the thumb. *J Hand Surg (Br)* 1993;18:533–9.
15. Damen A, van der Lei B, Robinson PH. Bilateral osteoarthritis of the trapeziometacarpal joint treated by bilateral tendon interposition arthroplasty. *J Hand Surg (Br)* 1997;22:96–9.
16. Davis TR, Brady O, Barton NJ, Lunn PG, Burke FD. Trapeziectomy alone, with tendon interposition or with ligament reconstruction? *J Hand Surg (Br)* 1997;22:689–94.
17. De Smet L, Sioen W, Spaepen D, van Ransbeeck H. Treatment of basal joint arthritis of the thumb: trapeziectomy with or without tendon interposition/ligament reconstruction. *Hand Surg* 2004;9:5–9.
18. Dell PC, Muniz RB. Interposition arthroplasty of the trapeziometacarpal joint for osteoarthritis. *Clin Orthop Relat Res.* 1987;220:27–34.
19. Dhar S, Gray IC, Jones WA, Beddow FH. Simple excision of the trapezium for osteoarthritis of the carpometacarpal joint of the thumb. *J Hand Surg (Br)* 1994;19:485–8.
20. Diao E. Trapezoid-metacarpal arthritis. Trapezium excision and ligament reconstruction not including the LRTI arthroplasty. *Hand Clin* 2001;17:223–36.
21. Downing ND, Davis TR. Trapezial space height after trapeziectomy: mechanism of formation and benefits. *J Hand Surg (Am)* 2001;26:862–8.
22. Eaton RG, Littler JW. Ligament reconstruction for the painful thumb carpometacarpal joint. *J Bone Joint Surg Am* 1973;55:1655–66.
23. Eaton RG, Glickel SZ, Littler JW. Tendon interposition arthroplasty for degenerative arthritis of the trapeziometacarpal joint of the thumb. *J Hand Surg (Am)* 1985;10:645–54.
24. Froimson AI. Tendon interposition arthroplasty of carpometacarpal joint of the thumb. *Hand Clin* 1987;3:489–505.
25. Gervis WH. Excision of the trapezium for osteoarthritis of the trapezio-metacarpal joint. *J Bone Joint Surg Br* 1949;31B:537–9.
26. Gervis WH, Wells T. A review of excision of the trapezium for osteoarthritis of the trapezio-metacarpal joint after twenty-five years. *J Bone Joint Surg Br* 1973;55:56–7.
27. Gerwin M, Griffith A, Weiland AJ, Hotchkiss RN, McCormack RR. Ligament reconstruction basal joint arthroplasty without tendon interposition. *Clin Orthop Relat Res.* 1997;342:42–5.
28. Gonzalez MH, Kemmler J, Weinzweig N, Rinella A. Portals for arthroscopy of the trapeziometacarpal joint. *J Hand Surg (Br)* 1997;22:574–5.
29. Gray KV, Meals RA. Hematoma and distraction arthroplasty for thumb basal joint osteoarthritis: minimum 6.5-year follow-up evaluation. *J Hand Surg (Am)* 2007;32:23–9.
30. Harris ED Jr, Glauert AM, Murley AH. Intracellular collagen fibers at the pannus-cartilage junction in rheumatoid arthritis. *Arthritis Rheum* 1977;20:657–65.
31. Hartigan BJ, Stern PJ, Kieffhaber TR. Thumb carpometacarpal osteoarthritis: arthrodesis compared with ligament reconstruction and tendon interposition. *J Bone Joint Surg Am* 2001;83A:1470–8.
32. Hay EL, Bomberg BC, Burke C, Misenheimer C. Long-term results of silicone trapezial implant arthroplasty. *J Arthroplasty* 1988;3:215–23.
33. Iyer KM. The results of excision of the trapezium. *Hand* 1981;13:246–50.
34. Kessler I. Silicone arthroplasty of the trapezio-metacarpal joint. *J Bone Joint Surg Br* 1973;55:285–91.
35. Kuhns CA, Meals RA. Hematoma and distraction arthroplasty for basal thumb osteoarthritis. *Tech Hand Up Extrem Surg* 2004;8:2–6.
36. Kvarnes L, Reikeras O. Rheumatoid arthritis at the base of the thumb treated by trapezium resection or implant arthroplasty. *J Hand Surg (Br)* 1985;10:195–6.
37. Luria S, Waitayawinyu T, Nemecek N, Huber P, Tencer AF, Trumble TE. Biomechanic analysis of trapeziectomy, ligament reconstruction with tendon interposition, and tie-in trapezium implant arthroplasty for thumb carpometacarpal arthritis: a cadaver study. *J Hand Surg (Am)* 2007;32:697–706.
