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# Characterization of Trapezial Pommel in Relation to Radiographic and Wear Patterns in Carpometacarpal Osteoarthritis

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## Abstract

**Background:** Trapezial pommel, or ulnar osteophyte positioned at the vertex of the saddle-shaped facet, is a consistent structural appearance in osteoarthritis (OA) of the first carpometacarpal. This study investigates its relation to radiographic measures (modified Eaton staging and thumb OA [ThOA] index) and wear patterns (trapezial surface morphology and cartilaginous eburnation). **Methods:** In all, 137 whole trapezia were explanted from 116 patients and evaluated for Eaton staging, morphology (saddle, cirque, or dish), and eburnation (degree of cartilaginous effacement) of the articular surface of the trapezium. In total, 131 Robert's views and 126 stress views were reviewed by 2 blinded senior surgeons for ThOA index and pommel size. Statistical analyses included Spearman correlation and linear regression. **Results:** Standardized pommel size achieved good intrarater reliability (correlation coefficient: 0.80-0.98) and moderate interrater reliability (correlation coefficient: 0.60-0.67). The ThOA index and pommel size were significantly correlated across Robert's ( $r_s = 0.51$ ) and stress views ( $r_s = 0.64$ ). The ThOA index better distinguished between stages compared with pommel size. All the radiographic measures inversely correlated with preserved cartilage and varied across morphologies. Pommel size differed significantly between dish and saddle, and the ThOA index was significantly different between all morphologies when using stress views. **Conclusions:** We reliably quantified the pommel feature and demonstrated significant correlations with other radiographic and topologic measures of arthritic disease. If future studies can demonstrate that the pommel is a pathogenic process in ThOA and its correction can curb disease progression, the identification of the pommel feature may help guide targeted intervention.

**Keywords:** CMC, arthritis, diagnosis, thumb, anatomy, osteoarthritis, radiology, specialty

## Introduction

Osteoarthritis (OA) of the thumb is a common condition that involves age-related degeneration of the first carpometacarpal (CMC) facet of the trapezium. Carpometacarpal OA has been reported to afflict about one-third of postmenopausal women,<sup>1,2</sup> leading to debilitating symptoms that restrict patients in many activities of daily life.<sup>3</sup> Morphological changes of the articular surface are well documented; however, the exact pathophysiology remains unknown.

Divergent wear patterns have been described by Van Nortwick et al,<sup>4</sup> revealing 3 common morphologies in end-stage explanted trapezia: retained saddle formation, cirque (preferential volar wear), and dish (central wear). Such variation may be explained by behaviors or repetitive forces that preferentially erode the bone in distinct ways, but also suggest that subtle differences in underlying carpal architecture may predispose patients to certain disease-prone biomechanical interactions.

Others have shown that articular tilt angle, flatter trapezial surfaces, and trapezial width impact joint stability and risk of osteoarthritic degeneration.<sup>5-9</sup> Although these structurally significant changes may offer insight into the bidirectional relationship between CMC form and function, such features are difficult to ascertain from routine imaging

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Supplemental material is available in the online version of the article.

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methods and may not reliably inform in vivo disease progression or clinical management.

We seek to identify a novel feature that is both structurally meaningful and may be reliably observed through radiographic evaluation. A large ulnar osteophyte on the trapezial facet positioned between the first and second metacarpals is frequently observed in severe CMC OA. Such an osteophyte extends from a vertex arising from the physiologic central ridge that runs in the ulnar-radial axis of the trapezial articular surface. Although sparsely described in the literature, this ulnar vertex was named in 1975 as *pommel* by Kuczynski because of its relation to saddle-like topography of the trapezial facet.<sup>10</sup> The pommel serves as a pivot on the axis along which the trapezial surface rotates. A prominent pommel may be an anatomical variant that either predisposes to disease-modifying kinematics or may correspond to end-stage damage secondary to biomechanical stress. If implicated at all, it is likely that a combination of these interactions is at play, although prospective studies are needed to evaluate the chronological progression of pommel features preceding disease presentation.

