Thumb Carpometacarpal Arthroplasty with Ligament Reconstruction and Interposition Costochondral Arthroplasty

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J Wrist Surg 2013;2:220–227.

Abstract

Background Thumb arthritis at the carpometacarpal (CMC) joint is one of the most common sites of arthritis, especially in women. Thumb arthroplasty is an effective method of relieving pain and improving function.

Materials and Methods Qualitative and quantitative outcomes were assessed clinically and radiographically in 58 patients (66 thumbs) with thumb basal joint arthritis limited to the trapeziometacarpal joint, treated with hemiresection arthroplasty of the trapezium, flexor carpi radialis (FCR) ligament reconstruction, and allograft costochondral interposition graft.

Description of Technique The thumb CMC joint arthroplasty is performed using an FCR tendon for ligament reconstruction combined with removal of the distal half of the trapezium, which is replaced with a life preserver-shaped spacer that is carved out of allograft cartilage.

Results Results of the validated Disability of Arm, Shoulder, and Hand (DASH) questionnaire at a mean follow-up time of 56 months (range, 24–103 months) revealed that 90% of the patients had a high level of function with minimal symptoms. Important improvements in web space with increased palmar and radial abduction and grip and pinch strength measurements were observed. The trapeziometacarpal space had decreased 21% after surgery, while trapeziometacarpal subluxation was 14% compared with 21% before surgery. There was an inverse correlation between the loss of trapezial height and subluxation and clinical outcome.

Conclusions The results of this study demonstrate that, although the preoperative trapezial height was not maintained, the reconstructed thumbs remained stable, with little subluxation and improved clinical outcomes.

Level of Evidence IV, retrospective case series

Keywords

- thumb arthritis
- thumb arthroplasty
- CMC OA
- Hemitrapeziectomy
- hand arthritis

Although several previous reports have indicated that excision arthroplasty has been effective in the treatment of basal joint arthritis of the thumb by relieving pain and preserving motion,^{1–7} others have indicated that arthroplasty of the thumb by excision of the trapezium alone causes a substantial loss of thumb strength and stability.^{5–7} Luria et al⁸ demon-

strated that the combination of ligament reconstruction plus an interposition arthroplasty provided optimal thumb stability. Furthermore, in many cases with the arthritis limited to only the trapeziometacarpal (TM) joint, complete excision of the trapezium did not appear to be warranted. In 1984, Littler developed a technique using an interposition material shaped

like a life preserver (or a piece of Life Savers candy) between the partially resected trapezium and the base of the thumb metacarpal for patients with arthritis limited to the TM joint.⁹ He coined the term “Life Saver technique” for this procedure and recommended allograft costochondral cartilage as the interposition material. The allograft cartilage was stabilized by the flexor carpi radialis (FCR) tendon through the trapezium, allograft cartilage, and base of the thumb metacarpal. With this technique there was no need for temporary pin fixation.

The purpose of this study was to determine the outcome of a cohort of patients treated with a costochondral allograft and tendon reconstruction with a minimum follow-up period of 2 years and to correlate the radiographic findings with patient outcome.

Patients and Methods

Patient Cohort

We performed 77 basal thumb joint costochondral allograft arthroplasties. Nine patients (11 thumbs) were excluded from this study because of inflammatory arthritis, pantrapezoidal arthritis, or other concomitant procedures involving the operated hand that would affect hand function. Five additional patients met the inclusion criteria during this interval, but could not be located to complete questionnaires and follow-up examinations. This study represents a retrospective clinical and radiographic assessment of 58 patients in whom 66 thumbs had basal joint arthritis limited to the TM articulation and who were treated with costochondral allograft interposition arthroplasty coupled with a tenodesis of the FCR to the thumb metacarpal. The average age at the time of surgery was 64 years (range, 40–88 years). There were 48 women and 10 men. Forty-one procedures were performed on the dominant hand. Although many of the patients had minor associated medical problems, none required insulin for diabetes or required steroids for their arthritis or other conditions. At the time of surgery, 28 of the patients were employed and 38 were retired.

