Review Article

Trapeziectomy with Abductor Pollicis Longus Tendon Interposition Arthroplasty for First Carpometacarpal Joint Osteoarthritis: A Systematic Review

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ABSTRACT

Background: The prevalence of osteoarthritis (OA) of the first carpometacarpal (CMC) joint and subsequent thumb disability is rising. Abductor pollicis longus tendon interposition arthroplasty (APLTIA) has gained popularity as a procedure to alleviate pain and restore thumb function.

Methods: A systematic review was performed to assess the current reported outcomes of APLTIA. Inclusion criteria involved clinical studies with case-series as the minimal accepted level of evidence. Our primary outcome focussed on PROMs data, whilst secondary outcomes focussed on objective measures of function and complications. Papers investigating pathologies other than CMC OA or procedures other than APLTIA were excluded.

Results: Twelve studies were included (485 thumbs), all of which were observational in study design. APLTIA appears to be associated with a reduction in pain and functional improvement. APLTIA was not found to complicate further surgery.

Conclusion: APLTIA may be associated with improvement in short-term pain relief and functional status. Further research is required to evaluate the benefits, duration of relief and long-term outcomes of APLTIA.

Keywords: Systematic review; Trapeziectomy; Abductor Pollicis Longus; Tendon interposition arthroplasty

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INTRODUCTION

Musculoskeletal system complaints are common, accounting for 14% of primary care consultations[1]. As life expectancy increases, the prevalence of musculoskeletal disorders, chronic pain and disability are also increasing[2]. One of the most common conditions found in those aged over 60 is first carpometacarpal (CMC) osteoarthritis (OA)[3]. The pain, weakness, and deformity associated with first CMC OA leads to marked disability in those affected.

Management aims to alleviate pain, restore joint function and reduce disability[4]. When determining the most appropriate management options for patients, it is important to consider their age, co-morbidities, profession and severity of disease. There is little evidence to suggest that

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non-surgical interventions such as splinting, NSAID and corticosteroid use, are effective, particularly in the advanced stages of disease[5]. Surgical intervention is therefore indicated in more severe case with thumb disability and when conservative measures do not provide early-stage symptomatic relief. Several surgical options have been described for first CMCJ osteoarthritis, which may be classified into four broad categories. These include trapeziectomy [6], trapezio-metacarpal joint arthrodesis[7], total joint arthroplasty[8] and trapeziectomy with ligament reconstruction tendon interposition[8].

Despite several procedures being depicted in the literature to manage CMC OA, there is no clear 'gold-standard'[9]. In recent years, ligament reconstruction suspension arthroplasty has gained popularity as an alternative surgical approach in treating first CMC OA. Cadaveric studies have demonstrated that the first intermetacarpal and oblique ligaments are key in maintaining stability of the first CMC joint, and preventing radial and dorsal subluxation[10]. Suspension arthroplasty with ligament reconstruction is thought to increase stability and strength of the thumb, whilst counteracting radial displacement forces and preventing early axial shortening of the thumb metacarpal[11]. Ligament reconstruction, therefore, is understood to be imperative by some to conserve a stable, pain-free, mobile basal joint [12, 13]. Numerous methods of suspension arthroplasty have been outlined; Pellegrini and Burton [14] described a method involving the excision of the trapezium whilst using the flexor carpi radialis (FCR) tendon to reconstruct the anterior oblique ligament. This became known as ligament reconstruction with tendon interposition (LRTI) arthroplasty. Despite good long-term outcomes being associated with this method[6, 15, 16], it has also been reported to lead to weaker wrist flexion and torsion[17].

To prevent the morbidity associated with using the FCR tendon, a technique utilising the abductor pollicis longus (APL) tendon to reconstruct the intermetacarpal ligament was described[18, 19]. This involved the excision of the entire trapezium through a dorsoradial incision and a distal radial strip of the APL tendon. This strip is used to twist the FCR and APL tendons together, securing the volar and ulnar aspects of the first metacarpal bone[20]. Multiple studies have reported no significant effect on hand or thumb function after harvesting the APL tendon[21].

In an effort to improve our understanding of the outcomes of APL tendon interposition arthroplasty (APLTIA) as a surgical technique to manage first CMC OA, a systematic review was performed. This focussed on patient reported outcome measures (PROMs), objective measures of function and complications.

METHODS

A systematic review was performed in accordance with the preferred reporting items for systematic reports and meta-analyses (PRISMA) statement. This review was registered in PROSPERO (CRD42019160309).

The primary outcome measure involved assessment of all relevant PROMs after APLTIA, including the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire, Patient-Rated Wrist Evaluation (PRWE), Visual Analogue Score (VAS), Arthritis impact measurement scales 2 Health status questionnaire (AIMS2-SF) and Michigan

Table 1: Inclusion and exclusion criteria questions.