To gain a better insight into the role of the pommel in CMC OA, we aim to establish a standard to quantify pommel features and chart its relationship to other morphological changes such as Eaton stage,<sup>11</sup> thumb OA (ThOA) index,<sup>12</sup> trapezial morphology,<sup>4</sup> and trapezial eburation.<sup>13</sup> We hypothesize that the pommel feature will correlate significantly with ThOA index and Eaton staging and perform comparably among other radiographic measures in predicting morphology or patterns of wear.

## Methods

We designed and conducted our retrospective study in compliance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) reporting guidelines and the approval of our institution's international review board. Subjects who underwent arthroplasty with removal of an intact, whole trapezium for CMC OA between March 2009 and December 2018 were offered recruitment into our study. Subjects with a history of known rheumatologic disorders or significant hand trauma were excluded because of complicating disease processes that likely do not reflect traditional degenerative OA.

In all, 116 patients with end-stage symptomatic CMC OA who underwent 137 arthroplasties involving an intact, whole trapeziectomy were included in our data set after obtaining informed consent. During the surgery, special care was taken to avoid directly disrupting the trapezial articular surface. A Kirschner wire was inserted through the trapezium parallel to the scaphotrapezial joint from radial to ulnar to serve as a lever while removing the ligaments sharply from the intact bone, with care taken to preserve the articular surfaces, flexor carpi radialis, and neighboring anatomical structures. Demographic data were extracted

from patient charts. Operative reports were reviewed for visual assessments of trapezial morphology and eburation, conducted by an expert hand surgeon with more than 10 years of practice. Eburation, or articular cartilage wear, was documented as the percentage of remaining cartilage (0% suggesting full eburation of all articular cartilages) using techniques that apply to OA of the thumb and other joints.<sup>13-15</sup> Articular wear was determined intraoperatively by the senior surgeon and surgical team consensus. Trapezial morphology was reported as retained saddle, cirque, or dish, as described by Van Nortwick et al.<sup>4</sup>

Preoperative imaging was used to assess Eaton staging<sup>11,16</sup> by 1 surgeon (A.L. or L.S.). All Robert's views (n = 131) and stress views (n = 126) were reviewed by 2 blinded expert readers (A.L. and A.W.). Each reader measured the ThOA index<sup>12</sup> and pommel size on the open-source platform ImageJ.<sup>17</sup> Each measurement was evaluated for interrater and intrarater reliability, and the intraclass correlation (ICC) coefficients were reported. A random selection of approximately half of the images consisting of 48 Robert's views and 71 stress views was reviewed by a third trained surgeon (L.S.) for further external validation. Altogether, each individual read and measured the radiographic features twice, at least 1 to 2 weeks apart. All radiographic images were assigned a distinct random code for each iteration.

The presence of the pommel feature (depicted in Figure 1) was recorded, and its size was calculated as a product of its width and height. The pommel width was measured as the base of the feature that emerged from where the ulnar process would physiologically terminate. The pommel height was measured as the greatest vertical length of the pommel from the approximate midline of the width to the distal-most point. The pommel size was then divided by the width of the scaphoid facet to standardize the measurement with the size of the patient's hand (see Figure 1). This standardized pommel size was used for all statistical analyses.