Clinical Evaluation

The diagnosis of TM arthritis of the thumb was based on both clinical and radiographic findings. The patients universally described a constant pain at the base of their thumbs that was exacerbated by activities involving substantial grip or pinch strength. Physical examination revealed tenderness at the TM joint and pain with axial joint loading of the thumb. Lateral radiographs confirmed the diagnosis of osteoarthritis of the thumb TM joint and excluded degenerative disease of the scaphotrapezium- trapezoid articulations. All patients underwent a trial of non-operative treatment before surgery that included a splint immobilizing the thumb and or an intraarticular injection of 40 mg dexamethasone phosphate.

Assessing Outcomes

The Disability of the Arm, Shoulder, and Hand (DASH) questionnaire^{10,11} was used to determine the patient's response to surgery. Overall satisfaction ranked on a numerical rating

scale from 1 (very unsatisfied) to 5 (no pain and completely satisfied.).

Objective Follow-up Evaluation

Grip strength and lateral pinch strength were determined for both hands using a Jamar dynamometer (Asimov Engineering, Los Angeles, CA) and a pinch meter (Therapeutic Instruments, Clifton, NJ). The web space angle was measured bilaterally as the maximal radial and palmar abduction between the thumb metacarpal and the index metacarpal. Using a modification of the classification of basal joint arthritis described by Eaton and Glickel,¹² the severity of arthritis was staged according to preoperative radiographic appearance. All thumbs had stage III arthritis without evidence of arthritis at the scaphotrapeziotrapezoidal (STT) joints (►Fig. 1); patients with stage IV arthritis (pantrapezial arthritis) were treated with a different surgical approach that included resection of the entire trapezium. Patients with stage III arthritis had radiographic evidence of destruction of the TM joint with complete loss of the joint space and/or sclerosis and cystic changes in the subchondral bone on either side of the joint. To measure how well the space between the thumb metacarpal and the proximal half of the trapezium was maintained, preoperative and postoperative thumb trapezium to metacarpal (TM) distances were calculated (►Fig. 2). The TM height was normalized by multiplying the TM height of the individual radiograph by the ratio of the patient's proximal phalanx height to the average proximal phalangeal height for all the patients.¹³ All radiographic distances were measured to the nearest 0.5 mm. Subluxation of the thumb TM joint was measured by drawing a line connecting the superior and inferior edges on the ulnar border of the trapezium and a line parallel to this incorporating the ulnar margin of the thumb metacarpal (distance A in ►Fig. 3). The relative subluxation of the thumb was determined as the ratio of distance A divided by the width of the articular surface of the base of the thumb metacarpal (distance B). The graft height was measured in the initial postoperative radiographs and then at the final follow-up visit. The height of the graft was reported as the average of the medial and lateral margins of the graft normalized by

Fig. 1 Lateral X-ray image demonstrating Eaton stage III STT-sparing osteoarthritis of the basal joint of the thumb.

Fig. 2 Preoperative posteroanterior radiograph of the thumb. TM distance is measured from the distal end of the thumb metacarpal, to the proximal end of the trapezium. Measurement of the proximal phalanx is used as a reference measurement.

multiplying the average by the ratio of the proximal phalangeal height to the average phalangeal height (►Fig. 4).

Data Analysis

Statistical analysis was performed using the Abacus concepts, Stat View II software program (Abacus Concepts, Inc., Berkeley, CA). Paired *t*-tests were used to compare preoperative and postoperative values for trapezium to metacarpal (TM) height as well as grip and pinch strengths. Spearman correlation coefficients (r_s) were used to analyze relationships between

Fig. 4 The height of the TM graft is measured as an average of the medial and lateral margins. The average height of the proximal phalanx is used to normalize the measurement.

Fig. 3 Subluxation of the metacarpal is measured as a ratio of the distance from the ulnar most border of the trapezium and thumb metacarpal, in comparison to the total width of the base of the thumb metacarpal.

trapezium to metacarpal height, grip and pinch strength, thumb motion, and the parameters determined in the DASH questionnaire.