Question	Minimum Criteria
What language is used?	English only
Does it address the topic?	Trapeziectomy *and* tendon interposition arthroplasty (limited to the APL tendon)
Does it address the study question?	Clinical outcomes of APLTIA for first CMC joint OA
Is it a clinical study?	Yes
What is the level of evidence?	Case series or above
Does it address relevant outcome measures?	Any of: • PROMs - *DASH, VAS, PRWE, Gartland and Werley, Michigan Hand Outcome Score and* AIMS2-SF • Objective measures of function - such as *grip or pinch strength, thumb function, range of movement and Kapandji 46 scale* • Complications of surgery

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Hand Outcomes score (MHQ). Secondary outcome measures included objective measures of grip strength, range of movement or the Kapandji 46 scale. Complications after APLTIA surgery, including infection, failure and requirement for salvage surgery were also included. Case series were the minimal level of evidence accepted. No restriction was applied on patient age or follow-up length, due to the varying causes of CMC OA of the thumb. Only articles available in English were considered. A minimal criterion for study inclusion was established and used (Table 1).

The search protocol for this systematic review was executed using MEDLINE, EMBASE, Google Scholar and the Cochrane Central Register of Controlled Trials. Results were not restricted by year of publication. The search terms used included: *Trapeziectomy, Trapeziumectomy, Tendon Interposition, Abductor Pollicis Longus, Patient Reported Outcome Measures, PROMs, DASH, PRWE, Michigan Hand Outcome Score, Kapandji 46 scale, Grip Strength, Pinch Strength, Range of movement and Complications.* Different combinations of these terms were used in a cyclical search strategy (Supplementary data). All identified titles and abstracts were analysed using screening questions (Table 1) and if eligible, the full paper was scrutinised. The reference lists of included studies were reviewed to identify additional studies and remove duplicate datasets.

Two authors independently performed the search strategy and extracted the relevant data. Disagreements were resolved by discussion with a third author. Data analysis was performed using R software (2019). A meta-analysis would only be performed if two or more studies reported comparable outcome measures. An assessment of bias was performed on each study using the Cochrane Risk of Bias tool for RCTs or the Quality Assessment Tool for Quantitative Studies for non-randomised studies. This included assessment of selection bias, study design, confounders, blinding, data collection and analysis methods, with each paper scored as "strong", "moderate" or "weak".

RESULTS

The search generated 1002 results (Supplementary data), with 227 duplicate records (Figure 1). As a result, the titles and abstracts of 775 records were

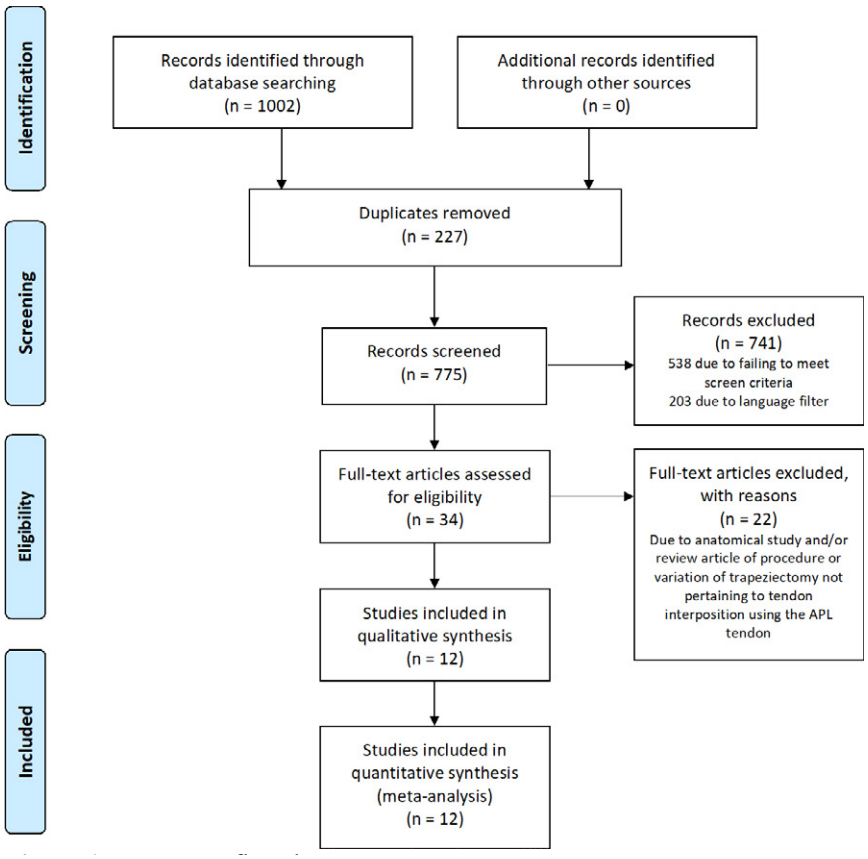


Figure 1: PRISMA flowchart.

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assessed using the screening criteria. Of these, 742 were excluded due to failing to meet the inclusion criteria (Figure 1). Full text analysis of 34 records was performed, leading to 21 exclusions due to anatomical study and/or review article of procedure or variation of trapeziectomy not pertaining to tendon interposition using APL (Figure 1). In total, 12 articles were included in this systematic review (Figure 1).

