RESEARCH ARTICLE

Morphometric Assessment of the Residual Width of the Distal Hamate Articular Surface after Graft Harvest for Hemi-hamate Arthroplasty

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Abstract

Background: The hemi-hamate arthroplasty (HHA) can restore joint congruity and stability in chronic fracture-dislocations of the proximal interphalangeal joint (PIPJ). Purpose of this study was to compare the width of the distal hamate articular surface (DHAS) to the width of the base of the middle phalanges (P2) of the fingers. We hypothesized the dimensions of the width of the DHAS would be similar to those of P2, leaving a small amount of residual DHAS width after autograft harvest.

Methods: Fifty-nine CT scans of the hand without any bony pathology were evaluated. Three observers measured the following parameters and compared: (a) Width of the DHAS in the axial and coronal planes; (b) Width of the P2 articular bases of all four fingers; (c) Maximum capitate length (MaxCap) in the coronal plane.

Results: The residual DHAS on the coronal plane after graft harvest (bone remaining on the radial and ulnar aspects each, not accounting for saw blade or osteotomy width thickness) among all patients was 1.3, 0.9, 1.4, and 2.4 mm for the index, long, ring and small fingers respectively. There was a strong correlation between DHAS and MaxCap r=0.76.

Conclusion: There is likely to be a very small amount of residual hamate articular surface width left after the graft is harvested if the entire base of P2 is reconstructed.

Level of evidence: III

Keywords: Hemi-hamate arthroplasty, HHA, PIPJ fracture-dislocations, Proximal interphalangeal joint

Introduction

Proximal interphalangeal joint (PIPJ) fracture-dislocations are complex injuries which can be challenging to manage. Most frequently, the dislocation involves a dorsal dislocation and fracture of the volar articular surface of the middle phalanx (P2). The size of the fracture fragment is typically used as a guide to determine treatment. Fractures involving less than 30% of the articular surface can be successfully managed nonoperatively. Fractures between 30-50% of the articular surface have tenuous stability and greater than 50% loss of the articular surface typically requires surgical intervention for stabilization (1). Surgical options include percutaneous pinning or open reduction and internal fixation to restore the stability

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of the joint. However, the fragments may be too small to repair in comminuted fractures, and chronic PIPJ dislocations often provide little bone stock to work with. In these cases, volar plate arthroplasty, dynamic external fixation, or an osteochondral graft can be used.

Hemi-hamate arthroplasty (HHA) has been increasingly used for unstable PIPJ fracture-dislocations, especially in the subacute or chronic setting. This technique utilizes an osteochondral autograft harvested from the distal, dorsal articular surface of the hamate at the carpometacarpal (CMC) joint as the donor site, which is then transferred and fixed with screws to recreate the volar base of P2 (2). HHA has been associated with variable surgical outcomes in these difficult injuries (3).

Depending on the size of the graft that is needed, a variably sized portion of the width of the distal hamate articular surface (DHAS) may remain after harvest. There is little information in the literature regarding the size relationships between the width of the DHAS and the width of the base of P2 in the coronal plane. The purpose of this morphometric study was to compare the dimensions of the width of the DHAS to the base of the P2 of the fingers. A second goal of this study was to determine whether there is a correlation between the capitate length and the width of the DHAS, in the event that this measurement could be used as a proxy for width of the DHAS, which can be difficult to measure reliably on plain x-rays. We hypothesized that the dimensions of the width of the DHAS would be similar to those of the width of the P2 on the coronal plane, leaving only a small amount of residual DHAS after autograft harvest. We also hypothesized that capitate length on the coronal plane would serve as a good proxy for DHAS measurement in the coronal plane.

