Obelionic Cranial Deformation in the Puebloan Southwest

Greg C. Nelson* and Felicia C. Madimenos

Department of Anthropology, University of Oregon, Eugene, OR 97403-1218

KEY WORDS Gallina; New Mexico; Ancestral Pueblo

ABSTRACT As a form of cranial deformation, obelionic flattening is rare. Originally named and described by Stewart (J Wash Acad Sci 29 (1939) 460–465), based on a small sample from Florida, it has been little noted since. Previously [Nelson and Madimenos, Paper presented at the Paleopathology Association annual meeting (2007)], we reported the discovery of two individuals from the Pueblo III Gallina site of Cañada Simon I who exhibit flattening of this type. Although technically undescribed in the Southwest before now, there are tantalizing clues in the literature that it occurred in low frequencies throughout the Ancestral Pueblo world. To determine whether the obelionic flattening found at Cañada Simon I was isolated or an indication of a more widespread phenomenon, we undertook a survey of crania from other Gallina sites, Chaco Canyon, and the literature (type of deformation can be determined on lateral photographs of crania properly positioned along the Frankfort Horizontal). We examined 146 crania (78 firsthand) of which seven exhibit obelionic flattening. Our results indicate that obelionic flattening should be added to the suite of cranial deformations that occur in the Southwest. Here, we propose parameters by which obelionic flattening can be described and differentiated from the more common lambdoidal and occipital forms and suggest that the three types of flattening form a continuum of cradleboard induced deformation, although the exact mechanism for obelionic flattening remains elusive. Am J Phys Anthropol 143:465–472, 2010.

Cranial deformation is ubiquitous among Ancestral Puebloan peoples and has been noted since the first skeletal material was unearthed in the middle to late-19th century. Traditionally, based on morphological aspects such as angle of flattening relative to the Frankfort Horizontal and anatomical landmarks nearest the center of the flattened area, two types are generally recognized, occipital and lambdoidal. Previously, we announced the discovery of an apparent third form, obelionic flattening, among individuals recovered from the Pueblo III Gallina phase site of Cañada Simon I (Nelson and Madimenos, 2007). To determine if obelionic flattening extends beyond this single site and whether it should truly be considered a third form of cranial deformation in the American Southwest, we undertook a survey of additional Ancestral Puebloan crania. Our findings suggest that obelionic flattening is morphologically distinct enough from the other forms to qualify as a separate entity and does represent a third discernable type of cranial deformation found among the Ancestral Puebloan peoples. Here, we present our findings, propose parameters by which obelionic flattening can be defined, and introduce revised and updated descriptions for occipital and lambdoidal deformation, which more clearly differentiate the three types.

CRANIAL DEFORMATION IN THE PUEBLOAN SOUTHWEST

As an artifact of cradling, Ancestral Puebloan cranial deformation is generally considered a post-Basketmaker (after 750 AD, Reed, 2000) phenomenon (Reed, 1949). During the succeeding Pueblo I–III periods (750–1,300 AD), lambdoidal deformation predominates and appears in ~90% of crania with the remainder split between individuals exhibiting occipital or no deformation. Beginning with Pueblo IV, occipital deformation replaces lambdoidal at ~90% of deformations with the remaining 10% made up of lambdoidal or no deformation (Stewart, 1937; Kamp, 2002) and continues into the historic period (Hrdliîcka, 1908).

The earliest Euro-American records of deformation in Ancestral Puebloan skeletal material from the Southwest are contained in reports deriving from the United States Geological and Geographical Surveys of 1872–1876. The first is that of Bessels (1876) who describes three skulls with deformation, one from Hovenweep, Colorado and two from the area around Abiquiu, New Mexico. Additionally, two other skulls from near Abiquiu (Severance and Yarrow, 1879) and one from Chaco Canyon (Hoffman, 1878) are noted as exhibiting deformation of the posterior portion of the cranium. Following these brief descriptions, the first comprehensive treatment of a Puebloan skeletal series is that of Retzius (1893) in which he describes 10 individuals recovered by Nordenskiöld from Mesa Verde in 1891 (Nordenskiöld, 1893), all of whom exhibit flattening to some extent. Here, Retzius describes deformation to the "superior parieto-occipital region" that "varies greatly in degree" (1893, p. IX) and attributes it to contact with some kind of flat object.

The origins of the current classificatory nomenclature, focusing on the terms "lambdoidal" and "occipital" as de-

*Correspondence to: Greg C. Nelson, Department of Anthropology, University of Oregon, Eugene, Oregon 97403-1218.
E-mail: gcnelson@uoregon.edu

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scriptive labels, evolved out of anatomical descriptions of flattening such as that of Retzius (1893) and particularly of Hooton (1930). In his extensive treatment of the large skeletal series from Pecos, Pueblo Hooton (1930) describes the majority of the Pecos individuals as having "an occipital flattening that affects the whole back of the head, producing a more or less plane surface, the transverse axis of which is nearly perpendicular to the sagittal plane of the cranium" (p. 35). He also notes that a minority of individuals exhibit "a flattening which affects the apex of the occipital bone and the portions of the parietals adjacent to lambda and which I call "lambdoid deformation"" (p. 35). Hooton goes on to further describe lambdoidal flattening as affecting the "crown" of the head resulting in a round or oval depression extending from the obelion region to a point "somewhere below lambda" and producing a angle of 35°–45° relative to the Frankfort Horizontal.