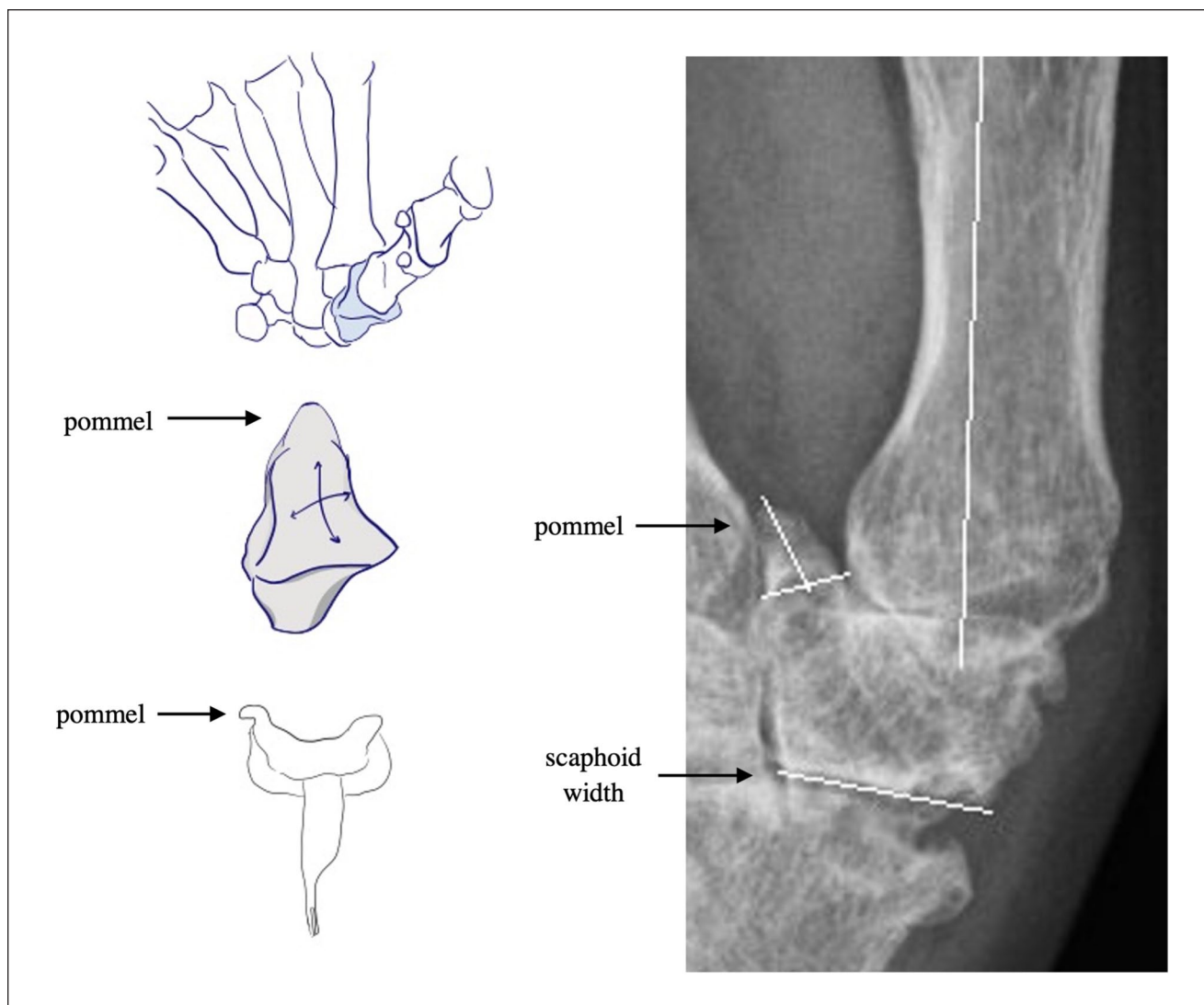
Spearman correlation tests were used to compare the relationship of radiographic values with clinical features. Relationships between radiographic measurements were also tested statistically using linear regression models. Tukey-adjusted *P* values were reported for any post hoc pairwise comparisons. All analyses used a 2-sided level of significance of .05.

Statistics and visualizations were conducted programmatically using R (version 4.0.2) and RStudio (1.2.1335), along with the Tidyverse package.

## Results

### Overview

In all, 137 samples from 116 patients were evaluated in this study. The age averaged 64.1 years ( $\pm 9.1$ ) and ranged from 43 to 84 years, and a majority were women (76.7%) as captured in the demographic breakdown in Table 1.



**Figure 1.** Graphic depicting pommel feature and measurements.

As shown in Table 1, the morphology was evenly distributed across retained saddle (54, 39.4%), cirque (51, 37.2%), and dish (52, 38.0%), while Eaton staging was heavily weighted by stage III (60, 43.8%), followed by stage IV (38, 27.8%) and stage II (35, 25.5%). The percentage of preserved articular cartilage ranged from 80% to 0% (reflecting full eburnation with complete cartilaginous wear). The percentage of intact, preserved cartilage upon assessment averaged 15.4% ( $\pm 18.0\%$ ). Similar distributions of ThOA index and Pommel size were observed between Robert's views and stress views.

