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THE INCIDENCE OF WORMIAM BONES AMONG JUVENILE CRANIA EXCAVATED FROM THE SCHILD MISSISSIPPIAN KNOLLS: A CASE STUDY

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ABSTRACT: Very little research concerning wormian bones has been done with juvenile cranial material. This study examines exactly how easy (or difficult) it is to detect the presence of these ossicles in juvenile archaeological remains discovered at the Schild Mississippian knolls in Illinois. Placement of these wormian bones was noted and tabulated. Fragmentary and warped cranial material predominates among the youngest of the specimens, rendering them quite difficult to study. However, uncertainty in analyzing these remains may be minimized, if an age group of 1 year to 20 years is selected. Hence, further research can and should be directed towards studying wormian bones in juvenile skeletal populations.

INTRODUCTION

Wormian bones have long been a source for study and research by anthropologist and biologist alike. Found along the cranial suture lines and fontanelles of certain individuals, these bones are considered to represent one of the many discontinuous morphological characteristics that may be observed on the skull (Bennett, 1965). They are isolated ossicles of varying size, and they have ossification centers independent from the other cranial bones (El-Najjar and Dawson, 1977). Furthermore, these ossicles are outlined by their own encompassing suture lines and fit like a "jigsaw puzzle piece" within the suture lines that separate the individual bone segments of the cranium.

Although the structure, growth, and development of wormian bones have been well-studied and researched, scholars are still uncertain as to what the underlying factors are that predispose them to particular individuals. Among the first reports that attempted to answer this question was Dorsey's study (1897, from Bennett, 1965) of the Kwakiutl crania. Dorsey suggested that wormian bones developed due to the stress on the cranium resulting from the practice of artificial cranial deformation.

Bennett (1965) further developed the "stress-hypothesis" for wormian bone formation. Bennett proposed that any stress around the cranial suture areas, such as artificial cranial deformation or certain pathological conditions like hydrocephaly, could result in the development of this discontinuous trait. In addition, he found that the particular growth and development of the basi-occiput may produce stress around the lambdoid suture, which in turn results in the formation of wormian bones. Bennett's study of Negro, White, and American Indian crania supported his hypothesis that these bones represent "secondary sutural characteristics which are brought about by stress" (Bennett, 1965).

Other studies have favored a different explanation; namely, that wormian bones are a genetic predisposition and that external factors such as artificial cranial deformation do not play a role in their formation. Among the proponents for this hypothesis are El-Najjar and Dawson (1977), who studied skeletal samples of Southwestern Pueblo Indians. According to their findings, wormian bones occur in deformed and non-deformed skulls with approximately the same regularity. Therefore, El-Najjar and Dawson concluded that wormian bones must be under genetic control. These findings were supported by D. J. Finkel (1976) in his study of wormian bone formation in the skeletal population from Lachish, Israel.

Other investigators advocate a less extreme position. In particular, wormian bones are believed to originate due to genetic factors, but these factors may be influenced or altered by some form of stress (such as artificial deformation) on the cranium. Ossenberg's (1970) analysis of Hopewell crania and Gottlieb's (1978) examination of Southwest Indian crania support this view, along with Pucciarelli's (1974) experimentation with Wistar rat skulls.

Trinkhaus and LeMay (1982) have added yet another factor that may cause stress on the cranium: that of the posterior growth of the brain. Their survey of occipital bunning among Neanderthals and anatomically correct humans alike led them to propose that this phenomenon is due to a posterior-wise increase in brain size that occurs relatively late within the normal time period of juvenile brain development.

The evidence of Trinkhaus and LeMay for the posterior growth of the brain rests on several observations. The first is the sequence of suture closure. The metopic suture is the first to close, followed by the coronal and sagittal sutures. The most posterior suture, the lambdoid, is the last to close and does so well after the others. Trinkhaus and LeMay believe this sequence implies a posterior brain growth, for fusion of the sutures implies that additional space is no longer needed for the development of the brain, as it has attained its maximum size.

The second observation made by Trinkhaus and LeMay dealt with the distribution of wormian bones. Taking the position that wormian bones are formed due to increased intercranial pressure, they noted that wormian bones are predominantly found along the lambdoid suture. Posteriorly directed growth might produce more stress along the posterior portion of the cranium, resulting in the formation of wormian bones.

Trinkhaus and LeMay's (1982) original study on occipital buns raises the question of whether the incidence of wormian bones and the posterior rate of growth in the brain **are** related. If so, then wormian bones would **not** be due solely to a genetic predisposition but rather to an **internal** stress placed on the cranium.

The growth of the brain is a fairly rapid process. At birth, the brain is already 25% to 33% of its adult size, and by the end of the first year, it increases to 70% of its adult size. By the fifth or sixth year, the brain is almost 95% of its adult size (Boyd, 1962, from Trinkhaus and LeMay, 1982). If one wants to test the above-mentioned hypothesis, one must examine juvenile skulls, preferably between the ages of birth and six years.