This somewhat ambiguous definition of lambdoidal flattening, using both the crown and the back of the head highlights the problem of adequately defining something that, in contrast to occipital flattening, has a wider range of appearance. The difficulty of deciding what, specifically, constitutes lambdoidal deformation is personified by the exchange between Gerhardt von Bonin and T.D. Stewart in the mid-1930s. In describing cranial material from Lowry Ruin and the Ackman site in southwestern Colorado, and using Hooton's (1930) descriptions from Pecos as comparative reference, von Bonin (1936, p. 166) states that deformation appears to have resulted from "a pressure on the occiput, centered apparently in the obelionic region." Stewart (1937) responds that cranial deformation from southwestern Colorado differs from that found at Pecos with an angle of 50°–60° to the horizontal and would fit within Hooton's (1930) definition of lambdoid flattening. In response to Stewart (1937), von Bonin (1937) relates that what he is describing from Lowry and Ackman does not, in fact, correspond to Hooton's 1930 definition of lambdoid flattening and that "If the obelion is marked on the contours of the Lowry skulls, it will be seen that it is closer to the center of the flattened area than the lambda" (p. 720). von Bonin continues on to name this type of deformation "obelionic flattening" to separate it from Hooton's (1930) moniker, because the deformation does not impact the occipital bone as much as it does the area superior to lambda. Although later officially defined by Stewart (1939), based on material from Florida, von Bonin can be credited with originating "obelionic flattening" as a descriptor of cranial deformation. Neumann (1942) later included Stewart's 1939 description in his discussion of cranial deformation based on specific compression points.

Although originally defined in the Southwest, obelionic flattening is never recognized as a separate type of cranial deformation found among Puebloan groups and soon disappears from use, probably subsumed into the wide range of lambdoidal deformation. This can be seen in Reed (1949, p. 106) where he states "There are two types of this flattening. 'Vertical-occipital' leaves the back of the skull quite or almost straight, at close to 90° from the Frankfort plane. 'Lambdoid' has the flattening applied to the upper part of the occiput at an angle of 50°–60°." Here, Reed (1949) includes the crania from Lowry Ruin that von Bonin (1936, 1937) would consider obelionic as lambdoidal and subsumes those skulls briefly described by Yelm (1935) as "obelion deformation" into the category of typical lambdoid. In addition, Reed (1949) describes those skulls with angles of 70°–75° as "intermediate or atypical lambdoid deformation" further blurring the boundaries between types of deformation.

Over the last 60 years, there has been little addition to, or refinement of, definitions of cranial deformation in the Southwest. In fact, Stewart (1973) flatly states that there are only two "simple" types of deformation found among prehistoric Puebloan peoples, vertico-occipital and lambdoidal. This convention is reflected in more recent research (i.e., studies which include material originating in the Southwest as part of the dataset being analyzed) focusing on various aspects of cranial deformation (e.g., Cheverud et al., 1992; Holliday, 1993; Konigsberg et al., 1993; Kohn et al., 1995; O'Laughlin, 2004) where only occipital and lambdoidal are discussed.

MATERIALS AND METHODS

To better understand the range of variation for cranial deformation in the Puebloan Southwest, we collected data on 146 crania representing six samples (Fig. 1 and Table 1). The Gallina and Chaco materials were examined first hand while information on other crania was derived from the literature. With both in hand and photographically represented specimens, initial determination of deformation type was based on previously established criteria for identifying deformation in the Southwest (Hooton, 1930; Reed, 1949; Stewart, 1973), which included the morphology of the posterior cranium but was heavily based on the angle of deformation. Because the primary quantifiable data for this study involves the angle of the deformation in relation to the Frankfort Horizontal, these measures were recorded directly on in hand crania and from photographs of crania properly positioned in either right or left *norma lateralis*. Measurements of actual (both right and left sides, when available) and photographically represented specimens (in all but one case only one side was presented) were taken with a clear plastic goniometer and recorded to the nearest degree. For fragmentary crania, the angle was estimated to the nearest 5°. Although fragmentary specimens are problematic, the issue is relatively minor for documenting presence/absence of cranial deformation since flattening can be determined when only a parietal is present. For measurement purposes, a partial cranium consisting of temporal, parietal, and occipital is adequate for estimation to the nearest 5°.