Materials and Methods

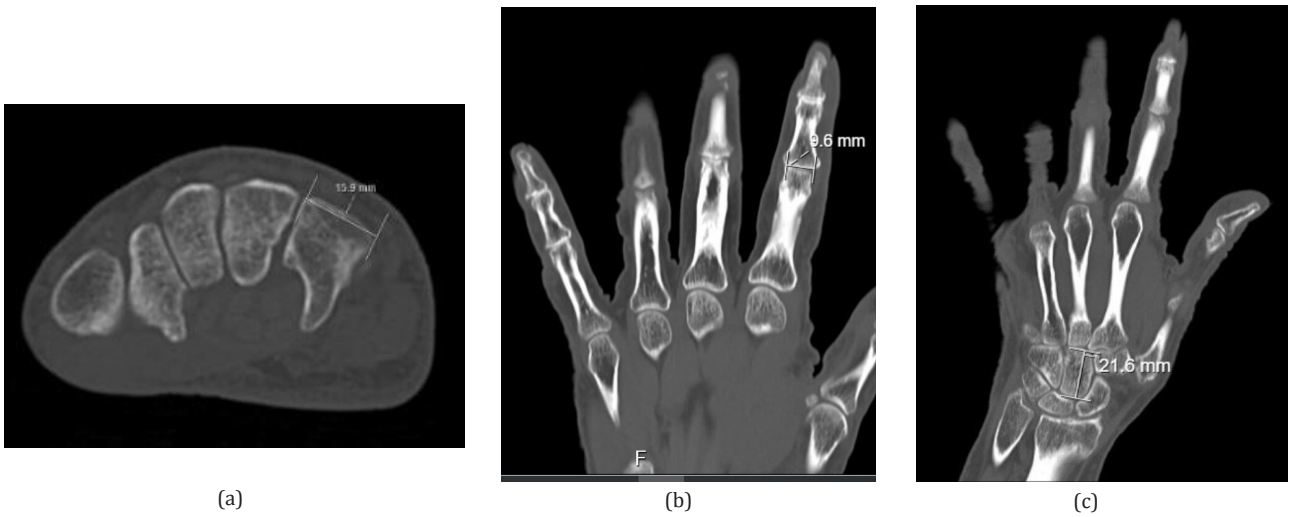
This study was approved by our Institutional Review Board, and informed consent was waived. We reviewed all computerized tomographic (CT) scans of the hand and wrist performed over a ten year period for patients who presented to our institution for treatment. Demographic information was collected including patient age and gender. CT scans were excluded from review if: 1) They lacked complete views of the hand and entire carpus; 2) They contained any visible acute or chronic osseous deformity of the capitate, hamate and phalanges; and 3) There were incomplete series in the axial, coronal, and sagittal planes. Out of the 75 hand and wrist CT scans initially identified, 59 were included for evaluation in this study.

Using digital imaging software from our PACS system (SECTRA, Linkoping, Sweden), the following parameters were measured and compared: 1) Maximum DHAS width measured on axial cuts 2) Width of the P2 articular bases of all four fingers; 3) Maximum capitate length (MaxCap) measured on coronal cuts [Figure 1]. For measurement of DHAS and P2 bases, the axial cut just proximal to the articular surface was chosen. The maximum width of the bone on this slice was measured and recorded. For measurement of MaxCap, the coronal cut with the greatest length of capitate was used and the length measured.

Pearson correlation coefficients were used to evaluate the relationship between the dimensions of the width of the DHAS and the width of the P2 bases, and DHAS to MaxCap. Interobserver agreement of the articular surface size of DHAS, the width of the P2 bases, and MaxCap by two independent observers was evaluated by an intraclass correlation coefficient (ICC) using a two-way mixed effects model with absolute agreement. Statistical significance was defined as $P<0.05$.

Results

The average age of patients in the study cohort was 41years of age (range 15-76 years). There were 42 men



(a) (b) (c)

Figure 1. (a) Maximum DHAS width measured on axial cuts; (b) Width of the P2 articular bases of all four fingers; (c) Maximum capitate length (MaxCap) measured on coronal cuts.

and 17 women. The mean width of the DHAS was 15.7 mm (SD 1.6). The mean width of the index P2 base was 13.1 mm (SD 1.1), of the long P2 base was 13.9mm (SD 1.2), of the ring P2 base was 13.0mm (SD 1.3), and of the small P2 base 10.9 mm (SD 1.3). Moderate correlations were identified between DHAS widths and P2 widths which were statistically significant (*P<0.05*). The relationships between DHAS and P2 bases are summarized in Table 1. The mean dimensions of the osseous structures divided by gender are given in Table 2. All of the differences between genders in all dimensions were statistically significant (*P<0.05*).