Unfortunately, very little work has been done with juvenile cranial material. This is because, for the most part, juvenile archaeological cranial remains are not discovered as often as adult skeletal remains. When juvenile cranial remains are found, they are usually found in fragmentary form or have become quite warped and distorted. An abundance of juvenile archaeological material is simply not available for study.

The following study examines exactly how easy (or difficult) it is to detect the presence of wormian bones in juvenile archaeological remains. The incidence of wormian bones among juvenile crania is calculated for the skeletal population found at the Schild Mississippian site (Knolls A and B). Placement of these wormian bones are noted and tabulated. Furthermore, a comparison is made between the juvenile data and young adult skeletal material, aged 20 years to 35 years, to see if any correlations are present.

MATERIALS AND METHODS

The cranial material used for this study was discovered at the Schild site, located on the eastern bluffs of the Illinois River in Greene County, Illinois. Excavated by Perino in 1962, the site yielded a total of 9 Late Woodland Mounds and a Mississippian cemetery divided into Knolls A and B (Perino, 1971). The Mississippian cemetery has an approximate radiocarbon date of 1069 AD. The skeletal remains in this cemetery are very well preserved and provide a better-than-average data base from which to study juvenile crania. The Schild Mississippian collections (Knolls A and B) are currently housed in the Anthropology Department at Indiana University in Bloomington, Indiana. This skeletal material was inventoried and processed in 1973 and 1974. Therefore, aging and sexing information for the collection were already available at the time of this study.

Cranial remains were classified as "juvenile," if their age was between birth and 20 years of age. The reasons for this were multifold. First, although the brain has essentially completed its growth by age 6, the individual has not yet completed his/her growth in other areas. In addition, sutures generally do not begin to fuse until after age 20. Finally, other factors besides brain growth may affect the incidence of ossicles in the developing skull. For example, Lestrel and Brown (1976) have shown that there is an adolescent growth spurt in the cranial bones. Such a growth spurt may influence the development of wormian bones. For these three reasons, it is best to study crania that span the entire time range of cranial development. Furthermore, this 1 to 20 year age range provides a sufficiently large data base with which to work.

A specimen was not considered "usable" unless a sufficient amount of cranial material remained to be examined. Sufficient cranial remains include complete skulls, some individual bones (such as the parietal, occipital, etc.) with sutures still attached, and/or cranial fragments that can be at least partially pieced together.

The juvenile material was analyzed and placed in one of five categories: wormian bones present, wormian bones probably present, indistinguishable, wormian bones probably not present, and no wormian bones present. The criteria for placement were as follows:

Wormian Bones Present:

1. Wormian bones were found along sutures of an articulated skull or on a disarticulated cranial fragment; or
2. Individual wormian bones were found within the remains but not necessarily connected with the remaining cranial material; or
3. Two or more disarticulated cranial bones could be fitted together along the suture lines and an evident space for a wormian bone could be detected.

Wormian Bones Probably Present:

1. Two or more disarticulated cranial bones could be fitted together along the suture lines, revealing an opening where a wormian bone might have been, but the evidence remains far from conclusive.

Indistinguishable:

1. No wormian bones were present, yet less than approximately 80% of the sutures were recovered; or
2. The remains were too broken to be pieced together; or
3. The remains were too broken and could not be reconstructed; or
4. Simply too few cranial remains were recovered; or
5. In the case of very young children (who still retained fontanelles), the formation of suture lines had not yet occurred and one could not be sure, if a separate wormian bone was once present but was simply not recovered in the archaeological excavation.

Wormian Bones Probably Not Present:

1. There was no evidence of wormian bones, yet the remains were just fragmentary enough that one could not tell for sure if the missing pieces perhaps housed some wormian bones (i.e., if close to but less than 80% of the suture lines were present).

No Wormian Bones Present:

1. At least 80% of the suture lines were present, but there was no evidence of wormian bones along these sutures.

Those specimens aged 20 to 35 years, an age range classified as "young adult," were selected as a comparison sample to the juvenile data. The sutures of these young adult crania have not completely fused yet, as they soon will in older specimens. Once the sutures fuse, the detection of wormian bones becomes nearly impossible.

Table 1. Statistics for specimens aged birth to 20 years from the Schild Mississippian site (Knolls A and B). (Note that each number here represents one individual; e.g., 28 individuals were found to possess one or more wormian bones along their lamboid suture.)