As we are more interested in where individual deformations fall within relatively broad categories (occipital, lambdoidal, and obelionic flattening), angle data was recorded both as the true value and rounded to the nearest 5°. For individuals with both left and right measurements, each side was recorded. In addition, because estimates from fragmentary crania are necessarily included and bilateral measurements, though rarely varying by more than 5°, were frequently not the same (owing to the asymmetric nature of many individual deformations in which the pressure point, and therefore the main area of deformation, is lateral to the sagittal plane), we found it useful to represent all individuals as a single data point equalized to the nearest 5°. For this reason, the variable "diagnostic" was created in which each individual is recorded at the nearest 5° interval that best reflects the angle of deformation. Simple bar charts and scatterplots were the most helpful for identifying patterns within the dataset and whether there is separation between the deformation types.

To test for measurement consistency, two error studies were done. In each, the technical error of measurement

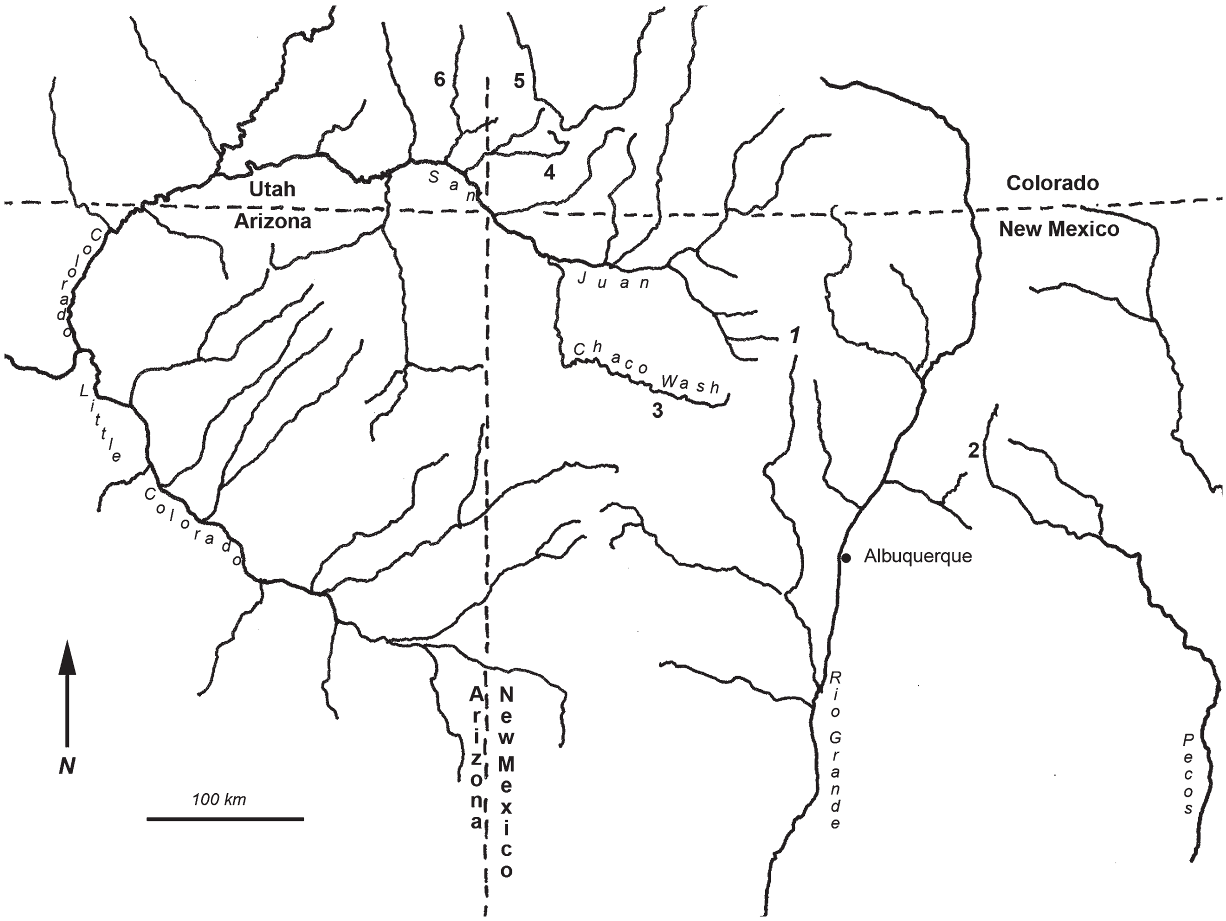

Fig. 1. Map of Ancestral Pueblo area with sites mentioned in text. (1) Gallina sites; (2) Pecos Pueblo; (3) Chaco Canyon; (4) Mesa Verde; (5) Lowry Ruin; (6) Alkali Ridge.

TABLE 1. Samples used in this study

Sample	N	Period	Approximate dates	Location/reference
Gallina (Llaves Valley sites)	57	Pueblo III	1100–1265 AD	Maxwell Museum; Colorado State; University of Oregon
Chaco	21	P II	900–1150 AD	Maxwell Museum
Lowry	6	P II–III	1060–1150 AD	von Bonin, 1936
Pecos	34	P IV	1300–1400 AD	Hooton, 1930
Mesa Verde	18	P III	1100–1280 AD	Retzius, 1893; Bennett, 1975
Alkali Ridge[a]	10	P II	900–1100 AD	Brew, 1946

[a] Alkali Ridge has sites that date from Basketmaker III through Pueblo III. The material studied here derives from Pueblo II contexts.