All included records were observational studies. Three articles employed a prospective study design and the remaining ten described a retrospective design. The level of evidence of included studies, as per the Oxford Centre for Evidence-Based Medicine [22], ranged from II to III. An assessment of bias was completed for each of the included studies using the Quality Assessment Tool for Quantitative Studies. This evaluated selection bias, study design, confounding, blinding, data collection methods and analysis methods for each study, with each paper finally being given a score of "weak", "moderate" or "strong"[23]. Six studies were of moderate quality, with three studies classed as weak (Supplementary data). A meta-analysis of the included records was not possible due to the lack of homogeneity in the reported outcome results.

Across the 12 articles included in this review, 485 CMC joints underwent APLTIA (Table 2). Three studies were prospective and nine were retrospective in study design. From the articles that reported age of participants, the mean age was 61.8 (ranging from 56 to 70.8 years). The majority of studies (4 each) were conducted in the United States of America and France. The overall follow-up period ranged from 1 to 15 years, with an average follow-up of 5 years. Similar indications for APLTIA were described, namely severe first CMC joint OA (Eaton stages III-IV), which failed conservative management. PROMs were measured in all 12 included articles (Table 3).

Pain relief post-surgery was reported through multiple methods. Of note, 4 of these articles reported pain by using a visual analogue scale, ranging from 0 representing 'no pain' and 10

Table 2: Baseline characteristics of included studies.

Study (year)	Study type	Location	Indication for surgery *	No. of patients	No. of thumbs	Mean patient age (years)	Mean follow up time (years)
Soejima et al (2005)	Prospective cohort	Japan	1st CMCJ OA	18	21	-	3
Chang and Chung (2008)	Prospective cohort	America	1st CMCJ OA	18	21	61	1
Rocchi et al (2011)	Prospective cohort	France	1st CMCJ OA	42	42	60	1
Sirotakova et al (2007)	Retrospective cohort	UK	1st CMCJ OA	74	104	60	1
Mathoulin et al (2008)	Retrospective cohort	France	1st CMCJ OA	50	60	60	4
Kochevar et al (2011)	Retrospective cohort	America	1st CMCJ OA	18	25	59	5.5
Avisar et al (2013)	Retrospective cohort	Israel	1st CMCJ OA	13	15	-	1.25
Avant et al (2015)	Retrospective cohort	America	1st CMCJ OA	33	33	62	1.5
Barthel et al (2018)	Retrospective cohort	France	1st CMCJ OA	35	46	69	6
Earp et al (2019)	Retrospective cohort	America	1st CMCJ OA	60	66	60.4	4.8
Lied et al (2016)	Retrospective cohort	Norway	1st CMCJ OA	47	55	56	3.5 & 11.5
Nanno et al (2019)	Retrospective cohort	Japan	1st CMCJ OA	26	30	70.8	2

* Severe first CMCJ OA, classified as Eaton-Littler grade 3 and 4, was the predominant indication in all of the studies. Rocchi et all (2011) and Mathoulin et al (2008) also included grade 2 disease.

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Table 3: Results of included studies

Study (year)	Patient Reported Outcomes Measures (PROMs)	Objective Function	Complications (number of cases)	Bias Global Rating and Limitations
Soejima et al (2005)	***PROMs:*** (a) 16/18 patients report thumb was more effective for pinching and gripping post-operatively (b) 2/18 reported weakness in metacarpophalangeal hyperextension when opening jars and using keys ***Pain reported:*** (a) preoperatively: (21/21 thumbs) during light activities; (8/21 thumbs) at rest (b) post-operatively: (13/21 thumbs) no pain; (5/21 thumbs) mild pain strenuous activity; (3/21 thumbs) light work	***Grip strength (kg) [pre-op to post-op]:*** *14 -7 to 16 -6 (p=0.178)* ***Key-pinch strengths (kg) [pre-op to post-op]:*** *2.7 - 1.8 to 4.0 - 1.2 (p=0.225)* ***Range of motion:*** (a) Radial abductions: improved from 42° - 24° to 56° - 9° (p= 0.094) (b) Palmar abductions: 48° -19° to 56° - 6° (p=0.069) ***Trapezial resection space ratio / length of the first metacarpal post-op:*** 0.20 to 0.17 (p=0.004)	Not specified	Retrospective study design Limited number of cases
Sirotakova et al (2007)	***Pain reported:*** (a) Pre-operative: with use 10; at rest 38; nigh pain 48 (b) Post-operative: 95 no pain; 9 at rest ***Stiffness reported:*** (a) Pre-operative: 50 none; 36 mild; 9 severe (b) 6 months post-operative: 75 none; 20 mild; 0 severe (c) 1 year post-operative: 91 none; 4 mild; 0 severe ***Weakness reported:*** (a) Pre-op: 9 none; 34 mild; 12 severe (b) 6 months post: 63 none; 25 mild; 0 severe (c) 1 year post-op: 89 none; 6 mild; 0 severe Majority reported a complete resolution of the disability or marked improvement after surgery.	***Grip strength:*** *41% increase post-operatively (bilateral); 65% post-operative increase (unilateral)* ***Tip pinch strength:*** *46% increase post-operatively (bilateral); 53% post-operative increase (unilateral)* ***Key-pinch strength:*** *19% increase post-operatively (bilateral); 77% - operative increase (unilateral)* ***Range of motion:*** (a) Radial abduction: pre-operatively 47° to 53° post-operatively (unilateral) & 45° pre-operatively to 51° post-operatively (bilateral) (b) Palmar abduction: 44° pre-operatively to 47° post-operatively (unilateral) & 42° pre--operatively to 45° post-operatively (bilateral) ***Kapandji score:*** mean thumb opposition 7.5 pre-operatively to 9 post-operatively (unilateral) & 7.3 pre-operatively to 8 post-operatively (bilateral) ***Return to work:*** 39 (retired; 14 women still active housewives); 22/35 office workers; 13/35 light manual workers (a) 29/35 returned (b) 6/35 returned with job modification	Not specified	Retrospective study design Lack of long-term follow-up