Surgical Technique

The surgery is performed using a curvilinear incision along the base of the thumb. The branches of the superficial radial nerve and deep branch of the radial artery are identified and protected (►Fig. 5). The distal half of the incision is placed in the border of the glabrous skin of the thenar eminence. The base of the thumb metacarpal is exposed between the

Fig. 5 A curvilinear incision is made on the volar radial aspect of the thumb basal joint. The dorsal radial sensory nerve, extensor pollicis longus (EPL), and deep branch of the radial artery are carefully dissected and protected with blunt retractors.

Fig. 6 Following preparation of the thumb metacarpal, a 0.054 Kirschner wire (K-wire) is used to create 4 holes extending through the radial volar aspect of the metacarpal into the prepared canal. Non-absorbable sutures are then used to repair the capsule, and APL.

abductor pollicis longus (APL) and the extensor pollicis brevis (EPB). The capsule and APL are sharply detached as a unit and repaired later using drill holes in the base of the metacarpal (►Fig. 6). In addition, a small arthrotomy is made in the STT joint to confirm that the joint is free of degenerative changes before proceeding with only partial excision of the trapezium. A small oscillating saw is used to remove the distal surface of the trapezium, taking care to protect the FCR tendon. The tendon sheath of the FCR is exposed and separated from the tendon so that a Freer elevator can be placed on the palmar surface of the tendon as it passes deep to the trapezium. We recommend performing the osteotomy with the power saw to remove 2 to 3 mm of distal articular surface of the trapezium to avoid injury to the FCR. The remainder of the osteotomy is completed with small osteotomes. A 12-cm strip of the FCR tendon is obtained through a single (►Fig. 7) 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 and brought out through the distal incision. A drill hole is made from the palmar surface of the trapezium to the distal surface of the trapezium after the distal articular surface has been removed with the oscillating saw. A second drill hole is made in the base of the metacarpal and connected with the drill hole made in the dorsal radial aspect of the thumb metacarpal base (►Fig. 8). A costochondral allograft measuring $\sim 1.5 \times 2.0 \times 4.0$ cm is fashioned into a disk for interposition into the TM. We obtained our allograft material from Community Tissue (Kettering, OH) (►Fig. 9). The allograft tissue is recovered aseptically, sterilized with 14 to 21 kGy of gamma radiation, and stored at -27°C . Before implantation the graft is thawed at 37°C for 30 min. The donors are screened for infectious, malignant, neurologic, and autoimmune disease and other exposures or habits that might result in unsatisfactory tissue. The allograft cartilage can be easily carved with a scalpel into a disk with a central hole (the shape of a life preserver or a piece of Life Savers candy) with a diameter matching that of the resected trapezium surface (►Fig. 10). It is helpful to leave the allograft disk attached to the rib cartilage to use as a handle when performing a trial reduction. Stainless steel wires, 22 gauge, are doubled over and used to pass the tendon through the holes

Fig. 7 Approximately 12 cm of the FCR tendon is harvested.

in the cartilage allograft and the bones (►Fig. 11). The tendon is sequentially passed through the trapezium, the allograft cartilage, and the base of the thumb metacarpal (►Fig. 12). The tendon is placed under tension to ensure the stability of the TM joint. The FCR tendon graft is then sutured back onto itself, and the capsule is closed with nonabsorbable sutures (►Fig. 13). Postoperative immobilization in a thumb spica

Fig. 8 FCR tendon is split in half lengthwise and harvested using a separate proximal longitudinal incision. A drill is used to create holes in the trapezium and proximal thumb metacarpal to prepare for final implantation of costochondral allograft with FCR tendon weave.

Fig. 9 Example of a costochondral allograft measuring $1.0 \times 2.0 \times 4.0$ cm.

cast is followed at 6 weeks by gentle range of motion exercises and a removable splint that immobilizes the thumb. Active exercises are begun for radial and palmar abduction of the thumb, but passive exercises are avoided to prevent stress of the ligament reconstruction. At 8 weeks, unrestricted thumb motion is allowed and the splint is discontinued.

