The Changing Shape of Empire: A GM Study of Chimú Bottles in Museum Collections

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After centuries of looting along Peru’s North Coast, archaeologists acknowledge that the pottery of the Chimú Empire is one of the most collected Andean artifacts, but also one of the most poorly understood. Much of the enduring classificatory uncertainty comes from the problematic provenance of most Chimú vessels, and the fact that the distinctive blackware identified as Chimú represents the production of workshops from across an extensive area, during periods of regional political decentralization (c. 900-1200 CE), imperial growth (c. 1200-1450), and foreign conquest by the Inca (c. 1450-1535) and Spanish (after 1532) empires. This chapter builds on previous seriations and field observations, using geometric morphometric analysis of a sample of 3D-scanned Chimú bottles from publicly held collections at the University of Texas (Austin) and the American Museum of Natural History. Since Chimú bottles were formed in workshops using molds, variations in vessel shape can serve as indicators of variable practices. We compare a sample of common Chimú blackware bottles with a sample of “Inca-Chimú” vessels that carry features typical of the short Inca occupation of the North Coast. Differences between the two samples offer new lines of evidence that can guide more precise classifications of these vessels, as well as new interpretations of the imperial history of Peru’s North Coast.

The Collecting History of an Imperial Ware

The distinctive blackware pottery of the Chimú Empire of Peru’s north coast is one of the most intensively collected styles, but also one of the least-defined. Thousands of well-preserved vessels occupy the shelves of museums in South America, North America, and Europe, from the vast collections of famous institutions like Berlin’s Ethnologisches Museum to local museums that possess a single vessel of unknown provenance. It is impossible to know when Europeans first began to collect Chimú blackwares, although published illustrations date back as far as the early eighteenth century (Frézier 1716). By that time, Spaniards had already been plundering Peru’s coastal *huacas* for nearly two centuries, mining them to extract the gold and silver found in rich burials. Nineteenth-century collecting shifted the emphasis of collection toward well-preserved human crania that could be used to buttress European beliefs in their own racial superiority, and Chimú ceramics (and other artifacts) were caught up in the new collecting regime as public museums grew in the global North (e.g., Hrdliča 1914:50-51). By the early twentieth century, large numbers of unauthorized diggers were working full-time excavating tombs at Chan Chan (Kroeber 1926:15), and Chimú pottery could be purchased from shops in the Peruvian city of Trujillo. Beuchat (1918:570) noted at that time that the blackware vessels of Peru’s north coast were already “very well represented in most ethnographic collections.”[[1]](#footnote-1) Since then, coastal blackwares have continued to be excavated and trafficked by illicit diggers who target more valuable metal artifacts and polychrome textiles (e.g., Atwood 2004), and today they can be readily found at internet auction sites for modest prices.

The history surrounding the collection of Chimú blackwares helps to explain why this ubiquitous artifact class remains poorly understood by professional archaeologists. When viewed as a byproduct of other collecting activities that unfolded over almost a half millennium, the Chimú ceramic corpus fragments into a fragile assemblage of orphaned objects. Almost all Chimú vessels lack a detailed archaeological provenience, and the chain of ownership for most museum pieces can rarely be traced back to Peru. Because most “Chimú” vessels cannot be affiliated to a particular context in coastal Peru, their identification derives from their stylistic attributes, even though some of the earliest Chimú ceramics documented in archaeological excavations appeared at the creation shrine of Pachacamac, hundreds of kilometers to the south of the political control of the Chimú Empire (Uhle 1902:756).

This contextual ambiguity intersects with a classificatory problem for Andean archaeology. Many treat “Chimú” pottery as typical of the Late Intermediate Period (c. 900-1476) on the north coast of Peru, a huge and undifferentiated period during which the Chimú polity established its capital and local dominion in the Moche Valley, carried out multiple waves of imperial expansion to the north and south, and fell under the hegemony of Inca imperial rule (1476-1532). Excavators have noted that similar blackwares continued to be produced during the half century of Inca rule, and into the earliest years of the Spanish colonial period. Without knowing when and where a particular museum object comes from, archaeologists have faced difficulties in subdividing “Chimú” pottery into phases and substyles, which would enable researchers to study changes and variations within the overall assemblage.