(TEM) and the relative technical error of measurement (rTEM) were calculated (Weinberg et al., 2005). The TEM calculates the measurement error in the measurement units used (here degrees), whereas the rTEM reports the average error as a percentage error across the sample. To test general intraobserver error, 30 photographs and 6 crania were remeasured (41 observations) by the original data collector (GCN) 1 year after the first measurements were taken. The TEM indicates little difference between first and second measures (TEM = 1.48°) and the rTEM (2.27%) was well below the 5% generally considered the boundary between precision and imprecision (Weinberg et al., 2005). In addition, an analysis of the cases that differed between measures shows that no difference was larger than 5°, and the average absolute difference was less than 1.5° (difference 1.22°, standard deviation 1.725°), correlating well with the TEM. To test the similarity between measurements on photographs and on actual specimens, 21 measurements were taken on lateral photographs of crania that were also measured in hand. Again, little difference between measurements was found. Both the TEM (1.26°) and the rTEM (2.30%) indicate that the difference between the first and second measures was small. As in the intraobserver error study, no difference between measures was larger than 5° and the average absolute difference was low (difference 1.19°, standard deviation 1.365°).

RESULTS

Of the 146 (129 measurable) crania examined, seven exhibit obelionic flattening morphology and have angles

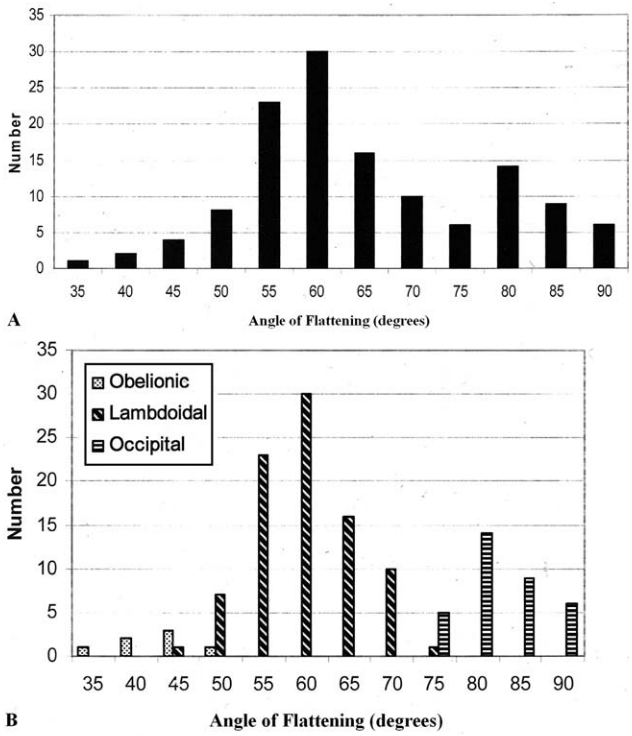

Fig. 2. Bar charts showing distribution of angle of flattening. All measured crania (**A**) and separated by type (**B**).

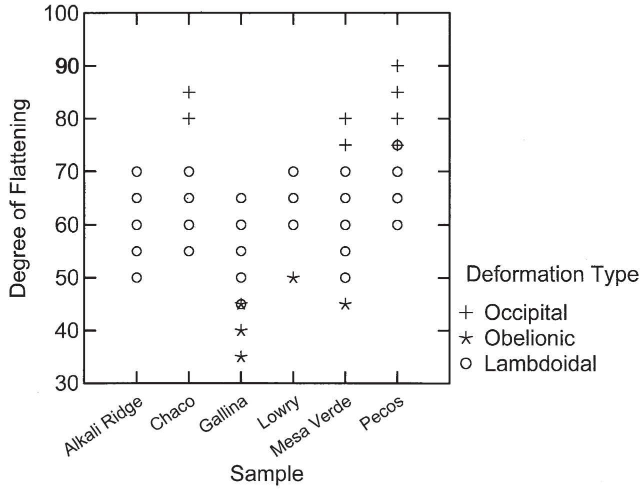

Fig. 3. Scatterplot showing distribution of deformation type within the studied samples.

of 50° or less. Five of these derive from Gallina contexts and two are from other non-Gallina associated sites, one each from Mesa Verde and Lowry Ruin.