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Continued Table 3: Results of included studies

Study (year)	Patient Reported Outcomes Measures (PROMs)	Objective Function	Complications (number of cases)	Bias Global Rating and Limitations
Chang and Chung (2008)	***Mean MHQ score [range 0-100]:*** post-operatively increased to 67 from 41 (p=0.03) within one year **ADL:** increased to 66 from 43 (p=0.01) one-year post operatively **Work performance:** increased to 65 from 41 (p=0.05) one-year post operatively **Patient satisfaction:** increased to 68 from 25 (p=0.01) one year post-operatively **Pain score:** decreased from 73 to 30 (p<0.01)+B10 one year post-operatively	***Grip strength (kg):*** decreased to 43% at 3 months; improved to 84% at 6 months and 102% at 1 year ***Jebsen-Taylor test scores:*** (a) 3 months post-op: improved from 47 seconds to 40 seconds (b) 6 months post-op: 34 seconds at 6 month (p=0.04) (c) 1 year post-op: 33 seconds at 1 year (p=0.02) ***Radiography post-op 1 year:*** (a) Loss of CMC space height was 38% (vs pre-op) (b) Proximal migration of greater than 15% in 3 patients (c) Remaining patients showed little/ no further loss in the height of the CMC space	Neurolysis required (1) Neurorelocation required (1) Localised infection (1)	Retrospective study design Lack of long-term follow-up Limited comparison between APL and FCR reconstruction in the functional outcomes
Mathoulin et al (2008)	***Pain reported:*** (a) Pre-operatively: 33 reported severe pain; 30 reported moderate pain (b) Post-operatively: 47 reported pain relief; 12 reported mild pain; 1 reported severe pain	**Grip strength (kg):** pre-operative mean of 16, post-operative mean of 29.1 **Pinch strength (kg):** pre-operative mean of 2.9, post-operative mean of 6 **Thumb opposition (Kapandji score):** pre-operative mean of 8.1, post-operative mean of 9 **Range of motion:** (a) MCP: pre-operative mean of 34.5° , post-operative mean of 41.6° (b) IP: pre-operative mean of 33.9° , post-operative mean of 39.3° ***Return to work:*** (a) Average of 8.7 (range 1–32) weeks (b) 50y/o business man: return 1 week (c) 67 y/o (developed CRPS Type 1) returned after 32 weeks	Complex regional pain syndrome (2) FCR tendonitis (4) Reaction to suture (1)	Retrospective study design

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Continued Table 3: Results of included studies

Study (year)	Patient Reported Outcomes Measures (PROMs)	Objective Function	Complications (number of cases)	Bias Global Rating and Limitations
Kochevar et al (2011)	***Arthritis impact measurement scales 2 Health status questionnaire (AIMS2-SF):*** **[Range: 0=health 10=illness]** (a) Writing pre-op vs post-op: 3.2 to 1.1; 65.6% change (p value <0.001) (b) Button shirt pre-op vs post-op: 1.5 to 0.6; 60% (p=0.005) (c) Turn key pre-op vs post-op: 1.7 to 0.6; 64.7% (p=0.002) (d) Comb hair pre-op vs post-op: 1.2 to 1; 16.7% (p=0.641) (e) Vigorous activities pre-op vs post-op: 2.5 to 2.6; 4% (p=0.813) (f) Arthritis pain pre-op vs post-op: 5.9 to 3.9; 51.3% (p=0.001) ***Pain relief:*** 17/18 excellent or good; 1/18 fair relief	***Grip strength (kg):*** pre-operative average of 13, post-operative average of 14.8; 14% change (p=0.001) **Tip pinch (kg):** pre-operative average of 3.2, post-operative average of 3.4; 6% change (p=0.073) ***Key pinch strength (kg):*** pre-operative average of 3.4, post-operative average of 3.8; 12% change (p=0.004) **Thumb opposition score:** 24/25 touch head of small finger metacarpal; 1/25 touch proximal interphalangeal joint	Not specified	Retrospective study design
Rocchi et al (2011)	***DASH scores:*** pre-operative average of 43.3, post-operative average of 14.5 ***Pain reported:*** pre-operatively (42/42); 3 months post-operatively (28/42); 6 months post-operatively (3/42 mild pain); 1 year post-operatively (1/42 mild pain) ***Satisfaction:*** mean 9.6/10 (SD 0.8) [range: 1= totally dissatisfied vs 10= completely satisfied]	***Grip strength (kg):*** *(a) pre-operatively 16.0 (SD 1.2)* *(b) post-operatively 1 year 19.2 kg (SD 0.5)* ***Key pinch (kg):*** *(a) pre-operatively 3.7 (SD 1.2)* *(b) post-operatively 5.6 (SD 1.5)* ***Web span an***gle: (a) pre-operatively 43° (SD 5) (b) post-operatively 77° (*SD 3)* ***Kapandji score:*** (a) pre-operatively 6 (b) post-operatively *9* ***X-ray 1 year post-operatively:*** distance between the distal scaphoid and first metacarpal base of 6.7 mm (SD 0.6)	Keloid (1) Temporary dysesthesia of thumb (2)	Retrospective study design Lack of long-term follow-up