### Reliability

Intraclass correlation coefficients for ThOA width and height ranged from 0.80 to 0.98 across both Robert's and

stress views, whereas pommel width and height ranged from 0.63 to 0.96. Both scaphoid width (0.78-0.95) and standardized pommel (0.78-0.91) were also reliable within raters. Interrater reliability for ThOA index and standardized pommel was moderate across both views (Table 2).

### Radiographic Features (Pommel, ThOA Index, Eaton)

The ThOA index correlated significantly with pommel size across both Robert's ( $r_s = 0.51, P < .05$ ) and stress views ( $r_s = 0.64, P < .05$ ). The distributions of both pommel size and ThOA index increased with advancing Eaton staging (Figures 2a and 2b). Pommel size distinguished Eaton stages II and III using Robert's views, but not stress views, although both distinguished stages II

**Table 1.** Overview of Demographic and Clinical Data.

Demographic or clinical category	Count (n = 116 patients)	Clinical parameter	Count (n = 126 specimens)
Age (mean $\pm$ SD) at first surgery	64.1 $\pm$ 9.1	Shape	
Min	43	Retained Saddle	54 (39.4%)
Max	84	Cirque	51 (37.2%)
Sex		Dish	32 (23.4%)
Female	89 (76.7%)	Eaton	
Male	27 (23.3%)	I	4 (2.9%)
Ethnicity		II	35 (25.5%)
Non-Hispanic	109 (94.0%)	III	60 (43.8%)
Hispanic	3 (2.6%)	IV	38 (27.8%)
Unknown	4 (3.4%)	Percent cartilage remaining	
Race		Mean $\pm$ SD	15% $\pm$ 18%
White	105 (90.5%)	Min	0%
Black/African American	0 (0.0%)	Max	80%
Asian	1 (0.9%)	Thumb OA index (stress view) (n = 126)	
Other	7 (6.0%)	Mean $\pm$ SD	2.19 $\pm$ 0.58
Unknown	3 (2.6%)	Min	1.24
Hand dominance		Max	4.49
Right	109 (94.0%)	Thumb OA index (Robert's view) (n = 131)	
Left	4 (3.4%)	Mean $\pm$ SD	2.12 $\pm$ 0.58
Both (ambidextrous)	3 (2.6%)	Min	1.25
Unilateral surgery	95 (81.9%)	Max	4.05
Bilateral surgery	21 (18.1%)	Standardized pommel size (stress view)	
		Mean $\pm$ SD	9.96 $\pm$ 6.82
		Min	0
		Max	38.74
Unilateral		Standardized pommel size (Robert's view)	
Right	53 (55.8%)	Mean $\pm$ SD	9.00 $\pm$ 6.68
Left	42 (36.2%)	Min	0
Bilateral		Max	39.92
Right first	7 (6.0%)		
Left first	14 (12.1%)		
Unilateral			
Dominant hand	54 (46.6%)		
Nondominant hand	38 (32.8%)		
Ambidextrous	3 (2.6%)		
Bilateral			
Dominant hand	7 (6.0%)		
Nondominant hand	14 (12.1%)		

Note. OA = osteoarthritis.

and IV (Table 3). Among both Robert's and stress views, the ThOA index differed significantly between Eaton stage II and stage III or IV.

### Radiographic Measurements vs Eburnation

Preserved cartilage inversely correlated with Eaton staging, although largely comparable between stages III and IV (Figure 2c). Both pommel size and ThOA index correlated

significantly with preserved cartilage, although with moderate effect (Table 4). Supplemental Figure 1 depicts the relationships among pommel size, ThOA index, and preserved cartilage. Although distorted by floor effects, trapezia with less eburnation predominantly had smaller pommel size and ThOA index measurements. Notably, a more even spread was observed with ThOA index compared with pommel size, especially among trapezia with intermediate pommel size (between 5 and 20).