Early Archaeological Classifications

From early on, classifications of Chimú ceramics focused on vessel attributes. Beuchat (1918:652-654) noted that coastal tombs had yielded “infinite” formal variations of blackware pots now found in museum collections. He placed these into five principal categories: (1) globular vessels with rectangular fields of low-relief decoration; (2) geometric vessels (cuboid, ellipsoids, ovular); (3) phytoform vessels shaped like squash or fruits; (4) zoomorphic vessels representing a broad range of fauna; and (5) anthropomorphic vessels. This classification emphasized aesthetic characteristics of vessel shape, rather than the kinds of formal and functional differences seen in later typologies, and Beuchat acknowledged the diversity found within each of his categories, especially the phytomorphic, zoomorphic, and anthropomorphic vessels. Without any provenience information to guide his analysis, Beuchat did not attempt to seriate Chimú pottery or to distinguish regional variations.

In 1926, Alfred Kroeber made the first concerted effort to describe different phases of Chimú ceramic production, based on a brief visit to the Trujillo area that he made as part of a Field Museum expedition to the central coast. Kroeber noted previous efforts by Uhle (1902) to differentiate between early and late ceramics from Trujillo, which could be tied to the Moche site of Huaca de la Luna/Huaca del Sol, and the Chimú capital of Chan Chan. Kroeber used the term “Late Chimú” to refer to Trujillo area blackwares that sometimes were found with Inca ceramics, a designation that encompasses Late Intermediate Period (c. 900-1400s), Inca (1400s-1530s) and some early Colonial pottery. Based on provenance information that identified the district where some Late Chimú vessels originated, Kroeber (1926:11) identified a broad distribution that stretched from Piura to Casma, with some vessels found as far south as the Nasca drainage. To build a typology and sequence of Late Chimú vessels, he studied the pottery from several collections that he purchased in Trujillo on behalf of the Field Museum.

Kroeber’s shape typology for Late Chimú vessels discusses vessels that were common in Moche and Chimú assemblages, and he lists (1926:22) about a dozen Late Chimú shapes, including stirrup-mouth vessels, double jars, double-spout vessels, head-and-spout vessels, figure-and-spout vessels, globular bowls, lipped pots (with and without handles), jars with flaring mouth, flat-handled jars, and jars with tapering spouts. The list of shapes also includes Inca narrow-mouth jars (*“aryballus*”) and cups (“*kero*”) in the Late Chimú assemblage. In his discussion of Late Chimú blackware, Kroeber recorded the relative abundance of the most common shapes found in two private collections that he saw while visiting Trujillo. The Mansiche and Jacoms collections comprised more than 200 vessels, but Kroeber estimated that hundreds of utilitarian pots, plates, and jars had been “rejected” by the collectors when purchasing vessels from the *huaqueros* who excavated them near Chan Chan. In his decorative analysis of vessels in private collections, Kroeber (27-28) identified the “face vase” and “rotund figure jar” as additional shapes found in the assemblage.

In his study of collected ceramics from Trujillo, Kroeber established the outline of a shape typology for Chimú blackware vessels, although it was not a comprehensive representation of ceramics in use on the north coast during the periods of Chimú, Inca, and Spanish imperial expansion. Building on the earlier observations of the high degree of diversity seen in Chimú blackwares, Kroeber made some important observations that inform subsequent studies. First, this pottery is widely distributed along the north coast of Peru, although Kroeber (1930:97) argued for strong continuity between regions, which would suggest that regional variations account for little of the overall diversity in the Chimú assemblage. Second, he noted that blackwares are strongly associated with mortuary contexts, and such pottery is not commonly seen on the surface of the urban core of Chan Chan. Such vessels are thus more indicative of Chimú funerary practices than everyday life. Finally, Kroeber described how the private collections that local agents assembled and sold to museums were already curated in a way that eliminated certain vessel shapes, so that museum collections cannot be considered representative of the original mortuary assemblage. As Kroeber noted (1930:95) in a later visit to the north coast, one Trujillo collector “refused to purchase from the *huaqueros* most of the unhandled jars, exceptions being made in favor of effigy pieces, or occasional plain ones when several vessels were bought in a lot in order to acquire one or two attractive ones.”