The mean MaxCap was 23.5 mm (SD 2.1). Therefore, the ratio between the DHAS and MaxCap was two/thirds (66.8%). There was a strong correlation between DHAS and MaxCap r=0.76 (*P<0.05*).

The residual DHAS on the coronal plane after graft harvest (bone remaining on the radial and ulnar aspects each, not accounting for saw blade or osteotomy width thickness) among all patients was 1.3, 0.9, 1.4, and 2.4 mm for the index, long, ring and small fingers respectively. [Figure 2].

The average ICC for all measurements (DHAS, MaxCap, index/long/ring/small P2 base) was 0.83, indicating very

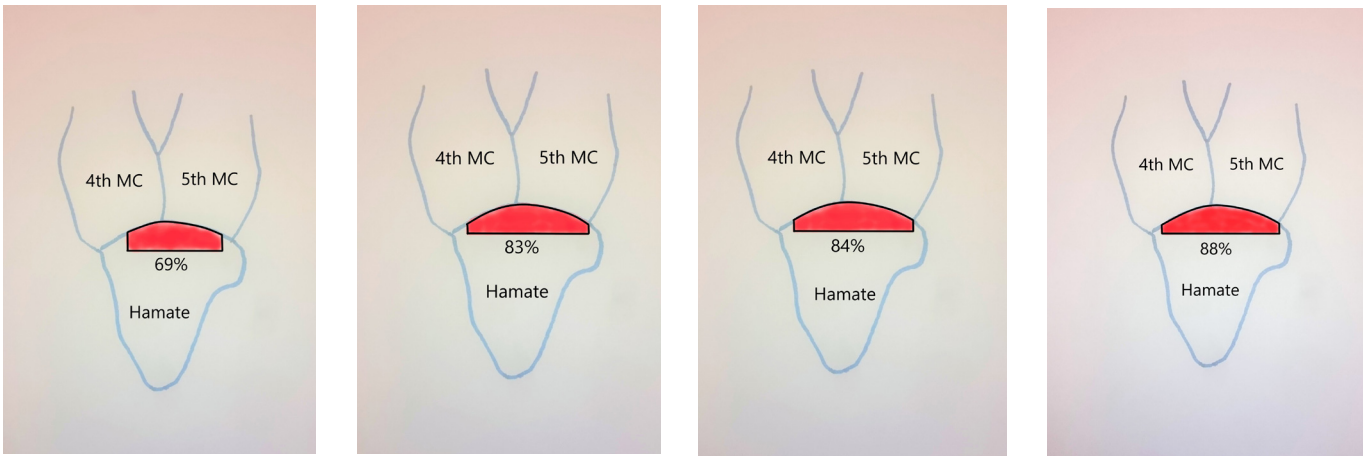
Table 1. Relationships between DHAS and P2 base of the digits, and MC

	Index	Long	Ring	Small
Ratio of P2 to DHAS	0.84	0.88	0.83	0.69
Width difference DHAS - P2 base (mm)	2.6	1.8	2.7	4.8
Correlation to DHAS (r)	0.64	0.64	0.61	0.56

Table 2. Bony dimensions by gender

	DHAS	Index	Long	Ring	Small	MaxCap
Women	14.3 (1.0)	12.3 (0.9)	12.9 (0.9)	12.0 (1.0)	9.9 (0.9)	21.3 (1.3)
Female width difference DHAS – P2 base (mm)		2.0	1.4	2.3	4.4	
Men	16.2 (1.1)	13.4 (0.8)	14.3 (1.3)	13.4 (1.7)	11.2 (1.1)	24.4 (0.7)
Male width difference DHAS – P2 base (mm		2.8	1.9	2.8	5.0	

Values are in mm, standard deviation in parentheses. All differences are statistically significant (*P<0.05*).



(a) (b) (c) (d)

Figure 2. Amount of DHAS removed for autograft harvest by finger. (a) Amount of bone that would have to be removed for the small finger. (b) Amount of bone that would have to be removed for the ring finger. (c) Amount of bone that would have to be removed for the index finger. (d) Amount of bone that would have to be removed for the long finger.

high interobserver agreement.