**Table 2.** Interrater Correlation Across Radiographic Views.

Feature	ICC	Lower 95%	Upper 95%
<b>Robert's view</b>			
ThOA index	0.66	0.59	0.71
ThOA index (<2)	0.60	0.43	0.74
ThOA index (>2)	0.60	0.45	0.73
Pommel width	0.53	0.39	0.64
Pommel height	0.63	0.34	0.78
Pommel size	0.67	0.43	0.80
Scaphoid base	0.74	0.60	0.82
Pommel size (standardized)	0.67	0.57	0.74
<b>Stress view</b>			
ThOA index	0.72	0.66	0.76
ThOA index (<2)	0.44	0.24	0.62
ThOA index (>2)	0.78	0.66	0.87
Pommel width	0.41	0.29	0.51
Pommel height	0.60	0.24	0.78
Pommel size	0.49	0.27	0.65
Scaphoid base	0.84	0.78	0.88
Pommel size (standardized)	0.60	0.22	0.78

Note. ICC = intraclass correlation; ThOA = thumb osteoarthritis.

### Radiographic Measurements vs Morphology

The distributions of pommel size and ThOA index also varied by morphology, with the largest values observed among dish morphology (Figure 3). The ThOA index varied more among morphologies compared with changes in pommel size, which was only statistically different between dish and saddle among both views (Table 4). The ThOA index was significantly different between cirque and saddle ( $P < .05$ ) and dish and saddle ( $P < .05$ ) when using Robert's views and between all 3 groups when using stress views ( $P < .05$  for each comparison). The relationship of all 3 is plotted in Supplemental Figure 2 and reveals a preponderance of retained saddle trapezia (shown in blue) among smaller or absent pommels and decreased ThOA index. The spread of both ThOA index and pommel size was greater for cirque and dish morphologies.

### Discussion

This study establishes that the trapezial pommel correlates to other metrics of disease progression and may serve as another radiographic feature for evaluating CMC OA progression. Its location correlates to a critical region of kinematics and loading in the normal and pathologic state, and thus structurally important in thumb pathomechanics.

The physiologic pommel is a tapered osseous extension that lies on the ulnar vertex of the central ridge of the saddle-shaped trapezial articular surface. The pommel is distinctly positioned to serve as a pivot along which the central ridge rotates in an ulnar-radial axis. Combined flexion/