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Continued Table 3: Results of included studies

Study (year)	Patient Reported Outcomes Measures (PROMs)	Objective Function	Complications (number of cases)	Bias Global Rating and Limitations
Avisar et al (2013)	***VAS scores:*** pre-operative average of 7.4 (SD 2.12), post-operative average of 2.133(SD1.19) ***DASH score:*** post-operative average of 16.85 (SD 11.51)	***Grip strength (kg):*** *average of 25.4 (S D8.25) vs mean 24.9 kg (SD 7.62) on the no-operated hands (p = 0.483)* ***Pinch strength (kg)****: post-operative average of 4.3 (SD 1.36) vs mean 4.5 kg (SD 1.14) on the non-operated hands (p =0.735)* ***Range of motion:*** (a) Mean MTPJ flexion: 31.33° (SD 12.74) (b) Mean MTPJ extension: 1.66° (SD 3.62) (c) Mean tip to palm distance: 0.166 mm (SD 0.36) ***Mean carpal height:*** 0.52mm ***Mean trapezial space ratio:*** 0.163mm	No complications	Retrospective study design Patients lost to follow-up
Avant et al (2015)	***VAS scores:*** pre-operative average of 7 (p = 0.49), post-operative average of 2 (p = 0.44) ***DASH scores:*** pre-operative average of 56 (p = 0.32), post-operative average of 40 (p = 0.44)	***Grip strength (kg):*** pre-operative average of 14 (p=0.38), post-operative average of 20 (p=0.27) ***Tip pinch (kg):*** pre-operative average of 4 (p = 0.19), post-operative average of 3 (p = 0.19) ***Key pinch (kg):*** pre-operative average of 5(p=0.41), post-operative average of 5 (p=0.39) ***Thumb opposition score (% opposition to small finger base):*** 78% (p=0.46) ***Radiographic metacarpal base to distal scaphoid distance (cm):*** 0.55cm (p=0.01)	Revision surgery required (1) Superficial infection (1)	Retrospective study design Lack of long-term follow-up Patients lost to follow-up Different surgeons performing the procedures
Barthel et al (2018)	***Quick DASH:*** post-operative mean of 15.19/100 (SD 18.282) (p = 0.055) ***Pain reported post-operatively:*** 2.157/10* SD=1.883 (p=0.503)	***Key pinch strength (kg):*** *4; (SD 1.309) (p = 0.3303)* vs 4.25kg SD=1.943 in trapeziectomy alone ***Pre- and postoperative key pinch strength difference (kg):*** *0.842 (SD 2.977) (p=0.3303) vs 0.389 SD=2.367 in trapeziectomy alone* ***Thumb opposition score (range 0-10):*** 9.263/10; (SD 1.194) (p=0.501) vs 2.481/10 SD=1.528 in trapeziectomy alone ***Thumb opposition score:*** 0.421 (SD 0.961) (p = 0.3033) vs 0.630 SD=1.079 in trapeziectomy alone	No complications	Retrospective study design Limited number of cases Compared only one type of suspensionplasty to trapeziectomy alone

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Continued Table 3: Results of included studies