Discussion

The goal of treatment of PIPJ fracture dislocations is a concentrically reduced and stable joint. HHA recreates the lost volar rim of the P2 base when comminution or chronicity limits open reduction and internal fixation, or after failed repair or reconstructive attempts. Although favourable clinical results can be obtained, degenerative arthritis develops in up to 50% of patients (3–5) . A likely contributing factor is mismatch between the autograft and recipient P2 base (6). In addition, excess autograft harvesting required for large defects may lead to a small amount of residual hamate. Therefore, a clear understanding of the dimensions the DHAS and P2 bases is important when performing HHA, a technically complex procedure.

Few studies have focused on preoperatively sizing the hamate for HHA. Capo et al performed a cadaver study comparing radii of curvature and dimensions of the P2 bases and hamate. They found that the average radius of curvature of the hamate was much shallower than that of the P2 base, only up to 62% of the hamate (2). Additionally, they performed biomechanical testing of the residual hamate and reported that although some specimens demonstrated carpometacarpal (CMC) subluxation, the results may not be clinically significant. They attribute the clinical stability from maintenance of the volar, radial, and ulnar CMC ligaments by removing only the central portion of the hamate. Interestingly, the dimensions of the P2 base width of the fingers and the DHAS measured in this cadaveric study are very similar to our measurements using CT scans.

Shih et al performed three-dimensional simulation of HHA using a P2 base fracture of 50% of the articular surface to determine the ideal position of the autograft. They found that the hamate graft consistently needed to be offset by >1 mm for all digits to recreate the curvature of the P2 base (7). Ten et al performed three-dimensional measurements of the hamate and P2 bases to determine the ideal surgical approach for hamate harvesting (8). Calva et al compared linear and angular radiologic measurements of the DHAS and P2 base articular surface to determine anatomic consistency. Using their criteria, the rate of consistency was low for all digits (6).

In our experience, only a small amount of DHAS in the coronal plane is left behind after a graft sized to match the entire articular width of P2. Our data confirms this experience, with residual DHAS on the coronal plane after graft harvest among all patients was 1.3, 0.9, 1.4, and 2.4 mm for the index, long, ring and small fingers respectively. Notably, these measurements do not account for the width of the saw blade or osteotome used to harvest the graft, which would further diminish the remaining DHAS.

While only a small amount of coronal DHAS remains after graft harvest, instability of the small and ring fingers carpometacarpal (CMC) joints does not appear to be a significant clinical problem. Nakamura et al performed a cadaver study identifying CMC ligaments and assessing CMC stability. In addition to the previously identified intermetacarpal ligaments and longitudinally oriented interosseous ligaments, their study found intra-articular ligaments between the third and fourth metacarpals and the capitate and hamate. After both dorsal and volar CMC ligament were transected leaving only the intra-articular ligament, no instability was detected by manual manipulation. The intra-articular ligament is therefore an important stabilizer of the CMC joint (9). Perhaps after near-complete excision of the hamate during HHA, these additional ligaments stabilize the CMC joint. Additionally, routine immobilization after surgery may reduce CMC subluxation. Given the stout nature of the CMC ligaments, the CMC joint can remain stable even if the entire width of DHAS is removed.

Capitate length in the coronal plane appears to be a good proxy for DHAS width. The DHAS was reliably 2/3 of the capitate height. Rather than performing CT scans preoperatively, the DHAS width could potentially be estimated using the capitate height on routine plain radiographs. Considering the high inter-observer and intra-observer agreements, this finding may have clinical utility in preoperative planning.

This study has several limitations. First, small variations in hand positioning, causing deviation of the CT image plane from the actual plane of the bony structure could cause minor inaccuracies. Second, we did not explore the stability of the CMC joints after hamate excision. Third, our measurements do not account for the amount of DHAS removed due to the width of the sawblade. This limitation in our methodology would lead to an underestimation of the residual DHAS, further supporting our hypothesis. Finally, the surgeon may elect not to restore the entire width of the P2 base and harvest a graft only partially restoring the recipient size, which would probably result in a larger amount of residual DHAS after harvest.

In conclusion, the dimensions between the DHAS and the P2 bases of the fingers are very similar. Differences exist between genders in all dimensions of the hamate and P2 bases. After accounting for bone lost from the osteotomies, there is likely to be a very small amount of residual coronal DHAS left, especially for the long finger.

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