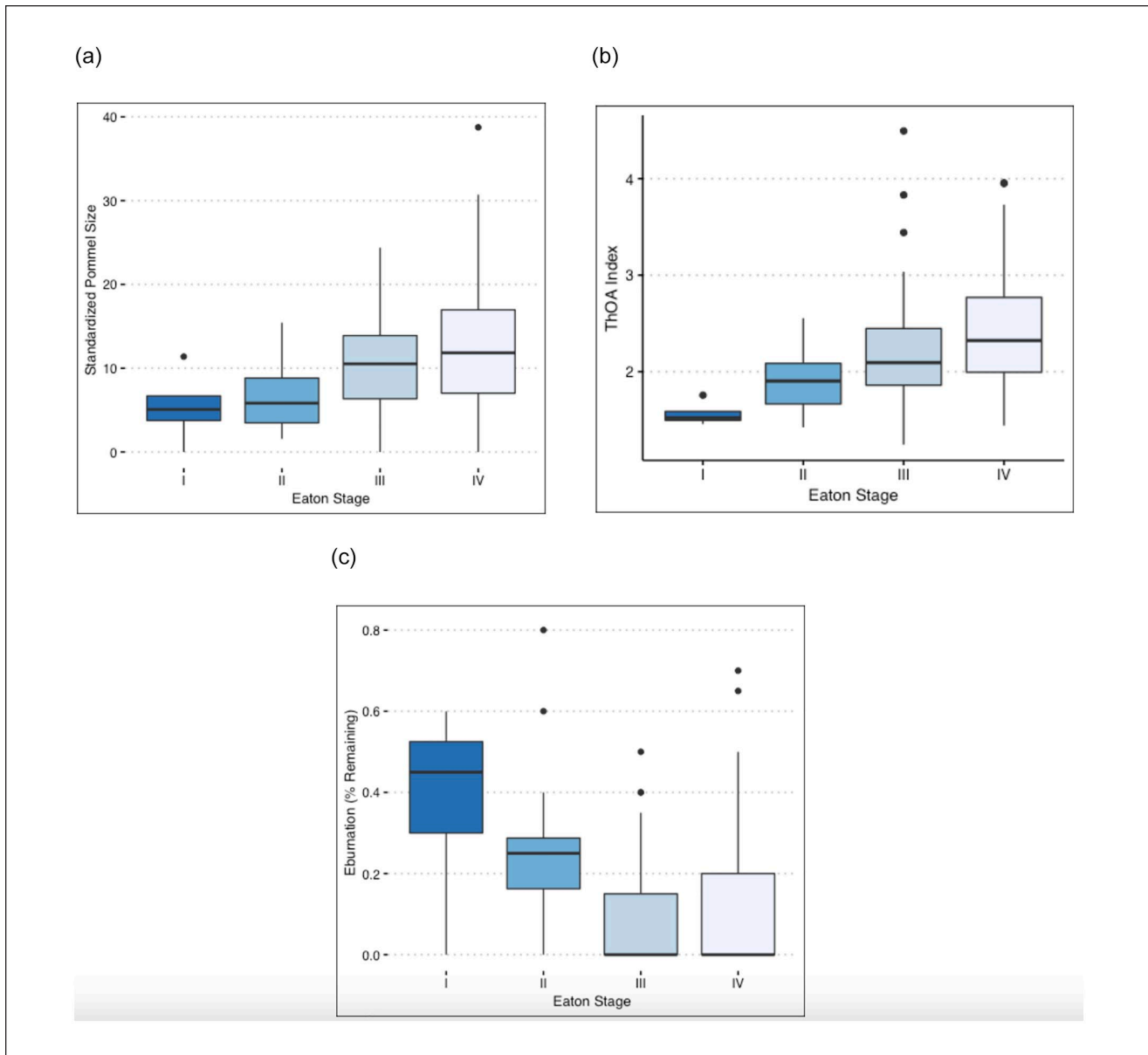
medial rotation and extension/lateral rotation is produced via rotation over the axis while thumb adduction and abduction generate torque along the axis itself.<sup>10</sup> Centrally compressive forces that contribute to CMC OA likely lead to the release of osseous material as an overhanging ulnar osteophyte that is commonly observed in end-stage disease. Indeed, others have observed that the osteophyte formation is greatest and earliest at the ulnar and radial margins of the trapezial facet.<sup>18</sup> The ulnar osteophytic protrusion not only reflects the particular strain that is endured by the pivotal point but is also significant as a stabilizing wedge between the first and second metacarpals.

We established that pommel size can be consistently measured with good intrarater reliability (correlation coefficient: 0.81-0.91), whereas interrater reliability was moderate for Robert's views (correlation coefficient: 0.66) and fair for stress views (correlation coefficient: 0.60). Within our data set, external validity varied with expertise. Correlation of pommel size improved when comparing measurements across surgeons with more than 20 years of practice: 0.87 for Robert's views and 0.68 for stress views. This performance largely exceeds that of Eaton staging, which has been shown to have poor interobserver reliability (correlation coefficient: 0.11-0.56).<sup>19</sup>

Although ThOA index has reached excellent intrarater reliability (correlation coefficient: 0.95) in the literature,<sup>12</sup> our study demonstrated slightly lower intrarater reliability (0.64 for Robert's views, 0.72 for stress views). It is possible that because ThOA index was a secondary radiographic endpoint compared to the pommel measurements, there was some degree of reader bias or fatigue that influenced the performance of ThOA index in our study.

Our analysis confirms that the pommel feature has a strong relationship with advanced osteoarthritic disease as measured by radiographic markers and patterns of wear. Correlations between pommel size and ThOA index reached statistical significance. This interaction is expected when considering that a prominent pommel that extends the trapezium laterally may simultaneously increase the ThOA index, which characterizes the width of the trapezium.

