Reliability of Metacarpal Subsidence Measurements after Thumb Carpometacarpal Joint Arthroplasty

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Abstract

Background Thumb metacarpal subsidence after trapeziectomy can affect clinical function over time. Methods for measuring subsidence after trapeziectomy have been described, and they rely on an intact thumb metacarpal or proximal phalanx for measurement. The authors evaluated the reliability and reproducibility of measuring the trapezoidal space ratio, using previously described methods. In addition, the authors evaluated a new method that measures trapezoidal space on a posteroanterior (PA) hand/wrist radiograph that does not rely on an intact thumb metacarpal or proximal phalanx for measurement, which can often be altered by degenerative changes or in cases in which metacarpophalangeal arthrodesis is performed during carpometacarpal (CMC) joint arthroplasty to correct excessive hyperextension. The authors hypothesized that a new method of calculating trapezoidal space would have comparable reliability and reproducibility to previously proposed methods.

Methods Thirty-seven PA hand/wrist radiographs from patients who had trapeziectomy with ligament reconstruction and tendon interposition were evaluated. Trapezoidal space was measured using PACS (Picture Archiving and Communication System) digital tools as the distance perpendicular to the tangents of the scaphoid and first metacarpal joint surfaces. All X-rays were evaluated individually by five fellowship-trained hand surgeons, twice, 4 weeks apart. The reviewers calculated trapezoidal space ratios, using three different methods, two previously described and a novel one: (1) trapezoidal space relative to first metacarpal length (classic 1); (2) trapezoidal space relative to proximal phalanx length (classic 2); and (3) trapezoidal space relative to capitate height (novel). Inter- and intraobserver reliabilities were measured using intraclass correlation coefficients (ICC) and limits of agreement for each method.

Results The authors identified excellent agreement between the classic 1, classic 2, and novel methods with an ICC greater than 0.8, indicating excellent agreement. The average trapezoidal space ratios for the thumb proximal phalanx, thumb metacarpal, and capitate methods were measured as 0.19, 0.12, and 0.24, respectively. The upper and lower limits of the 95% confidence intervals for both the inter- and intraobserver agreements of the aforementioned trapezoidal space ratios were (0.17–0.26), (0.11–0.17), and (0.21–0.34) for the interobserver rates and (0.11–0.25), (0.06–0.16), and (0.12–0.33) for the intraobserver rates, respectively.

Conclusion Measuring trapezoidal space is an important diagnostic tool to assess postoperative changes in thumb length. The trapezoidal space indexed to the capitate height method (novel) provides a simple and similarly reliable method for calculating the trapezoidal space ratio on a PA radiograph of the hand/wrist when other measurement techniques are unavailable and when the thumb metacarpal or proximal phalanx is not intact. The authors found a high degree of reproducibility and inter- and intraobserver reliability as measured by the ICC and the 95% limits of agreement that compare with previous agreements in the literature.

Keywords

- carpometacarpal joint
- intraclass correlation coefficient
- trapezoidal space ratio

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Introduction

Thumb carpometacarpal (CMC) joint arthritis is a debilitating condition that impairs function of the hand and can lead to pain and disability.^{1,2} End-stage CMC joint arthritis is commonly treated by basal joint arthroplasty, which includes partial or complete trapeziectomy and is often combined with associated procedures, such as ligament reconstruction, tendon interposition, temporary pinning of the joint, and/or suspensionplasty. These procedures reliably provide pain relief and improve function.³⁻⁶

Preservation of the trapezial space (the space between the distal pole of the scaphoid and the first metacarpal [MC] base) is thought to confer thumb strength and prevent thumb collapse and arthrosis at the new MC scaphoid interface.^{5,7} Therefore, the ability to measure the height of the trapezial space is important for evaluating the integrity and stability of the reconstructed CMC joint over time, as well as predicting strength.