Figures 2 and 3 depict the range of angle of deformation and the correlations between angle, deformation type, and sample. Figure 2a comprises the entire sample of measured crania and reveals two obvious modes whose peaks correspond to lambdoidal (60°) and occipital (80°) deformation. Figure 2b is a composite bar chart in which the three types of deformation are overlaid. When viewed in this manner, a third mode is revealed that of obelionic. Figure 2b also shows that some overlap in angle exists between occipital and lambdoidal and between lambdoidal and obelionic and exposes a problem encountered during this research in that, although angle has historically been an important part of definitions of deformation type, and we use it here to quantify deformation and explore its variation, angle and morphology do not always have a 1:1 correlation. We found that for the vast majority of individuals, angle of flattening does reflect type of deformation but at 45°–50° and 75° a few individuals may present either obelionic or lambdoidal or lambdoidal or occipital morphology, respectively. For example, all individuals with angles of 55°–70° degrees are morphologically lambdoidal, those of 80°–90° morphologically occipital, and those less than 45° are obelionic. However, one of eight individuals expressing 50° angles is morphologically obelionic, one of four individuals at 45° is morphologically lambdoidal, and one of six 75° individuals has lambdoidal morphology.

The scatterplot in Figure 3 shows the range of deformation type for each of the study groups. Only Alkali Ridge is uniform in deformation type and only Mesa Verde records all three. The narrowest ranges are those at Lowry and Alkali Ridge, but these sites also have the smallest samples sizes so an increase in number of individuals would probably increase the range of variation for these samples.

DISCUSSION

Our analysis indicates that, although rare, obelionic cranial deformation does constitute a third identifiable type of deformation within the Puebloan Southwest, has a distinct morphological pattern, and does occur among Ancestral Puebloans beyond Cañada Simon I and the Gallina core area.

The problem with defining and identifying cranial deformation in the Puebloan Southwest is that the distinguishing characteristics for deformation types have, to a certain extent, been a moving target. With the exception of extreme cases, the occipital and both parietals are involved in all Puebloan deformations affecting the portion of the cranium posterior to the coronal suture. "Occipital" flattening has been used to define a wide range of deformation morphologies from direct vertical flattening to anything involving the occipital bone, whereas lambdoidal has included a range of manifestations including being centered on lambda to any variation that is not classified as occipital (Table 2). In part, this variation in definitions reflects the evolution of the classification system as evident in Hooton's (1930) work where deformations that today would be easily classified as lambdoidal were included in the occipital category. Although Hooton (1930) used angle of flattening to some extent, Stewart (1937, 1939) and Reed (1949) brought forth a more systematic outlook to the problem by incorporating the angle in their definitions of deformation.

Unfortunately, emphasizing angle in descriptions of Puebloan cranial deformation introduces error into the process of classifying individual deformations, because there is not a 1:1 correspondence between type based on morphology and type based on angle. On the surface, it appears that Southwestern cranial deformation has definite types that can be categorized by angle alone but, contra Stewart (1973), at 45°–50° and 75° determining which type is present in an individual is not simple and requires careful examination of the deformation mor-

TABLE 2. Descriptions of cranial deformation in the American Southwest through time

Describer	Occipital	Lambdoidal	Obelionic
Retzius (1893)		Described as artificial deformation of the superior parieto-occipital region centered on lambda, but not named.	
Hooton (1930)	Nearly perpendicular plane surface.	Apex of the occipital and portions of the parietals adjacent to lambda. Also, the crown of the head 35°–45° angle.	
von Bonin (1936, 1937)			Obelion is closer to the center of the flattened area than lambda.
Stewart (1937, 1939, 1973)	The plane of the flattened occiput is parallel to the axis of the body… the term vertical-occipital is applied (1973).	Cites Hooton (1930) for term "lambdoid" but says angle is 50°–60° (1937). Flattening of the back of the skull well above the prominence of the occiput (1973).	Deformation occurs between bregma and lambda…inclined ~30° to the horizontal. Includes a broadening of the vault and bulging forehead (1939).
Neumann (1942)		Uses Chaco as examples with plane of flattening as 50°–60°	Cites Stewart (1939) but increases angle range to 30°–40°.
Reed (1949)	Vertical-occipital with back of head quite or almost straight at close to 90°. When Discussing a specimen from Alkali Ridge (Brew, 1946) notes that its 75° angle is "quite different from the lambdoids."	Flattening applied to the upper part of the occiput at an angle of 50°–60°. Intermediate or atypical lambdoid with angle about 70°.	
Nelson and Madimenos (this study)	Near vertical to vertical flattening (75°–90°) of posterior cranium. Pressure point inferior to lambda.	50°–70° angle of flattening with pressure point at or slightly superior to lambda. Nuchal area frequently shelflike in lateral view.	Angle of flattening ≤50° with pressure point at or superior to obelion. Flattened area generally ovoid with elongated parietal bosses and bunlike nuchal area.

phology. Therefore, for determining the deformation type of an individual, morphology is superior, but to examine the range of variation within Puebloan cranial deformation angle is useful for quantifying the data.