Both ThOA index and pommel size increased with advancing Eaton staging and significantly differed between Eaton stages II and IV across both views (Table 4). However, the ThOA index was additionally sensitive to differences between Eaton stages II and III using stress views, whereas pommel size was only significantly different between stages II and III when using Robert's views. This difference may be explained by the better vantage afforded by Robert's views for evaluating pommel size. Notably, although differentiating Eaton stage II and stage III is clinically valuable, neither measurement was significantly different between stages III and IV. This may be attributable to stage IV classification that involves extra-articular degeneration (eg, at the scaphotrapezium joint) that does not necessarily



**Figure 2.** Distribution of (a) pommel size, (b) ThOA index, and (c) preserved cartilage with increased Eaton staging on stress views. Note. ThOA = thumb osteoarthritis.

reflect degeneration at the first CMC joint and thus has poor relationship with ThOA index or pommel size that is directly related to the trapezial-metacarpal articulation.

Compared with pommel, the ThOA index had a slightly stronger interaction with eburnation, although both radiographic metrics were statistically significant across both radiographic views. By morphology, the ThOA index was more sensitive to differences beyond saddle versus dish, which was the only interaction distinguished by pommel size (Table 4). This suggests that the degenerative process involved with the dish pattern is directly linked with ulnar osteophyte formation at the pommel site.

Our study is limited in a number of ways. Evaluation of in vivo wear such as eburnation or trapezial morphology necessitated the investigation of explanted trapezia, and thus end-stage disease that warranted surgical intervention. Outside of 4 Eaton stage I specimens, the large majority do not reflect the full arc of disease progression that occurs gradually. To optimize the sample size and data collection, some subjects who underwent bilateral surgeries were included; however, confounding biologic or environmental considerations in these instances may introduce bias into our study. In addition, because some metrics such as eburnation or topography were evaluated by a single expert

**Table 3.** Comparisons of Pommel Size and ThOA Index by Eaton Staging.

Radiographic view		Standardized pommel size		ThOA Index	
		Difference	P value	Difference	P value
Robert's view	Eaton staging				
	I vs II	-0.9	.993	0.2	.938
	I vs III	3.6	.694	0.5	.268
	I vs IV	5.4	.367	0.8	.040*
	II vs III	4.5	.008*	0.3	.021*
	II vs IV	6.3	<.001*	0.6	<.001*
	III vs IV	1.8	0.517	0.3	.118
		Difference	P value	Difference	P value
Stress view	Eaton staging				
	I vs II	1.2	.985	0.3	.659
	I vs III	4.7	.499	0.7	.093
	I vs IV	7.8	.104	0.9	.011*
	II vs III	3.5	.086	0.3	.043*
	II vs IV	6.6	<.001*	0.6	<.001*
	III vs IV	3.1	0.110	0.2	.155

Note. ThOA = thumb osteoarthritis.

\*denotes statistically significant difference with p-value < 0.05.

**Table 4.** Relationships Between Pommel Size and ThOA Index Versus Cartilage Preservation and Shape.

		Standardized pommel size		ThOA index	
		Coefficient or difference	P value	Coefficient or difference	P value
Robert's views	Preserved cartilage	-0.27	.002*	-0.41	<.001*
	Shape				
	Cirque vs fish	-1.1	.755	-0.2	.189
	Cirque vs saddle	2.6	.114	0.3	.005*
	Dish vs saddle	3.7	.041*	0.6	<.001*
		Coefficient or difference	P value	Coefficient or difference	P value
Stress views	Preserved cartilage	-0.30	<.001*	-0.43	<.001*
	Shape				
	Cirque vs dish	-3.5	.059	-0.3	.032*
	Cirque vs saddle	1.8	.374	0.4	.001*
	Dish vs saddle	5.3	.002*	0.7	<.001*

Note. ThOA = thumb osteoarthritis.