Total number of individuals: 223		
Total number of specimens with recoverable cranial remains: 69		
Breakdown:	Ages birth to 1 year	19
	Ages 1 year to 20 years	50
	Ages birth to 6 years	35
	Ages 6 years to 20 years	34
Total number of viable cases for study (i.e., those specimens with some remnants of cranial remains): 154		
Breakdown:	Ages birth to 1 year	62 (40.26%)
	Ages 1 year to 20 years	92 (59.74%)
	Ages birth to 6 years	118 (76.62%)
	Ages 6 years to 20 years	36 (23.38%)
Total viable cases breakdown		
	Wormian bones present	30 (19.48%)
	Wormian bones probably present	4 (2.60%)
	Indistinguishable	90 (58.44%)
	Wormian bones probably not present	1 (6.49%)
	No wormian bones present	20 (12.99%)
Areas where wormian bones were found; special wormian bones		
	Sagittal suture	2
	Lambdoid suture	28
	Parieto-mastoid suture	3
	Occipito-mastoid suture	5
	Coronal suture	1
	Inca wormian bone	1
	Apical wormian bones	8
	Bregmatic wormian bones	0
	Pterionic wormian bones	0

Only those adult specimens with at least 80% of their sutures present among the cranial remains were studied. When analyzing this sample, only three of the five above-mentioned categories were utilized: wormian bones present, indistinguishable, and no wormian bones present.

In addition, this second sample was broken down into "male" and "female" categories, to see if any general conclusions about wormian bones and sex could be drawn. Such a breakdown could not be drawn for the juvenile specimens, as it is virtually impossible to sex pre-pubescent skeletal material. The main reason for this is that sexually dimorphic changes in the skeleton do not appear until well after puberty.

Finally, the juvenile data were broken down into several different age

Table 2. Specimens from the Schild Mississippian site (Knolls A and B) broken down by age.

Case breakdown for ages birth to 1 year: 62		
Wormian bones present	1	(1.61%)
Wormian bones probably present	1	(1.61%)
Indistinguishable	52	(83.87%)
Wormian bones probably not present	6	(9.68%)
No wormian bones present	2	(3.23%)
Case breakdown for ages 1 year to 20 years: 92		
Wormian bones present	29	(31.52%)
Wormian bones probably present	3	(3.26%)
Indistinguishable	38	(41.30%)
Wormian bones probably not present	4	(4.35%)
No wormian bones present	18	(19.57%)
Case breakdown for ages birth to 6 years: 118		
Wormian bones present	14	(11.86%)
Wormian bones probably present	3	(2.54%)
Indistinguishable	79	(66.95%)
Wormian bones probably not present	10	(8.48%)
No wormian bones present	12	(10.17%)
Case breakdown for ages 6 years to 20 years: 36		
Wormian bones present	16	(44.44%)
Wormian bones probably present	1	(2.78%)
Indistinguishable	11	(30.56%)
Wormian bones probably not present	0	(0.00%)
No wormian bones present	8	(22.22%)

groups. The incidence of wormian bones among the entire juvenile group (ages birth to 20 years) was calculated first. The other two breakdowns were:

1. Birth to 1 year and 1 year to 20 years; and
2. Birth to 6 years and 6 years to 20 years.

The reasons for such breakdowns were to see if the uncertainty arising from dealing with some of the very young fragmentary remains could be minimized, as well as to see if any general patterns would arise as a result of these new breakdowns.

RESULTS

A surprisingly large number of juvenile specimens did not have any recoverable cranial remains at all (Table 1). Furthermore, close to 60% of the remaining usable juvenile specimens were classified as "indistinguishable." As mentioned earlier, cranial remains were often too few, too fragmentary, or too warped for one to distinguish the presence or absence of ossicles with certainty. From this Schild Mississippian sample, half of the remaining 40% of the juvenile

Table 3. Specimens of ages 20 years to 35 years from the Schild Mississippian site (Knolls A and B) compared by sex for the presence of wormian bones.

Total number of viable cases for study: 38

Female specimens	19	(50.00%)
Male specimens	19	(50.00%)

Breakdown of total viable cases

Wormian bones present	23	(60.53%)
Indistinguishable	5	(13.15%)
No wormian bones present	10	(26.32%)

Breakdown of the occurence of wormian bones by sex

	Male	Female
Wormian bones present	12 (63.16%)	11 (57.89%)
Indistinguishable	3 (15.79%)	2 (10.53%)
No wormian present	4 (21.05%)	6 (31.58%)

Areas where wormian bones were found; special wormian bones

	Total Population	Males Only	Female Only
Sagittal suture	0	0	0
Lambdoid suture	15	8	7
Parieto-mastoid suture	8	4	4
Occipito-mastiod suture	13	7	6
Coronal suture	3	1	2
Inca wormian bone	1	1	0
Apical wirmian bones	3	2	1
Bregmatic wormian bones	1	0	1
Pterionic wormian bones	2	1	1

specimens had some evidence of wormian bones. However, due to the high number of 'indistinguishable'' specimens, no generalizations about wormian bones among the juvenile population as a whole could be made.