Study (year)	Patient Reported Outcomes Measures (PROMs)	Objective Function	Complications (number of cases)	Bias Global Rating and Limitations
Earp et al (2019)	***VAS score (median interquartile range):*** 0 (ranging from 0-2) ***DASH score:*** post-operative average of 9.1 (ranging from 2.3-26.1)	***Grip strength (kg):*** 18.8 post-operatively (11.1 SD); 94% improvement ***Key pinch strength (kg):*** post-operatively 4.7 (2.1 SD) 84% improvement ***Tip pinch strength (kg):*** post-operatively 3.2 (1.7SD) 86% improvement	Revision surgery required (1) Capsulodesis required (1) Superficial infection (2)	Retrospective study design No pre-operative data regarding VAS or DASH score
Lied et al (2016)	***VAS scores:*** **mean [range 0-100; 0=best vs 100=worst; VAS<16 excellent]:** - Pain: 11 (65% excellent) - 15 (61% excellent) - Satisfaction: 5 (62% excellent) - 15 (67% excellent) ***DASH scores:*** pre-operative average of 28, post-operative average of 20 ***Number of patients who regret having surgery:*** 4/55 - 3/36 ***ADL:*** **Pre-operative [n=55] - 3.5 years post op [n=55] - 13 years post op [n=36]** (a) Open car key: 13 can't - 11 improved - 17 improved (b) Use door-key: 10 can't - 7 improved - 20 improved (c) Open Jam jar: 42 can't - 14 improved - 13 improved (d) Wiring cloth: 30 can't - 21 can't - 15 better 3.5 years post-operative [n=55] - 13 years post-operative [n=36]	***Grip strength (kg):*** *3.5-year post-operative average of 21 (SD 10), 13-year post-operative average of 24 (SD 6)* ***Key pinch strength (kg):*** *3.5-year post-operative average of 3.8 (SD 1.4), 13-year post-operative average of 5 (SD 1.5)* ***Range of motion:*** (a) Thumb radial abduction: 51° (SD 16) 3.5 years post-operatively & 36° (SD 9) 13 years post-operatively (b) Wrist extension: 62° (SD 12) 3.5 years post-operatively & 59° (SD 10) 13 years post-operatively (c) Wrist flexion: 68° (SD 15) 3.5 years post-operatively & 71° (SD 8) 13 years post-operatively ***Radiograph; Median distance between the scaphoid and the 1st metacarpal bone (mm) [pre-op; 3.5-year review; 13-year review]:*** 11; 4.9; 4.3	Not specified	Retrospective study design No pre-operative data regarding PROMs or objective function
Nanno et al (2019)	***VAS scores:*** pre-operative average of 8.01 (range 0.89-80.1), post-operative average of 1.68 (range 1.20-1.68) ***Quick DASH:*** pre-operative average of 46.0, post-operative average of 17.1	***Grip strength (kg):*** *pre-operatively 11.8, post-operatively 18.9* ***Pinch power (kg):*** *pre-operatively 3.51, post-operatively 4.30* ***Range of motion:*** (a) Thumb radial angles 30.1° to 45.5° (b) Palmar abduction angles 36.8° to 46.2° ***Trapezial space ratio:*** 0.31 to 0.21	No complications/surgical revisions	Retrospective study design Limited number of cases

* 0= no pain; 10= worst pain imaginable

indicating 'worst pain'[9, 24-26]. Out of the 159 patients these studies investigated, the authors report an overall improvement in pain levels from 7.47 to 1.9 [9, 24, 26]; whilst Earp et al. [25]reported 0 post-op (no retrospective pre-op VAS available). Rocchi et al. [27]& Mathoulin et al. [28] reported pain using a categorical grading system, ranging from 'severe, moderate or mild' after APLTIA. Out of the 92 patients enrolled by the authors, 75 (85%) reported pain was severe pre-operatively; whilst 88 (95.6%) reported no pain post-operatively. Lied et al. [29]reported that 65% and 61% of patients had an excellent pain relief (defined as a VAS score <16) at the 3.5 and 13-year follow ups.

Kochevar et al. [30]utilised a categorical pain grading system, ranging from excellent pain relief to no improvement. Out of the 18 patients these studies investigated, 17 patients reported an 'excellent' improvement in pain levels post-APLTIA, whilst 1 reported 'fair' relief.

Chang and Chung [31] reported pain using a 100-point grading system, with 0 indicating no pain and 100 indicating the most severe pain. The author reports to have found an average improvement in pain levels by 43 points. This was statistically significant when compared to pre-operative levels (P <0.01).

Soejima et al. [32]& Sirotakova et al.[33] reported pain using a different categorical grading system, ranging from 'pain with use', 'pain with rest' and 'no pain' after APLTIA. Out of the 92 patients (with 125 thumbs) enrolled by the authors, 31 reported pain with activity and 94 at rest pre-operatively; whilst 108 reported no pain post-operatively, 8 mild pain with use and 9 reported pain at rest.

Finally, Barthel et al. [34] reported pain using a 10-point scale, with 0 indicating no pain and 10 indicating the most severe pain. The author reports an improvement in pain levels, with an average of 2.2/10 (P=0.503).

Patient satisfaction levels were reported in two included studies (Table 3). Rocchi et al. [27] reported patient satisfaction through a categorical scoring system, ranging from 1 (completely dissatisfied) to 10 (completely satisfied). Of the 42 patients enrolled in this study, overall satisfaction was 9.6/10 post-APLTIA. Chang and Chung [31]employed a similar categorical scoring system to assess patient satisfaction, ranging from 0 (dissatisfied) to 100 (very satisfied), concluding that patient satisfaction increased from 25 to 68 (P < 0.01) post-APLTIA.