Attempts at Seriation

In the years following Kroeber’s work, analysis of Chimú ceramics continued to be oriented around the integration of regional Andean sequences, and the pottery of the Chimú Empire continued to be discussed alongside Moche ceramics that were considered to be Early Chimú (e.g., Bennett 1937; Willey 1945). It was not until the 1960s that a concerted effort was made to move beyond the master sequence, to developed a more fine-grained description of the assemblage associated with the Chimú Empire as it developed, expanded, and fell under Inca and Spanish dominion. In 1966, Harry Scheele and Thomas Patterson published a “preliminary seriation” of Chimú ceramics. They noted (1966:15) that one reason that so little work had been done to classify such material was its abundance: “probably no other pottery style from the Americas is so well represented on the shelves of museums and private collectors throughout the world.

As noted already, this prevalence was remarked on almost 50 years earlier, the result of large-scale collections acquisitions that major museums had engaged in since the late 1800s (e.g., Květinová 2011:65-66). But Chimú pottery continued to flow into established museum collections, and to be sought as new museums were established (see Mowat 1988 for an example of donation and accessioning practices). Collection-building accelerated after World War II—an estimated 95% of the world’s museums were founded after 1945 (Lowenthal 1998:3)—and continued with limited constraints until after 1970, when the UNESCO Convention regarding cultural property established guidelines that gradually altered legal standards and ethical practices surrounding collecting (Gerstenblith 2013). Although some museums continued to send curators to Peru to purchase from antiquities dealers, a cursory review reveals that many of these vessels came as gifts from individual donors, who provided little or no provenance information. For example, the Metropolitan Museum of Art received a feline bottle (64.228.17) from Nathan Cummings in 1964, who had purchased the vessel a decade earlier from a collector in Buenos Aires.[[2]](#footnote-2) The piece was one of more than 1000 artifacts that Cummings is credited with donating to the museum. The Cleveland Museum of Art, founded in 1913, also built its collections through donations, including a blackware jar (1959.333) given by William Ellery Greene in 1959.[[3]](#footnote-3) It was the only Andean artifact given to the museum by the donor.

Building on preliminary work by Pedro Rojas Ponce and Dorothy Menzel, Sheele and Patterson (1966) compared illustrations from the published literature with vessels from Peru’s Museo Nacional de Antropología y Arqueología and Harvard University’s Peabody Museum of Archaeology and Ethnology. They created a preliminary seriation of Chimú ceramics from the end of the Middle Horizon to the early Colonial Period, distinguishing seven different phases based on the identification of different vessel shapes, decorative elements, and firing characteristics. Although the seriation was developed to build a more fine-grained relative chronology, the small sample sizes of some phases presented interpretive challenges. For example, the fourth phase “Lambayeque,” was based on seven vessels from a single grave in the Lambayeque Valley, located approximately 175 km to the north, and probably reflects regional ceramic diversity more than a distinct period of Chimú production in the Moche Valley. Other phases were based on small sample sizes and vessels with limited provenance information. One important distinction in the Scheele and Patterson seriation was between Chimú ceramics of the late LIP (Chimu Phase T-1) and those from the time of the Inca occupation (Chimu Phase T-2). The former was defined based on the prevalence of stirrup-spout vessels and the “less carefully made” production of mold-produced vessels that seem to represent a more restricted set of shapes than the preceding phase (Trujillo Phase T-2). The Chimú-Inca phase maintained elements of existing ceramic production, adding features from Inca vessel shapes. Scheele and Patterson note (1966:24) that this phase seems to be distributed beyond earlier Chimu political boundaries and economic networks—it has been identified on the south and central coast and in the Cuzco region. Overall, Scheele and Patterson’s work clarifies how some vessel shapes developed over time, making it possible to assign provenienced gravelots to more specific late prehispanic periods. It also identified some important aspects of production practices and hybridity that have been important for subsequent archaeological fieldwork.