38. Maffulli N, Irwin A, Chesney RB. Modified Burton and Pellegrini procedure for trapezium excision, ligament reconstruction and interposition arthroplasty of the tendon of flexor Carpi radialis. *Oper Orthop Traumatol* 1997;9:69–79.
39. Martinel V, Mansat P, Mansat M, Rongieres M, Bonneville P. Partial trapezectomy with suspension and interposition tendino-

- plasty for trapezometacarpal osteoarthritis: 5 years results. *Chir Main* 2007;26:103–9.
40. Menon J. Arthroscopic management of trapeziometacarpal joint arthritis of the thumb. *Arthroscopy* 1996;12:581–7.
 41. Menon J. Arthroscopic evaluation of the first carpometacarpal joint. *J Hand Surg (Am)* 1998;23:757.
 42. Minami A, Iwasaki N, Kutsumi K, Suenaga N, Yasuda K. A long-term follow-up of silicone-rubber interposition arthroplasty for osteoarthritis of the thumb carpometacarpal joint. *Hand Surg* 2005;10:77–82.
 43. Muller GM. Arthrodesis of the trapezio-metacarpal joint for osteoarthritis. *J Bone Joint Surg Br* 1949;31B:540–2.
 44. Murley AH. Carpometacarpal osteoarthritis of the thumb. *Lancet* 1970;2:312.
 45. Nilsson A, Liljensten E, Bergstrom C, Sollerman C. Results from a degradable TMC joint Spacer (Artelon) compared with tendon arthroplasty. *J Hand Surg (Am)* 2005;30:380–9.
 46. Nusem I, Goodwin DR. Excision of the trapezium and interposition arthroplasty with gelfoam for the treatment of trapeziometacarpal osteoarthritis. *J Hand Surg (Br)* 2003;28:242–5.
 47. Nylen S, Johnson A, Rosenquist AM. Trapeziectomy and ligament reconstruction for osteoarthritis of the base of the thumb. A prospective study of 100 operations. *J Hand Surg (Br)* 1993;18:616–9.
 48. Orellana MA, Chow JC. Arthroscopic visualization of the thumb carpometacarpal joint: introduction and evaluation of a new radial portal. *Arthroscopy* 2003;19:583–91.
 49. Perez-Ubeda MJ, Garcia-Lopez A, Marco Martinez F, Junyent Vilanova E, Molina Martos M, Lopez-Duran Stern L. Results of the cemented SR trapeziometacarpal prosthesis in the treatment of thumb carpometacarpal osteoarthritis. *J Hand Surg (Am)* 2003;28:917–25.
 50. Roberts RA, Jabaley ME, Nick TG. Results following trapeziometacarpal arthroplasty of the thumb. *J Hand Ther* 2001;14:202–7.
 51. Sai S, Fujii K, Chino H, Inoue J. Tendon suspension sling arthroplasty for degenerative arthritis of the thumb trapeziometacarpal joint: long-term follow-up. *J Orthop Sci* 2004;9:576–80.
 52. Swanson AB. Disabling arthritis at the base of the thumb: treatment by resection of the trapezium and flexible (silicone) implant arthroplasty. *J Bone Joint Surg Am* 1972;54:456–71.
 53. Swanson AB, Herndon JH. Flexible (silicone) implant arthroplasty of the metacarpophalangeal joint of the thumb. *J Bone Joint Surg Am* 1977;59:362–8.
 54. Tomaino MM, Pellegrini VD Jr, Burton RI. Arthroplasty of the basal joint of the thumb. Long-term follow-up after ligament reconstruction with tendon interposition. *J Bone Joint Surg Am* 1995;77:346–55.
 55. Trumble TE, Rafijah G, Gilbert M, Allan CH, North E, McCallister WV. Thumb trapeziometacarpal joint arthritis: partial trapeziectomy with ligament reconstruction and interposition costochondral allograft. *J Hand Surg (Am)* 2000;25:61–76.
 56. Varley GW, Calvey J, Hunter JB, Barton NJ, Davis TR. Excision of the trapezium for osteoarthritis at the base of the thumb. *J Bone Joint Surg Br* 1994;76:964–8.
 57. Walsh EF, Akelman E, Fleming BC, DaSilva MF. Thumb carpometacarpal arthroscopy: a topographic, anatomic study of the thenar portal. *J Hand Surg (Am)* 2005;30:373–9.
 58. Yao J, Osterman AL. Arthroscopic techniques for wrist arthritis (radial styloidectomy and proximal pole hamate excisions). *Hand Clin* 2005;21:519–26.