The DASH score, ranging from 0 (no disability) to 100 (most severe disability), was reported by 7 papers[9, 24-27, 29, 34]. Four authors reported an averaged DASH score of 17.23 post-operatively for 155 patients enrolled in the study, without investigating the baseline DASH score pre-operatively. Three authors[24, 26, 27] reported the mean change in DASH scores for 149 patients from 42 pre-operatively to 25 post-operatively. As standard deviations and individual-level data were not provided in these studies, a meta-analysis was not possible.

Nanno et al. [26] and Barthel et al. [34] reported QuickDASH, scores. Barthel et al. [34] found that following APLTIA the average QuickDASH score improved from 46 pre-operatively to 17 post-operatively. Nanno et al. [26] reported a QuickDASH score of 15 post-operatively but did not provide pre-operative results.

Function was reported in all 12 articles (Table 3). Kochevar et al. [30]utilised the AIMS2-SF, with a score of 10 indicating illness and 0 indicating good health. The authors report an average functional improvement from 2.7 pre-operatively to 1.6 after APLTIA (Table 3). Chang and Chung [31] reported functional scores utilising the MHQ score, concluding that mean function improved significantly from 41 to 67 [range 0-100; with 100 denoting optimum hand function] (p=0.03).

Return to work was reported by two studies and was assessed by grouping patients into those that resumed their regular job, required amended duties or did not return to work [28, 33]. Out of a total of 74 patients, 39 were retired. Of the remaining 35 patients, 29 resumed their regular work and 6 patients resorted to amended duties.

Range of motion was objectively assessed in 6 included studies (3 via goniometer) (Table 3) [9, 26, 28, 29, 32, 33]. Nanno et al. [24] reported that thumb radial abduction increased (from 30° to 46° post-operatively) and palmar abduction (from 37° to 46°). Soejima et al. [32] reported that thumb radial abduction increased, ranging from 24° to 42° pre-operatively to 9° to 56° post-operatively (p=0.094); and palmar abduction from 19° to 48° pre-operatively to 6° to 56° post-operatively (p=0.069). Avisar et al. [9] reported an average MTPJ flexion-extension arc of 31° and 2° respectively but provided no comparison to pre-operative degree of motion. Sirotakova et al. [33]reported that radial abduction increased from 47° to 53° on unilateral cases, whilst bilateral cases increased from 45° to 51° post-operatively. Palmar abduction increased from 44° to 47° on unilateral

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cases, whilst bilateral cases increased from 42° to 45° post-operatively. Lied et al. [29] reported that post-operative wrist extension decreased from 62° 3.5 years following the procedure, to 59° 13 years post-operatively; whilst wrist extension increased from 68° to 71°. This study also found that thumb radial abduction was 51° at 3.5 years after APLTIA, and 36° after 13 years. Lastly, Mathoullin et al.[28] reported an average increase in MCPJ range of movement from 35° to 42° post-operatively; and IPJ ROM from 34° to 39°.

Grip strength was reported in eleven papers[9, 24-33] and assessed via a dynamometer (Table 3). The authors report an overall average improvement in grip strength from 14 to 20 kg in 214 patients post-APLTIA. Avisar et al. [9] reported a mean grip strength of 25 kg in 212 patients after APLTIA, which was no different when compared to the contralateral unaffected hand (p=0.735). Chang and Chung [31]noted a 43% decrease in grip strength 3 months post-surgery, which improved by an increase of 84% at 6 months and 102% after 1 year, when compared to baseline levels. Sirotakova et al. [33]reported a 41% increase post-surgery for bilateral cases and 65% increase in unilateral cases. Similarly, Earp et al. [25]reported a 94% improvement in grip strength. Finally, Lied et al. [29] described a grip strength of 21 kg 3 months post operatively, followed by 24 kg after 13 years, but did not provide any pre-operative data.

Pinch strength was reported in eleven papers, with some reports further examining key pinch and tip pinch strength (Table 3). Nanno et al. [26]and Mathoulin et al. [28] report an average increase in pinch strength from 3 kg to 5 kg post-operatively for 76 patients. Avisar et al. [9] reports a pinch strength of 4 kg post-operatively, compared to 4.5 kg on the contralateral unaffected hand (p=0.735). Pre-operative data was not provided as a comparison.

Four papers[24, 27, 30, 32] report key pinch strength with pre and post-operative comparisons, with an average increase from 3.7 kg pre-operatively to 4.6 kg post-operatively. Statistical significance was reported by Kochevar et al. [30] (p=0.004). Barthel et al reported a 0.8 kg increase in key pinch strength (p=0.033), with no raw data provided. Lastly, Lied et al.[29] reports improved key pinch strength of 3.8 kg and 5 kg at 3.5 years post-operatively and 13 years respectively. Although objective measures of function were widely reported, studies were heterogenous in assessment, reporting and pre-operative measurements were commonly not provided.

Surgical complications post-APLTIA were reported in only five included articles (Table 3)[24, 25, 28, 31]. Eight articles reported no complications. Surgical failure, defined as the need for further operations were reported in four of the included studies. Out of a total of 485 hands, 5 patients (1%) required further surgery. Of these patients, 2 received a revision arthroplasty, 1 required capsulodesis, whilst 1 received surgical neurolysis, and another required resection of a neuroma from a branch of the radial nerve.