Results

The mean follow-up was 56 months. The average postoperative pain severity was 4.8 ± 1.0 on a scale of 1 to 10. Despite

Fig. 11 Preoperative PA radiograph of the thumb. TM distance is measured from the distal end of the thumb metacarpal to the proximal end of the trapezium. Measurement of the proximal phalanx is used as a reference measurement.

Fig. 10 Lateral x-ray image demonstrating Eaton stage III STT sparing osteoarthritis of the basal joint of the thumb.

some continued pain, increases in pinch, grip, and other objective measurements show overall improvement in presenting symptoms. The average DASH score was 11 (range 3–21). Significant improvements were noted in grip and pinch strength. Preoperative grip strength averaged 15.6 ± 6.1 , compared with 22.9 ± 6.6 kgf after surgery ($p < 0.01$; **Table 1**). Postoperative grip strength was not significantly different from the grip strength of the contralateral side (23.2 ± 6.0). Pinch strength averaged 3.2 ± 1.3 before surgery compared with 5.2 ± 1.7 kgf after surgery ($p < 0.01$), but this was still less than the pinch strength of the contralateral side, which averaged 5.5 ± 1.0 kgf ($p < 0.05$). Thumb palmar abduction averaged $44 \pm 6.6^\circ$ before surgery; this increased to $51 \pm 6^\circ$ after surgery ($p < 0.05$). The thumb palmar abduction on the contralateral side for the patients with unilateral surgery was slightly greater than on the operated hand ($52 \pm 8^\circ$), although we detected no statistically significant difference. The thumb radial abduction averaged $48 \pm 7^\circ$ before surgery and increased to $50 \pm 9^\circ$ after surgery. This was not a significant improvement, however; the angle after surgery remained less than that of the contralateral side, which maintained $52 \pm 10^\circ$ of motion. The motion of the thumb metacarpophalangeal joint motion

Fig. 12 The FCR is doubled over and sewn back onto itself following confirmation of appropriate tension and stability of the costochondral graft.

decreased from $59 \pm 24^\circ$ before surgery to $58 \pm 21^\circ$ after surgery, but this was not a significant change. The thumb interphalangeal joint motion did not significantly change after surgery ($74 \pm 15^\circ$) compared with before surgery ($78 \pm 21^\circ$). Only one patient demonstrated radiographic evidence of STT arthritis at the follow-up examination. The preoperative TM height averaged 53.1 ± 4.0 mm. In the initial postoperative radiographs (obtained within 6 months of surgery), the TM height averaged 53.8 ± 5.2 mm. On the final follow-up examination the radiographs of the normalized TM height averaged 50.6 ± 4.5 mm, for an average loss of 2.5 ± 1.5 mm on the final postoperative radiographs and

Table 1 Grip and pinch strength values taken preoperatively, postoperatively, and comparing the contralateral side; measured in kilograms of force

Grip before, kgf	16.0 ± 6.1
Grip after, kgf	22.9 ± 6.6
Grip contralateral, kgf	23.3 ± 6.0
Pinch before, kgf	3.2 ± 1.3
Pinch after, kgf	5.2 ± 1.7
Pinch contralateral, kgf	5.5 ± 1.0

Fig. 13 Final repair of the joint capsule and APL.

3.2 ± 1.7 mm from the initial postoperative radiographs, because the graft was thicker than the segment of bone removed from the trapezium. This corresponded to a decrease in the graft height from 7.1 ± 1.8 mm to 3.8 ± 1.4 mm (a 46% decrease). The average height of the trapezium was 12 mm before surgery. The 2.5-mm decrease in the TM space corresponded to a 21% decrease in the space once occupied by the trapezium. In 15 patients there were radiographs available ~ 1 year following the surgery. The normalized TM height in these patients averaged 50.0 ± 4.7 mm, indicating that most of the loss of height of the allograft cartilage had occurred within the first year. The subluxation of the TM joint decreased from 0.21 ± 0.11 before surgery to 0.16 ± 0.13 after surgery ($p < 0.05$).