Field Archaeology and the Reconstruction of Production Practices

Although the first attempts at defining Chimú ceramics within a broader north coast sequence utilized museum collections, archaeological excavations have increasingly contributed to the reconstruction of ceramic production practices. In the mid-20th century, excavators turned to cemeteries as a source of well-provenienced vessels that could be used to elaborate the regional sequence (e.g., Collier 1955; Willey 1947). Such work represented only a miniscule proportion of Chimú ceramics that were being dug up at that time, most of which were acquired by *huaqueros* whose illicit work supplied private collectors and museums around the world. Studies of whole vessels concluded that the use of molds increased in late prehispanic periods on the north coast (Collier 1955), and by the 1960s, some researchers had identified molds and matrices in the pottery collections acquired by some museums (e.g., Grossman 1969-1970; Thompson 1963). Such work constituted an important step toward moving from straightforward aesthetic considerations to questions about the production and consumption of Chimú ceramics, but it remained rooted in mortuary collections that did not focus on evidence of production practices.

At the end of the 1960s, Moseley and Mackey’s Chan Chan-Moche Valley Project (1969-1975) began to increase the intensity of professional archaeological research, with regional survey work in the lower Moche Valley and mapping and excavations at Chan Chan and other nearby sites. While not focused on cemetery sites, this project and related studies encountered additional mortuary contexts with well-preserved ceramics (see Donnan and Mackey 1978). It was not until the 1990s, however, that archaeologists began to identify loci of ceramic production based on the presence of overfired sherds, molds and matrices, stamps, tools, kilns, and other evidence (Donnan 1997; Hayashida 1999; Mackey 2003; Mackey and Sapp 2021; Tschauner 2006, 2009). Some of the workshops were in use during the Inca occupation of the north coast, although others reflect ceramic production practices during the preceding era of Chimú imperial expansion. Surface collections and excavations in production areas produced multiple lines of material evidence, including large numbers of potsherds that could not easily be assigned to the diverse array of shapes identified in collection-based classifications.

The study of Chimú and Chimú-Inca pottery workshops has focused on two central themes: specialization and cultural (dis)continuity under foreign rule. These issues were nascent in many of the earlier collection-based studies, but the careful excavation and analysis of production contexts added invaluable evidence to the discussion. Molds and matrices encountered at workshops indicate that multiple vessel parts were mass-produced and had to be assembled following a specific sequence, which Tschauner (2006:179) interprets as evidence of specialized production during Chimú times. Tschauner’s excavations at the Pampa de Burros workshop in the Lambayeque Valley identified heavy use of vertical half-molds to produce jars, canteens or flasks, bottles, and ollas—virtually all of the shapes that were used by Chimú-era settlements in the surrounding valley (2006:182). He sees the local potters as relatively unskilled producers who relied on more adept makers of ceramic molds, and whose “market-oriented” work could flexibly adapt to consumer preferences (2006:183-185). Levine (2011) builds on this idea, noting that some of the extreme variability seen in the Chimú assemblage could come from ceramic producers “mixing and matching” molds for different vessel parts and adornments to produce new combinations.

For the Inca period, scholars acknowledge a degree of continuity in local potting practices, but also some significant changes. At Tambo Real and La Viña in the Leche Valley, Hayashida (1999) notes the continuity of local practices for shaping vessels (press molds, paddle and anvil) and firing. While local jar shapes persisted in Inca times, she notes the presence of a mold for an Inca flared jar neck (1999:345), which could be added to jars that were shaped using local press molds. Overall, Hayashida sees little evidence of Inca “retraining” of Chimú potters.