Two methods have been described to measure trapezial space for the purpose of calculating the degree of thumb MC subsidence: one comparing the thumb MC length to the trapezial space⁸ and a second comparing the thumb proximal phalanx (PP) length to the trapezial space.^{9,10} In many cases, surgical intervention in the form of thumb metacarpophalangeal (MP) fusion is necessary to address concomitant hyperextension in the setting of CMC joint arthritis. These anatomic and surgical changes can render the established methods of MC subsidence less reliable. The purpose of this study was to evaluate the intraclass correlation coefficient (ICC) and inter- and intraobserver reliability of these methods and investigate a new method of measuring trapezial space based on a PA wrist X-ray comparing to the capitate height (CH).

Methods

After institutional review board (IRB) approval (#13D.432) was obtained, X-rays of all patients who underwent basal joint arthroplasty with ligament reconstruction and tendon interposition by three fellowship-trained hand surgeons between 2010 and 2013 were collected. The mean age was 64 years and 74% were female. Patients were excluded if they had partial trapeziectomy, a preexisting carpal injury/defor-mity, or thumb MP joint fusion.

X-rays were performed by radiology technicians in the authors' Hand Surgery Clinics using digital radiography. Patients had preoperative PA combined hand/wrist films, and films were taken between 2 and 2 weeks postoperatively that were compiled on a Picture Archiving and Communication System (PACS, Sectra AB, Linköping, Sweden). The X-rays were obtained as full DICOM (Digital Imaging and Communications in Medicine) images and stored using a wavelet, lossless compression system at a 1:3 compression ratio. No postprocessing modifications were made.

The X-rays were randomized by one of the nonreviewing authors. The images were then evaluated by five fellowship-trained hand surgeons using the PACS system on

a personal computer. The reviewing surgeons were asked to measure the trapezial space height using three different methods: (1) classic 1—the TS (trapezial space = the base of the first MC to the distal scaphoid pole) relative to the length of the thumb MC or the ratio of TS/MC⁸; (2) classic 2—the TS relative to the length of the thumb PP or the ratio of TS/PP⁹; and (3) novel—the TS relative to the CH on the PA view or the ratio of TS/CH (► Fig. 1). All these measurements were performed using the digital measurement tool in the PACS system. The observers were instructed to measure based on the distance between the tangents to the respective articular surfaces. After the first assessment, the X-rays were re-randomized and reevaluated by the five surgeons 4 weeks later using the same methodology. All reviewers were provided with instructions and a diagram on use of the three measurement methods.

For each of the measurements obtained from the post-operative X-rays—classic 1, classic 2, and novel—intraclass correlation coefficients (ICC) and limits of agreement were measured. The ICC was measured to assess how strongly the measurement results resembled each other. Inter- and intraobserver agreement was measured using limits of agreement were calculated to understand how likely the reviewing surgeons were to agree with each other and over time with respect to the ratio measurements. All statistical analyses for these parametric data were performed using R 3.1.2 (R Foundation for Statistical Computing, Vienna, Austria). No non-parametric data were evaluated in this study.

Results

Thirty-seven X-rays were evaluated. The average trapezial space ratio and the 95% confidence intervals (CI) for these ratios for between and within each observer were similar for all three methods (► Table 1). These results represent excellent intra- and interobserver reliability.

In addition, the ICC for all three methods was found to be greater than 0.8, indicating excellent agreement (► Table 1).

Discussion

The goal of this study was to evaluate the inter- and intraobserver agreement of the previously established methods of trapezial space height as well as introduce an additional method of calculating subsidence to be used where the established methods are unavailable. Two methods have been previously proposed to evaluate the trapezial space. Yang and Weiland (classic 1) describes measuring the trapezial space on standard static X-rays of the thumb with the measurement indexed to the thumb MC length.⁸ The second method (classic 2), as described by Downing and Davis and Kadiyala et al, uses thumb X-rays with the trapezial space indexed to thumb PP length.^{9,10}

These two methods rely on an intact thumb MC or PP to evaluate subsidence. In patients with CMC joint arthritis, the MP joint can also be altered by degenerative changes that may limit the applicability of these methods. Moreover, the MP joint is not infrequently surgically fused during CMC joint

Fig. 1 Trapezial space height ratio calculated by taking the measure of the trapezial space height and dividing it by the length of the static index (first metacarpal, first proximal phalanx, or the capitate).