By far the most common site for wormian bones among juvenile crania was along the lambdoid suture. There are 28 incidences of one or more wormian bones along the lambdoid suture, compared to 11 incidences along the remaining 4 sutures. Furthermore, there were generally multiple bones along the lambdoid suture, whereas the other sutures tended not to possess multiple ossicles.

The two separate breakdowns of the juvenile data provided other useful information (Table 2). If one would like to see if brain growth and the presence of wormian bones are somehow interdependent, the ideal sample population should be aged from birth to 6 years. (Remember that brain growth is essentially complete by age 6.) Although the sample size for the breakdown from birth to 6 years in this study is rather large, the number of "indistinguishable" specimens is equally large (Table 2). Hence, the same problem arises as was encountered with the juvenile specimens (see above); no generalizations could be made with so much uncertainty in the sample.

The second age breakdown (i.e., birth to 1 year and 1 year to 20 years) was set up to see if the uncertainty could be minimized. Upon analyzing the cranial material, it soon became apparent that the very young specimens would be quite difficult to classify. If suture lines have not yet formed (which is typical for most children under 1 year of age), it is impossible to determine whether or not wormian bones were once present, and simply had not been recovered. In addition, the younger the specimen, the more fragile and tiny the cranial remains are. Hence, even if cranial remains were recovered, they were in poor condition. As a result, over 83% of the birth to 1 year material was classified as "indistinguishable."

Those specimens aged 1 year to 20 years yielded more tangible results. Although the "indistinguishable" percentage is still rather high (41.30%), this figure has been minimized using this breakdown. Approximately 40% of the remaining 60% of the specimens could be classified as possessing wormian bones.

Upon analysis of the data, a third age breakdown was considered—that of material aged 1 year to 6 years. Several problems made such a breakdown infeasible. First, the number of specimens classified as "indistinguishable" would be greater than that in the 1 year to 20 years sample. More importantly, the database would be reduced greatly in size and would not yield a sufficiently large population for statistical analysis.

The problem of having so many unusable and "indistinguishable" specimens in a juvenile archaeological skeletal sample will almost always exist. However, the 1 year to 20 years sample will produce the most efficient and statistically reliable database, given these limitations.

The young adult comparison sample (Table 3) yielded more interesting and more concrete results. There happened to be an equal number of males and females in the sample. Unlike the juvenile sample, the number of "indistinguishable" specimens was small (just over 13%). Because approximately 60% of the specimens possessed wormian bones, this population appears to exhibit a tendency towards developing ossicles. In addition, the presence and incidence of wormian bones appear to be equally distributed among the males and females. This finding agrees with that of Cosseddu, *et al.* (1979), who determined that sex differences in wormian bones are minimal to irrelevant.

In the young adult sample, the posterior-most sutures (such as the lambdoid and the occipito-mastoid) had over twice the incidence of wormian bones than the more anterior sutures (i.e., sagittal, parieto-mastoid, and coronal). This finding correlates with the results of other surveys; i.e., that the majority of wormian bones are found along the posterior-most sutures (Berry and Berry, 1967, from Trinkhaus and LeMay, 1982).

CONCLUSIONS

The results presented here suggest that detecting wormian bones in juvenile archaeological specimens is problematic at best. Fragmentary and warped cranial material predominates among the youngest of the specimens, making it quite difficult to study them. However, uncertainty in analyzing these remains may be minimized, if an age group of 1 year to 20 years is selected. Although this is not the ideal situation, because one must dismiss from consideration some specimens that may have potential for yielding insight into cranial development, it is nevertheless the "best-case scenario" with which the anthropologist has to work.

Among the Schild Mississippian population, wormian bones were apparently a common occurrence among both juvenile and adult crania. The presence of these ossicles can be established with certainty in over 30% of the 1 year to 20 years sample and in over 60% of the young adult sample.

The presence and incidence of wormian bones were found to be distributed equally among the male and female crania in the young adult sample. This observation would indicate wormian bones are not a sex-related trait. Similar data could not be collected for the juvenile crania, as there are no reliable methods to sex prepubescent skeletal remains.

For both age samples, ossicles are most commonly found and most abundant among the posterior-most cranial sutures. Of those juvenile crania possessing ossicles, over 75% had one or more of these bones along the lambdoid suture alone. In the young adult sample, close to 80% of their wormian bones were found along the lambdoid and occipito-mastoid sutures.

Further research needs to be done with the incidence of wormian bones among juvenile crania. Such studies may yield insight into the formation and predisposition of these ossicles. Although there are many problems that arise when working with juvenile cranial material, this study has shown that these problems are not insurmountable. Hopefully, this study will inspire others to perform research in this long-neglected area.

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