Other Inca-Chimú workshops in the Jequetepeque Valley provide evidence that practices varied at different production locations. Donnan’s (1997:32-35) surface collections at Cañoncillo encountered dozens of mold fragments, most of which were for shaping the bottom and top hemispheres of *ollas*. Donnan identified molds for shaping jars along a vertical axis, and for producing bottles, including the distinctive Inca “aryballoid” shape. Although he reports that no molds appeared for shaping handles or rims, there were molds for producing stirrup spouts, as well as for humans, birds, and other animals. The production evidence from this site suggests that while some vessels were largely shaped using molds, some elements were hand-formed and showed variations suggesting the work of multiple potters. At the administrative center of Farfán, Mackey (2004:336-338) excavated a small workshop that produced large jars (*tinajas*) for brewing or storage, using the paddle-and-anvil technique. Finally, the excavation of three workshop patios at El Algarrobal de Moro, a lower-order Chimú administrative center, encountered 25 mold fragments, including molds for a stirrup spout vessel and a miniature jar (Mackey and Sapp 2021:21-22).

Technological Approaches to Chimú Ceramics

The accumulation of excavation assemblages with Chimú blackwares occurred as archaeologists developed new approaches to the study of ancient pottery. Archaeologists often find it difficult to map the shape-based categorizations developed from whole vessels in museum collections onto the broken fragments they encounter in excavation contexts other than tombs. Middens and house floors often generate an assemblage that is not fully represented in the corpus of collected vessels, which is biased toward mortuary offerings and shaped by the aesthetic values of dealers and collectors. Field researchers have used stylistic approaches to assign rough dates from the relative sequence, but the anthropological analysis of excavated pottery has inspired archaeological ceramicists to focus on the social practices underlying the production, distribution, use, and discard of pottery. The shift from style to technology has coincided with the introduction of methods to study the composition of clays, tempers, and pigments used for produce archaeological ceramics.

Given the acknowledged challenges in classifying Chimú vessels, it is not surprising that recent ceramic studies have embraced technological analyses, including petrography (Krzanowski and Pawilowski 1980), neutron activation, X-ray diffraction, X-ray fluorescence, particle-induced X-ray emission (Cunha Lima 2010), and Mössbauer spectroscopy (Tschauner and Wagner 2003). Shimada and Wagner (2019) note, the reconstruction of the *chaîne opératoire* for north coast blackwares remains incomplete. It should be noted that many of the techniques used to reconstruct production practices are amenable to using with fragments of pottery that can be removed to the laboratory, and potentially altered or destroyed in the process of analysis. More recently, researchers have brought non-destructive techniques such as CT scans (Wauters 2016) and linear morphometric analysis (Květinová 2011) to the study of museum collections. This work emphasizes the variability found in different vessel categories, as well as the reconstruction of productive processes, including the use of molds to manufacture vessel bodies and other elements.

3D Scanning and Geometric Morphometrics Analysis of Chimú Pottery

After a century of classifying Chimú ceramics and reconstructing their production and social uses, archaeologists have yet to bring order to the “infinite” diversity of the museum assemblage, but they have developed important questions for empirical analysis. Rather than attempting to fit Chimú vessels into a neat taxonomy, researchers have drawn attention to the different factors influencing diversity in late prehispanic blackwares. Blackware ceramics were produced over several centuries and across a broad stretch of the north coast, and a significant degree of variation comes from the practices of individual potters at different workshops, who were producing different vessels to meet the changing aesthetic tastes of coastal consumers. There appear to have been differences in the organization of pottery workshops, and some producers relied more on the use of molds and matrices than others. It is not presently clear who designed and produced molds and matrices, or how broadly used and consistently replicated such production templates were. A fine-grained three-dimensional study of vessel bodies and key elements known to have been molded in some instances (e.g., stirrup spouts) could quantify the amount of variation seen in well-preserved vessels, contributing to the discussion of how hierarchical and centralized Chimú ceramic production was beyond the local workshop.