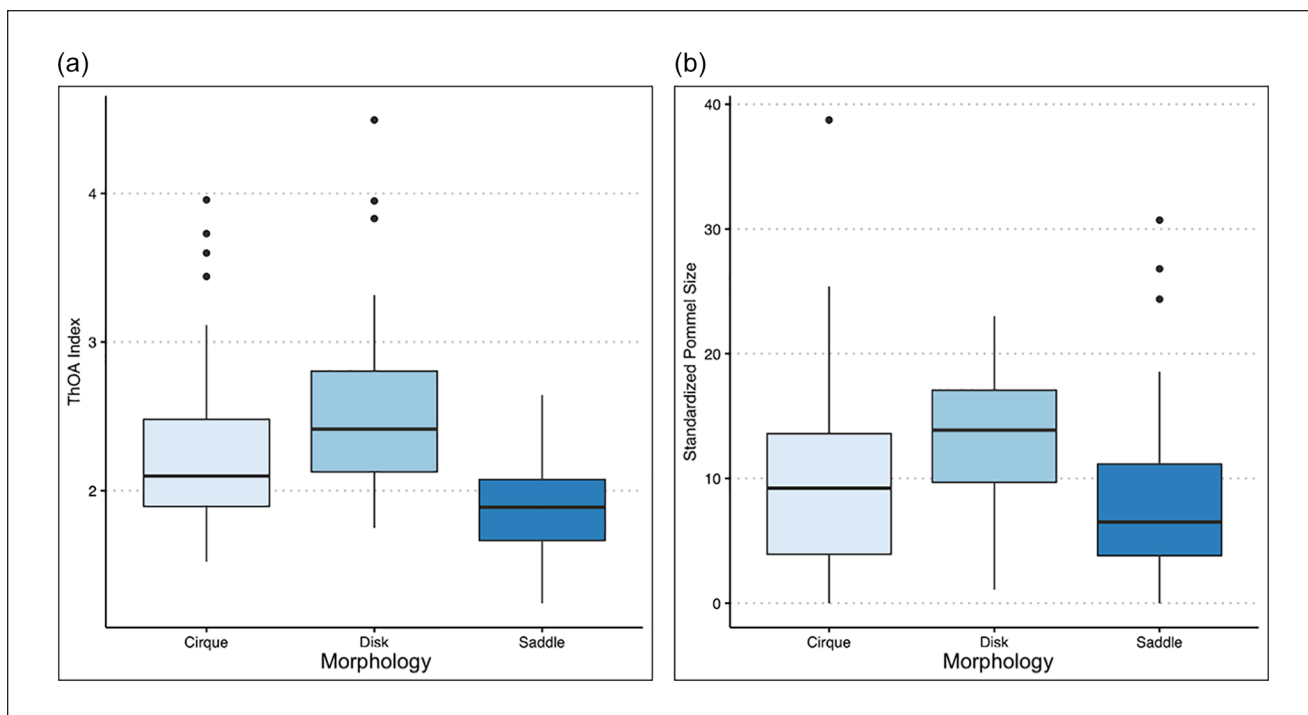
\*Denotes statistically significant difference with p-value < 0.05.

reviewer with surgical team consensus, it is possible that these results may differ between observers, especially as they are visually assessed and lack objective quantifiable measuring techniques. Finally, the moderate reliability of pommel size and ThOA index suggests that these metrics may require further standardization to be employed more broadly.

In summary, we demonstrated that a reliable quantification of pommel size significantly correlated with other radiographic and biomechanical measures of CMC OA.

Specifically, we established a strong relationship between pommel size and dish morphology. Future prospective studies are required to evaluate whether the pommel feature precedes and predisposes to osteoarthritic disease or whether it emerges through the evolution of osteoarthritic changes in late-stage disease. This would inform further understanding of potentially bidirectional interactions between pommel form and hand kinematics. For example, the pommel feature may affect kinematic forces that drive biomechanical wear patterns or osteophyte formation that ultimately incur





**Figure 3.** Distributions of (a) ThOA and (b) pommel size across trapezial morphology using stress views.  
 Note. ThOA = thumb osteoarthritis.

symptoms or functional impairment. If future studies demonstrate a correlation between pommel size and biomechanical drivers for disease progression, this may provide a framework for designing early diagnosis and treatment intervention.

### Ethical Approval

This study was approved by our institutional review board.

### Statement of Human and Animal Rights

The study was conducted in compliance with institutional review board–approved protocol.

### Statement of Informed Consent

Informed consent was obtained for all study subjects in accordance with institutional review board protocol.

### Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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