Defining obelionic deformation in the Southwest

This analysis of cranial deformation in the Puebloan Southwest allows us to offer the following descriptions of the cranial morphology distinctive to each of the three forms. As the descriptions are revisions of prior convention, the terminology remains basically the same. However, we do introduce the term "pressure point" as a replacement for the common descriptor "center of deformation," because it better reflects the deformation process although the terms are, in effect, interchangeable. For these descriptions, we define the pressure point as that point, generally in the sagittal plane, that, were the flattened area a plane surface, would be the balance point for the area encompassed by the area of deformation. For asymmetrical deformations, this point will be lateral to the sagittal plane. As a diagnostic tool, pressure point location comes into play at the transition zones. For example, between 55° and 70°, lambda is the nearest cranial landmark to the pressure point but at 75° it shifts inferiorly towards opisthocranion, though never really reaching this point. It is important to note that the pressure point is not an exact, metrically defined, point but a point area. Although at first there is a contact "point" where the infant's head rests on the cradle once the final form is reached, after the individual grows to adulthood, the irregularity of the flattened area's border, as well as the external morphology of the bone itself, precludes exact measurement of a point on the plane of flattening where the cradle first contacted the head. For purposes of deformation description, the pressure point is located by eyeball, is easily determined, and is highly repeatable.

Occipital deformation. Flattened area, in general, has equilateral superior–inferior and bilateral dimensions and forms a 75°–90° angle with the Frankfort Horizontal (Fig. 4a). On the sagittal plane, the deformed area extends from at, or inferior to, obelion inferiorly to the inferior nuchal lines involving the entire occipital squama. In extreme cases, the area may extend beyond the inferior nuchal lines. The pressure point may be as high as lambda, but, in most cases, is located inferior to lambda on the occipital planum of the squama between lambda and the external occipital protuberance. The resulting cranial morphology includes an anteroposteriorly shortened neurocranium particularly in individuals in which the plane of flattening approaches 90°. Parietal bosses are slightly exaggerated and terminate abruptly posteriorly. Vertex can be located 2–3-cm posterior to apex in extreme cases as the parietals become high and rounded posteriorly. The external occipital protuberance and superior nuchal lines become flattened.

Lambdoidal deformation. Flattened area is roughly circular with superoinferior and bilateral dimensions roughly equal and forming an angle relative to the Frankfurt Horizontal of 50°–70° (Fig. 4b). On the sagittal plane, deformed areas extends from at, or slightly