Intergroup Analysis

Postoperative pinch and grip strength correlated directly with overall satisfaction ($r_s = 0.413$ and 0.526 , respectively) and inversely with pain severity ($r_s = -0.258$ and -0.215 , respectively) and loss of confidence ($r_s = -0.363$ and -0.561 , respectively). Grip and pinch strength also correlated inversely with activities requiring strength such as jar opening ($r_s = -0.510$ and -0.532 , respectively) and recreational sports with impact ($r_s = -0.351$ and -0.447 , respectively). Comparison of the loss in the TM height to the qualitative and

Table 2 Spearman correlation coefficient demonstrating an inverse relationship between maintained TM height and decreased DASH score based on specific heavy activities and lighter activities

Activity	<i>r_s</i> value
Cutting with a knife	−0.412
Heavy household chores	−0.564
Changing light bulbs	−0.326
Placing objects on a shelf	−0.353

quantitative clinical outcomes revealed that there was a significant inverse correlation between the overall DASH score and the maintenance of the trapezium to metacarpal (TM) height ($r_s = -0.516$). The responses to specific questions that required greater strength (e.g., cutting with a knife, $r_s = -0.412$, and doing heavy household chores, $r_s = -0.564$) demonstrated stronger inverse correlation than less strenuous activities (e.g., changing light bulbs, $r_s = -0.326$, and placing objects on a shelf, $r_s = -0.353$) (→Table 2). The overall DASH score also decreased with decreasing TM subluxation ($r_s = 0.537$). Pain with work activities ($r_s = 0.425$) and pain with activities of daily living ($r_s = 0.483$) also decreased with decreasing subluxation of the TM joint. Outcome assessments by the DASH, satisfaction, and pain questionnaires as well as quantitative measurements of grip and pinch strength and thumb motion did not demonstrate a significant correlation between age, gender, and hand dominance. There were no significant differences between the patients included in the study and patients who were excluded or lost to follow-up evaluation with respect to age, gender, hand dominance, and radiographic parameters.

Complications

One patient in this series developed recurrent pain of the basal joint 72 months after the initial surgery. Radiographs demonstrated collapse of the joint space with bone-on-bone contact and stage IV arthritis involving the scaphotrapezial joint.¹² The patient was treated with a revision arthroplasty, including resection of the entire trapezium, reconstruction with a silicone rubber implant, and ligament reconstruction using the remaining half of the FCR tendon, which was woven through the abductor pollicis longus tendon to stabilize the implant. The silicone rubber implant was chosen because the space remaining after the resection of the entire trapezium was too large to be filled in by allograft cartilage. The most recent grip strength, at 2 years follow-up, averaged 15 kgf (before surgery, 13 kgf), and pinch strength averaged 5 kgf (before surgery, 3 kgf). One patient who was subsequently lost to follow-up evaluation had fractured the interposition allograft cartilage following a fall and had recurrence of subluxation and pain. This patient was treated with arthrodesis of the thumb TM joint. At last report, the patient was doing well with a solid arthrodesis 9 months after the second surgery.

Discussion

The major strategies in motion-preserving treatments for arthritis of the thumb TM joint have included simple excision of the trapezium,^{1,2,5,6} trapeziectomy and interposition (i.e., silicone rubber, tendon graft),^{3,14–17} ligament reconstruction,^{18,19} and ligament reconstruction with interposition.^{7,20–22}

Using the cartilage allograft interposition technique, there was a 0.7-mm increase in the TM distance in the initial postoperative radiographs compared with the preoperative radiographs. Although a 47% loss in height of the implant occurred, the net loss in the trapezial space was only 22%.

Based on the facts that only 22% of the initial trapezial height is lost at the final follow-up examination, which ranged from 24–103 months, and that subluxation averaged only 16% after surgery compared with 21% before surgery, it appears that this technique offers sufficient stability to prevent proximal thumb metacarpal migration despite the lack of reconstruction of the palmar oblique ligament. Similar to the findings noted in previous studies, the clinical data in this outcomes analysis demonstrate a high degree of patient satisfaction, with 38 of the 41 patients (92%) willing to undergo the procedure again. In 34 patients (82%) there was no pain restricting work activities. In 39 patients (95%) there was no pain with activities of daily living.