Table 1 Observer agreement for measuring trapezial space ratio

Method	Average trapezial space ratio	Interobserver 95% CI	Intraobserver 95% CI
Classic 1 (metacarpal)	0.12	0.11–0.17	0.06–0.16
Classic 2 (proximal phalanx)	0.19	0.17–0.26	0.11–0.25
Novel (capitate)	0.24	0.21–0.34	0.12–0.33

Abbreviation: CI, confidence interval.

arthroplasty to correct excessive hyperextension.^{11,12} For the capitate method introduced herein (novel), subsidence can be measured in cases in which only wrist X-rays are available and in cases in which the anatomy of the thumb MC and PP is anatomically altered by disease or surgery.

There is only one study published assessing the reproducibility of thumb MC subsidence measurements. Bhat et al reported the 95% limits of agreement for intra- and interobserver differences in trapezial space height measured on the lateral stress views of the thumb as –1 to +1 mm and –2 to +1 mm, respectively.¹³ The authors found high ICC for all three methods of subsidence measurement, suggesting that all the reviewers on average calculated similar results for each of the X-rays. The authors also demonstrated that measuring trapezial space from the PA X-ray of the wrist and indexing to the first MC, PP, and capitate were reproducible techniques. These data suggest that observers agreed over a narrow 95% CI with small limits of agreement that compares to those results found in the literature.¹³ The authors also found that the intraobserver agreements, based on the limits of agreement, were similar for all surgeons with a slightly better consistency using the PP and MC indices compared with the capitate. As stated previously, the

capitate method may be more appropriate in cases in which only wrist X-rays are available or in situations in which previously established methods cannot be used secondary to MP joint pathology or surgical changes. The capitate offers an easy and reproducible index measurement, and it is less likely to be affected by degenerative or rotatory changes with more consistent geometric references compared with other carpal bones.

The clinical implications of thumb MC subsidence after trapeziectomy have been extensively evaluated. Some studies have shown that decreased thumb length may lead to a loss of mechanical advantage and therefore poorer clinical outcomes such as pinch strength.^{5,14} In others, functional power was improved secondary to decreased pain, but grip strength and thumb pinch were found to be significantly reduced.^{15,16} De Smet et al found a statistically significant relationship between the residual trapezial space and the key pinch force, and Varley et al noted a 20% decrease in pinch strength in more than 50% of patients at an average follow-up of 5 years.^{14,16} Similarly, Iyer documented that three quarters of their postoperative patients had a reduction in grip and pinch strength owing to a reduction in mechanical length and instability.¹⁵

In contrast, several recent studies have suggested that subsidence is not associated with any clinically relevant deficits.^{3,7,17} Yang and Weiland noted an average first MC subsidence of 21% with respect to the preoperative X-rays and an additional 10.5% subsidence on stress radiography.⁸ However, there was no statistical association between the amount of subsidence and the key pinch, tip pinch, or grip strength postoperatively. Kadiyala et al reported 43% subsidence when comparing normal thumbs with postoperative thumbs with approximately 22% reduction between normal thumb trapezial space and preoperative arthritic patients and an additional 27% reduction in space between pre- and postoperative patients.¹⁰ The authors suggest that tendon interposition was inadequate to both restore and maintain length but did not find a correlation with function.

There are several limitations of this study. First, this study size included only 37 postoperative patients' films. Though this sample size was adequate to measure agreements, more patient data would be helpful to perform subgroup analysis for variables such as sex and age. Second, the authors used the limits of agreement to evaluate inter- and intraobserver agreement because these data are continuous. This presents a challenge when evaluating ratios because they are unitless and have only relative value, comparable only to previous literature estimates of what constitutes good agreement. Last, the authors measured subsidence, using a PA X-rays of the wrist/hand, which, though easier to obtain, makes a comparison to previous studies difficult, where lateral stress and nonstress views of the thumb are used.

In conclusion, the established methods of trapezial space measurements have a high degree of reproducibility and reliability. Trapezial space indexed to the CH provides a simple and similarly reliable method for calculating the trapezial space ratio on a PA radiograph of the hand/wrist when other measurement techniques are unavailable and when the thumb MC or PP are not intact.

Conflict of Interest

None.

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