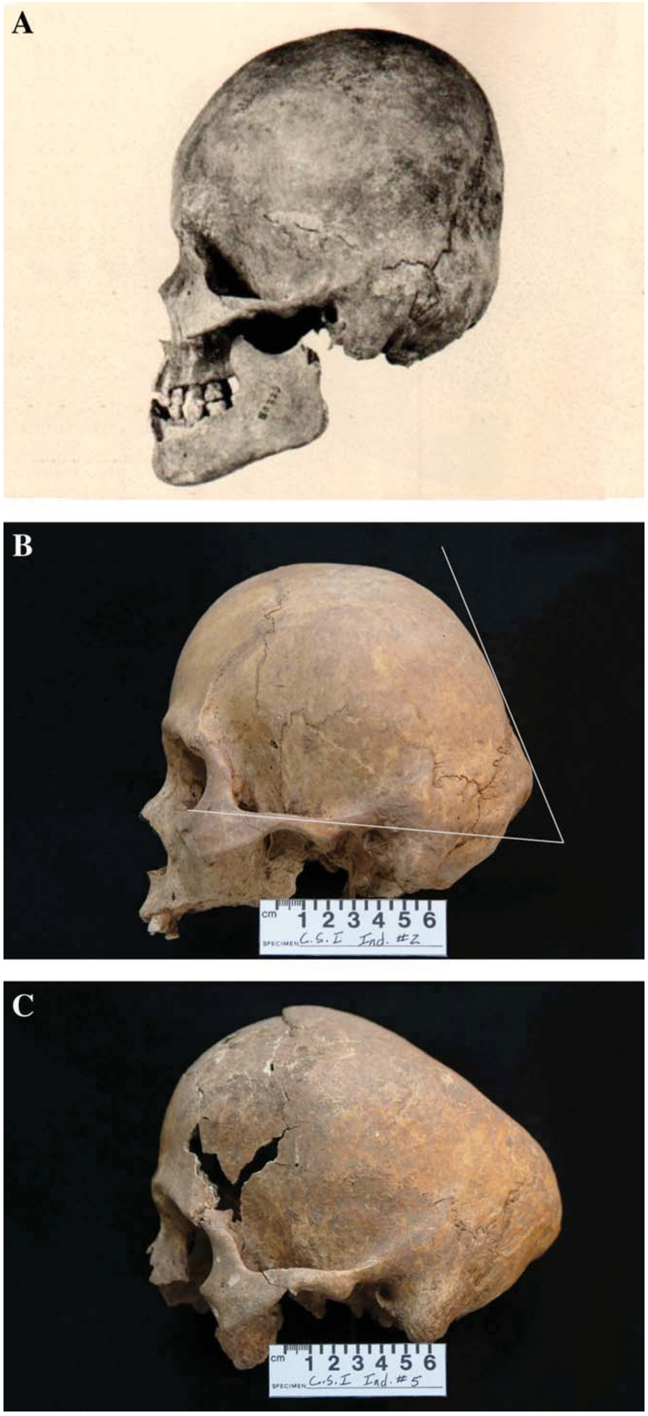

Fig. 4. Examples of cranial deformation types. **A**: Occipital of 90° [Pecos no. 60222, adapted from Hooton (1930), Plate III-9]; (**B**) Lambdoidal of 65° with angle superimposed (Individual no. 2 from Gallina site Cañada Simon I); (**C**) Obelionic of 40° (Individual no. 5 from Gallina site Cañada Simon I). Color photographs available in the online version. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

superior to, obelion inferiorly to the superior nuchal lines and the external occipital protuberance involving the entire occipital planum of the squama. The pressure point is at, or slightly superior to, lambda. The resulting cranial morphology includes exaggerated (and sometimes bulbous in superior view), but not elongated, parietal bosses and an external occipital protuberance/superior nuchal line complex that frequently becomes pronounced and shelflike when viewed laterally.

Obelionic deformation. Flattened area is ovoid with its long axis tending along the sagittal plane with the angle of deformation of 50° or less (Fig. 4c). Although variable, the deformed area generally extends from a point 2–3-cm posterior of bregma to above the superior nuchal lines involving only the superior portion of the occipital planum of the occipital squama. The pressure point is at, or superior to, obelion. The resulting cranial morphology includes exaggerated and superoanterior to posteroinferiorly elongated parietal bosses and a bunlike appearance of the occipital when viewed laterally. The lateral extent of the flattened area is frequently wide enough to incorporate the superior temporal lines, so that they wrap around the elongated parietal bosses on to the flattened area.

These descriptions highlight the fact that cranial deformation impacting the posterior portion of the skull constitutes a continuum of form with a shifting, and variable, morphology exemplified by the pressure point that moves from the occipital planum, to lambda, to obelion, and an angle of flattening (in relation to the Frankfort Horizontal) that runs from 90° to 35°. In addition, the areal extent of the deformation varies with that of occipital tending to be confined to the occipital bone with the superior margin rarely extending beyond lambda with lambdoidal encompassing the occipital squama and the posterior portions of the parietals, whereas obelionic extends superoanteriorly to near vertex and incorporates a larger portion of the parietals.

In practice, the three types of cranial deformation are easily recognized and classified by sight alone, because, at a very basic level, each type is distinctive in lateral view. Obelionic presents a long, low appearing, profile with a sloping postbregmatic area, lambdoidal exhibits a higher, round, profile with a steeply sloping posterior, and occipital shows a high, round, profile with a near vertical to vertical posterior. Classification of an individual deformation only becomes problematic in the area of the transitional zones we have identified. Particularly with the transition between obelionic and lambdoidal, it is necessary at times to closely examine the morphology to determine the type of deformation. This is exemplified by the Lowry no. 47619 skull (Fig. 5a,b). This specimen presents an angle of 50° but expresses predominantly obelionic morphology, and we have classed it as such. Beyond its general obelionic appearance, due primarily to the anterosuperior to posteroinferior elongated parietal bosses, Lowry 47619 also exhibits the bunlike nuchal area characteristic of obelionic flattening. Transitional aspects of its morphology include a flattened area that is only slightly ovoid and a pressure point that falls midway between lambda and obelion.

In general, however, lambdoidal and obelionic deformation in the 50° range are easily distinguished as can be seen in the Llaves Valley Gallina individuals depicted in Figure 5c,d, which present quite different and distinctive profiles. The cranium in 5c exhibits a classic lambdoidal form including a pressure point near lambda and a shelflike nuchal area while recording an angle of 50°. In contrast, the cranium in Figure 5d is obelionic (at