Previous analyses have also noted variable degrees of continuity and change seen in the production of ceramics during the period of Inca hegemony on the north coast. Local potters continued to produce blackwares using many of the same techniques and tools, but they also incorporated new vessel shapes and elements (e.g., flaring jar rims) that were distinctly Inca. Chimú-Inca pottery is often classified qualitatively, but a quantitative analysis of Inca vessel features that appear on such pottery would make it possible to address questions of hybridity, including the degree of foreign influence and the potential resistance of potters working in specific workshops to provide pottery for populations that experienced Inca imperial dominance in different ways.

These two questions can be addressed using three-dimensional data from well-preserved vessels, an approach that presents logistical challenges. To date, Wauters (2016) has used CT scans and X-ray radiography to study 16 stirrup-spout bottles from the Royal Museums of Art and History of Brussels and the Ethnography Museum of Geneva. To produce the scans, the vessels had to be removed from the museums and transferred to hospitals where the necessary equipment could be accessed. While generating high-resolution data, funding constraints and ethical considerations would make it difficult to conduct such research with large sample sizes. As an alternative, portable high-resolution 3D scanning equipment can be brought into museums to scan collections *in situ*, using the resulting data for geometric morphometric analysis. Between 2018 and 2020, we conducted exploratory research on Chimú ceramics in two collections using this approach.

Collections and Research Ethics

For our exploratory study, we scanned vessels from two collections that reflect the broader history of collecting and curating Chimú ceramics. Our first collection was the Art and Art History Collection (AAHC), a small “orphan” collection given to the University of Texas at Austin by several individuals donors who provided little or no provenance information. The ancient pottery in the AAHC was previously curated by the Texas Memorial Museum, which transferred them to the department of Art and Art History in 2004 as the museum implemented new curatorial priorities. [How many Andean vessels, how much Chimú?]

The second collection was a curatorial acquisition from the early days of museum collecting. The Bandelier Collection at the American Museum of Natural History consists of nearly 8,000 Andean artifacts from Peru and Bolivia. The Swiss-American archaeologist Adolph Bandelier acquired these pieces as part of his 1890s Andean expedition, which was initially funded by Henry Villard. Bandelier visited the Trujillo area in 1893, where he sketched the ruins of Chan Chan and acquired several hundred Chimú vessels and other artifacts that were accessioned by the museum. Although the records of Bandelier’s expedition remain unpublished, the collection offers a large sample size of vessels that were collected at the same time, during a period of archaeological collecting when dealers were less attuned to the targeted collecting that Kroeber observed a generation later. [More on this collection?]

Methods and Results

Vessels were scanned with a Creaform GoSCAN 20 at a 0.5mm resolution in VXelements. Scanner calibration was optimized prior to each scan, with positioning targets required for increased accuracy, and shutter speed reconfigured in each scanning instance. Clipping planes were established to reduce the amount of superfluous data collected, and the final mesh was rendered following application of the clean mesh function in VXelements. This process removed isolated patches, self-intersections, spikes, small holes, singular vertices, creased edges, narrow triangles, outcropping triangles, narrow bridges, and non-manifold triangles prior to export as an ASCII stl file. The stl was subsequently imported to R where each mesh was subjected to an automated post-processing routine using the Rvcg package to detect and correct any abnormal poly-faces in advance of performing a global remesh to improve mesh quality (Schlager 2017). The final meshes were then imported to Geomagic Design X (Dx) for landmarking.

*Landmarks and semilandmarks*

A total of seven landmarks and 38 semilandmarks segregate each bottle into three discrete components corresponding with the rim/neck, belly, and base. Landmarks and semilandmarks were populated along a spline across the vessel profile that included no/minimal abstraction/s associated with sculptural elements. Application of landmarks and semilandmarks began on the side of the vessel profile determined to include the widest point, calculated using a series of measurements from the reference vector. Each component was isolated using a series of spline splits, where landmarks were later placed followed by a series of equidistant semilandmarks. Spline splits occur at the horizontal tangent at the rim, the point of highest curvature at the intersection of the neck and belly, the point of highest curvature at the intersection of the belly and base, and at the only intersection of the reference vector and spline at the center of the base. The constellation of landmarks and equidistant semilandmarks used in this study draws influence from the characteristic points and tangents employed in the study of aesthetic measure by Birkhoff (1933), as well as a selection of studies that followed (e.g., Denkowska et al. 1994; Staudek 1999).