In our study, grip strength improved from 16 kgf before surgery to 21 kgf after surgery (31% increase), and pinch strength improved from 3.4 kgf before surgery to 4.6 kgf after surgery (35% increase).

Certain limitations regarding this retrospective study are acknowledged. Our measurements of the preoperative functional status and patient expectations by postoperative questionnaire rely on patients' ability to recall information years after surgery, which may influence subjective outcomes measurements.

There are very few data regarding the effect of long-term cartilage allograft implants. There are no reports involving implanted costochondral allografts.

Our data suggest that there is high patient satisfaction and improved objective measurements of grip and pinch strength and thumb abduction with this technique of basal joint arthroplasty. Costochondral allograft interposition arthroplasty with tenodesis of the FCR is a safe and effective treatment method for treating patients with isolated TM arthritis.

Conflict of Interest

None

References

- 1 Burton RI, Pellegrini VD Jr. Basal joint arthritis of thumb [letter]. *J Hand Surg Am* 1987;12(4):645
- 2 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(2):195–196
- 3 Murley AH. Carpometacarpal osteoarthritis of the thumb. *Lancet* 1970;2(7667):312

- 4 Dell PC, Brushart TM, Smith RJ. Treatment of trapeziometacarpal arthritis: results of resection arthroplasty. *J Hand Surg Am* 1978;3(3):243-249
- 5 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(4):485-488
- 6 Gervis WH. Excision of the trapezium for osteoarthritis of the trapezio-metacarpal joint. *J Bone Joint Surg Br* 1949;31B(4):537-539
- 7 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(1):56-57
- 8 Luria S, Waitayawinyu T, Nemechek 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(5):697-706
- 9 Eaton RG, Lane LB, Littler JW, Keyser JJ. Ligament reconstruction for the painful thumb carpometacarpal joint: a long-term assessment. *J Hand Surg Am* 1984;9(5):692-699
- 10 Hudak PL, Amadio PC, Bombardier C, and the Upper Extremity Collaborative Group (UECG). Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder, and hand) [published correction appears in *Am J Ind Med* 1996;30:372]. *Am J Ind Med* 1996;29:602-608
- 11 Amadio PC. Outcomes assessment in hand surgery: What's new? *Clin Plast Surg* 1997;24(1):191-194
- 12 Eaton RG, Glickel SZ. Trapeziometacarpal osteoarthritis: staging as a rationale for treatment. *Hand Clin* 1987;3(4):455-471
- 13 Kadiyala RK, Gelberman RH, Kwon B. Radiographic assessment of the trapezial space before and after ligament reconstruction and tendon interposition arthroplasty. *J Hand Surg Br* 1996;21(2):177-181
- 14 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;54A:456-471
- 15 Sotereanos DG, Taras J, Urbaniak JR. Niebauer trapeziometacarpal arthroplasty: a long-term follow-up. *J Hand Surg Am* 1993;18(4):560-564
- 16 Ashworth CR, Blatt G, Chuinard RG, Stark HH. Silicone-rubber interposition arthroplasty of the carpometacarpal joint of the thumb. *J Hand Surg Am* 1977;2:345-357
- 17 Goldberg I, Amit S, Peylan J, Adler A. Tendon interposition arthroplasty vs Kessler silicone prosthesis for basal joint arthritis of the thumb [in Hebrew]. *Harefuah* 1994;126:696-699, 764
- 18 Burton RI. The arthritic hand. In: *Evarts CM, ed. Surgery of the Musculoskeletal System. Vol. 2. 1st ed. New York, NY: Churchill Livingstone; 1983:670-681*
- 19 Eaton RG, Littler JW. Ligament reconstruction for the painful thumb carpometacarpal joint. *J Bone Joint Surg Am.* 1973;55(8):1655-1666
- 20 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(3):346-355
- 21 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(5):645-654
- 22 Nylén S, Johnson A, Rosenquist A-M. Trapeziectomy and ligament reconstruction for osteoarthritis of the base of the thumb: a prospective study of 100 operations. *J Hand Surg Br* 1993;18(5):616-619