DISCUSSION

For OA of the thumb CMC, a surgical procedure that would alleviate pain, improve thumb motion and grip strength without lengthy immobilization should be considered as the gold standard. Numerous surgical treatments and techniques have been described in the literature, including trapeziectomy with or without ligament reconstruction and tendon interposition, joint replacement and/or fusion [11, 12, 14]. This systematic review provides evidence that APLTIA may be associated with significant pain relief and functional improvement in patients with first CMC joint OA. APLTIA appears to be a safe surgical option with limited complications and fast post-operative recovery, from the current available evidence. Interestingly, it may also be associated with improvements in grip and key pinch, compared to FCR LRTI [31]and/or trapeziectomy alone[34].

Various modifications of the original technique for APLTIA, including changes to the surgical approach or tunnelling method, were observed in the included papers within this systematic review[35]. Variability of the surgical technique, including the tunnelling method utilised, may represent a significant limitation when interpreting the overall effect of APLTIA[30].

In the wider literature, several studies have suggested that APLTIA may lead to superior outcomes compared to using the FCR tendon. For example, some report that by preserving FCR tendon integrity, wrist flexion and stability may be better conserved[31]. APLTIA may also lead to fewer post-operative complications and shorter tourniquet times, when compared to using the FCR tendon[31]. However, other studies comparing APL and FCR LRTI have reported that the latter may lead to improved key pinch and grip strength[36]. There remains no apparent gold standard technique and

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no consensus among expert opinion. Awareness of different surgical treatment options for CMC arthritis is important, given that individual anatomy may hinder a particular technique[25]. As such, future research is required to investigate functional outcomes of FCR versus APL LRTI.

The data assessed and included in this systematic review is subject to limitations. Due to the lack of randomised control trials, quantifying the overall benefits and risks of APLTIA, compared to the alternative surgical options remains difficult. The bias assessment (Table 3) revealed a risk of selection, attrition and reporting bias in differing variations across the twelve included articles, mainly resulting from deficiencies of study design. Defining APLTIA failure by re-operation rates also contributes directly to detection bias, as decision to re-operate may be influenced by both patient and surgeon preferences and beliefs. Whilst conducting the review, incomplete retrieval of appropriate records may have occurred (posing a selection bias), this was minimised as repetition of the search strategy was employed. The study was also limited to work published in English, and so it was not possible to identify results from the worldwide literature.

CONCLUSION

CMC OA of the thumb is increasing in prevalence as the population ages. Inevitably, this disease leads to significant disability and functional decline. Viable treatment options are available to alleviate pain, such as total trapeziectomy or LRTI (FCR) arthroplasty. APLTIA has gained popularity as an alternative surgical technique, preserving the FCR tendon. With the limited data available, APLTIA is associated with improvements in short-term pain relief, patient satisfaction and functional level. This, combined with the ability to conduct salvage operations unhindered in cases of failure, presents APLTIA as a possible alternative to LTRI surgical interventions.

Further research is clearly required to evaluate benefits, duration of relief, optimal surgical techniques and long-term complications of APLTIA, especially when compared to trapeziectomy alone and LRTI with FCR. This may be approached through differing avenues. Firstly, evidence is required to evaluate both the short and long-term benefits (pain relief and functional status) and risks (infection, failure and further operation). Ideally, this can be evaluated through a combination of observational studies and randomised controlled trials (RCTs). RCTs evaluating APLTIA, compared to other mainstay surgical techniques may help establish its superiority. Finally, research is required to evaluate the specific surgical techniques employed, including the common modifications of the original Thompson's technique. In all cases standardised and validated outcome measures should be assessed thoroughly, pre-operatively and post-operatively to enable future meta-analyses.

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CONFLICTING INTERESTS

The authors declare no conflicting interests.

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Appendix S1 (Search Strategy):

Search Strategy	All database total hits	Exclusions
"Trapeziectomy"	344	Language (42) Excluded – screening criteria or duplicate (300) Remaining records – 2
"Tendon interposition"	287	Language (35) Excluded – screening criteria or duplicate (252) Remaining records – 0
"Trapeziectomy AND Tendon interposition"	247	Excluded – Screening criteria or duplicate (226) Remaining records - 21
"Trapeziectomy AND Abductor Pollicis Longus"	38	Excluded – Language, screening criteria or duplicate (31) Remaining records - 7
"Trapeziectomy AND Tendon interposition" AND "Patient reported outcome measures; PROMs; DASH; VAS PRWE; Michigan Hand Score; AIMS2-SF; Kapandji 46 scale; Grip Strength; Pinch Strength; Range of movement; Range of motion; Proprioception; complications"	86 (OVID)	Excluded – Language, screening criteria or duplicate (84) Remaining records – 3

Appendix S2 (Review author's bias assessment of included articles – Red indicates weak, orange indicates moderate and green indicates strong studies):



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