*Analysis*

Landmarks and equidistant semilandmarks were exported as x, y, and z coordinate data from Dx. Those data were aligned to a global coordinate system (Kendall 1981, 1984; Slice 2001), achieved through generalized Procrustes superimposition (Rohlf and Slice 1990) performed in R 4.1.2 (R Development Core Team 2022) using the geomorph library v.4.0.1 (Adams et al. 2018; Adams and Otárola-Castillo 2013). Procrustes superimposition translates, scales, and rotates the coordinate data to allow for comparisons among objects (Gower 1975; Rohlf and Slice 1990). The geomorph package uses a partial Procrustes superimposition that projects the aligned specimens into tangent space subsequent to alignment in preparation for the use of multivariate methods that assume linear space (Rohlf 1999; Slice 2001). The mean consensus configuration and Procrustes residuals were calculated using a generalized Procrustes analysis (GPA). This initial view of the data demonstrates the degree of variability in the aggregated sample of Caddo bottles. As an exploratory measure, GM methods—to include GPA—aid in clarifying shape differences as well as the production of novel *a posteriori* hypotheses (Mitteroecker and Gunz 2009).

Principal components analysis (Jolliffee 2002) was used as an exploratory means of visualizing shape variation among the vessels. The shape changes described by each principal axis are commonly visualized using thin-plate spline warping of a reference 3D mesh (Klingenberg 2013; Sherratt et al. 2014). Principal components analysis (PCA) was conducted on scaled, translated, and rotated landmarks and semilandmarks, and demonstrates that the first two PC’s account for 55 (PC1) and 25 (PC2) percent of the variation in bottle shape, with each remaining PC representing eight or fewer percent of the variation. The first two PCs are plotted in Figure XX, where warp grids represent the shape changes that occur in PC1 and PC2.

A residual randomization permutation procedure (RRPP; n=10,000 permutations) was used for all Procrustes ANOVAs (Adams and Collyer 2015; Collyer and Adams 2018), which has higher statistical power and a greater ability to identify patterns in the data should they be present (Anderson and Ter Braak 2003). To assess whether shape differs by size (allometry) and site, Procrustes ANOVAs (Goodall 1991) were run that enlist effect-sizes (z-scores) computed as standard deviates of the generated sampling distributions (Collyer et al. 2015). A Procrustes ANOVA was also run to assess whether shape changes with size. The assumption of allometric slope homogeneity was tested with the procD.allometry function using the PredLine option (Adams and Nistri 2010). Should this test not yield a significant result, then allometric slopes are similar--if not identical--across the categories used in the analysis.

A Procrustes ANOVA was used to test for significant allometry. Results of the ANOVA indicate that allometry is significant (RRPP=10,000, Rsq=0.17594, Pr(>F) = 1e-04), meaning that vessel shapes vary significantly with size. Plots of predicted allometric trajectories for bottles and jars are presented in Figure XX. The null hypothesis of parallel slopes is rejected by the homogeneity of slopes test for group allometries (RRPP=10,000, Rsq=0.04251, Pr(>F) = 0.0038). A second Procrustes ANOVA was used to test for a significant difference in bottle shape by group (RRPP=10,000, Rsq=0.32574, Pr(>F) = 1e-04). The test for morphological disparity of shape did not yield significant results; however, the test of morphological disparity by size did prove to be significant.

Discussion

Conclusions

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1. “…muy bien representada en la mayor parte de las colecciones etnográficas.” At that time, collectors tended to use “Chimú” to refer to Trujillo-area ceramics from the Early Intermediate Period up to the time of the European invasion. [↑](#footnote-ref-1)
2. <https://www.metmuseum.org/art/collection/> [↑](#footnote-ref-2)
3. <https://www.clevelandart.org/art/1959.333> [↑](#footnote-ref-3)