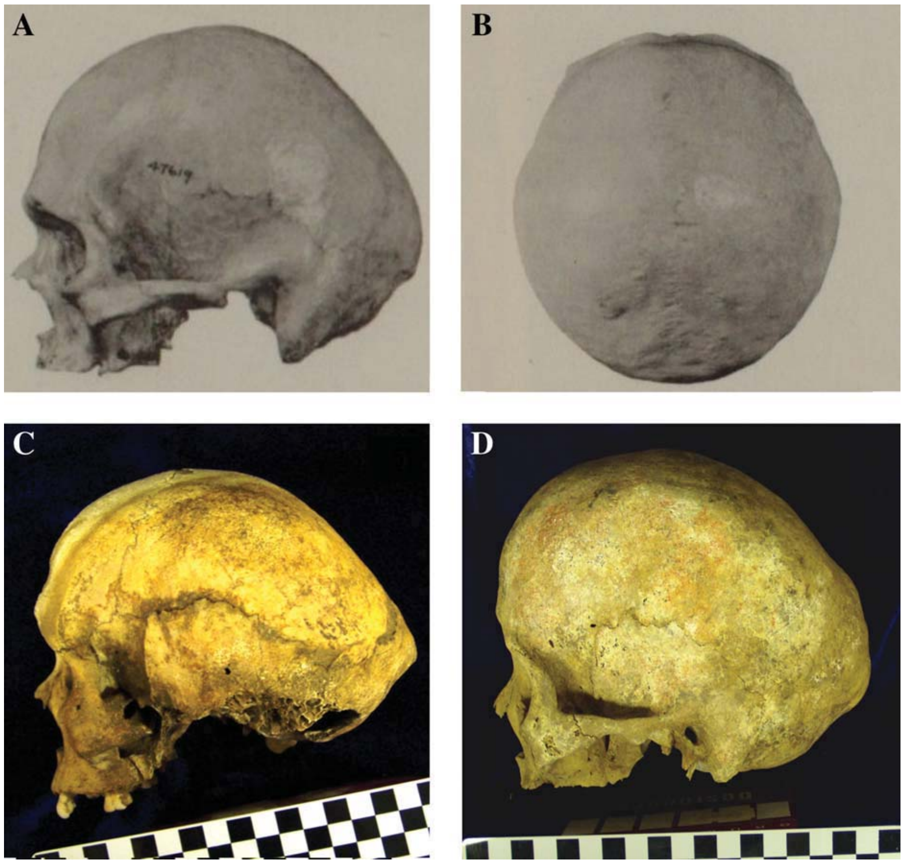

Fig. 5. Variation in deformation morphology in the 50° angle of flattening range. **A, B**: Individual (Lowry no. 47619) with 50° angle of flattening exhibiting obelionic morphology. A: Left lateral; (B) superior (adapted from von Bonin, 1936, plate LXXXIX); (C) Llaves Valley Gallina individual 84.1.2 with lambdoidal deformation (50°); (D) Llaves Valley Gallina individual 84.1.9 with obelionic deformation (47°). See text for descriptions. Color photographs available in the online version. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

47°) with a bunlike nuchal area and a pressure point at or near obelion

Etiological considerations

Cranial deformation in the Puebloan Southwest has long been considered an artifact of the practice of cradleboarding of infants (Hooton, 1930; Dingwall, 1931; Kamp, 2002), a conclusion not disputed here. Although obelionic deformation superficially resembles scaphocephalic craniosynostosis (Ortner and Putschar, 1985; Kutterer and Alt, 2008), and some forms of artificial cranial deformation have been linked to increased frequencies of craniosynostosis (White, 1996), none of the individuals examined for this study exhibit any abnormal sutural fusion. In addition, morphologically, there is little resemblance between the sagittal suture complex in obelionic deformation and scaphocephalic individuals with the former being flat or slightly concave while the latter frequently presents a convex ridge running the length of the suture.

The general uniformity of the deformation types during Pueblo I–III and later periods indicates a uniformity of process where cradling infants is concerned with the vast majority of Pueblo I–III deformations falling in the 55°–70° range. The differences in deformation between Pueblo I–III and Pueblo IV, the shift from predominantly lambdoidal to predominantly occipital flattening has been attributed to changes in cradleboard style or method of attaching the infant to the cradle (Kamp, 2002) and implies cultural change in cradleboarding practices at the Pueblo III–IV boundary.

Although obelionic deformation appears quite aberrant, necessitating different causal factors than the more common lambdoid and occipital forms, we feel this may not be the case and that it could be due to ostensibly minor differences in the relationship between a child's head and contact points with various cradle structures. Although these differences may be as simple as accidental differential placement of a headrest or the addition of a hard shade, the general conformity of deformations within the Pueblo I–III periods (lambdoidal) and the Pueblo IV–V periods (occipital) leads us to posit other, as yet undetermined, cultural factors dictating some combination of cradle design, method of affixing the infant to the cradle, and head rest variability. Hooton (1930) was vexed with this problem as well stating (p. 37) "By no conceivable contortions of the infant could this flattening be effected by lying upon the back with the head resting on the occiput. It would hardly be possible to produce such an effect even if the infant were stood upon its head or the cradle carried upon the mother's back in an inverted position." We concur.

CONCLUSIONS

Despite the uncertainty in etiological background, we are comfortable concluding that obelionic flattening can be classed as a third type of cranial deformation occurring during Ancestral Pueblo III times and that it exists outside the Gallina core area. Morphologically, obelionic deformation is quite distinct from lambdoidal and occipital and although relatively rare we feel, now that it is recognized, that more examples will be found and a clearer idea of its temporal and spatial range can be elucidated. In addition, we suggest the application of a more systematic means of measuring and recording cranial deformation in the Southwest that reemphasizes morphology combined with angle of deformation. A more defined empirical approach of recording and measuring cranial flattening could potentially lead to a greater understanding of the various mechanisms underlying deformation as well as provide an alternative framework for interpreting the etiology of flattening types among and between populations.

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