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Disciplines
Anthropology

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A Study Comparison of Post-cranial and Dental Ages on Juveniles
From Tepe Hissar

Neerav Sheth

Advisors
Dr. Alan Mann
Dr. Janet Monge
Abstract

The following study applies post-cranial and dental aging methods on juveniles from the Tepe Hissar sample.

Introduction

Numerous techniques have been proposed to accurately age individuals based on cranial, dental, and post-cranial occurrences, such as suture closure, dental eruption patterns, and epiphyseal unions. The static nature of dental eruption time has allowed it to become the industry standard in aging techniques. Based on wear patterns and the eruption timing sequence, it has become possible to ascertain relatively accurate ages for individuals. Aging based on post-cranial remains, however, is not as static, as the post-cranial skeleton is highly susceptible to conditions of environmental and nutritional stresses, much more so than dental eruption timing.

In stable, fit populations, the degree of difference between the age determined via dental eruption and the age determined via post-cranial methods should not be significant. Thus, given one of the two measures, it is possible to correctly ascertain the age, within one or two years, for juveniles within that population. However, juveniles of populations available for study are not usually fit throughout childhood. The amount of environmental stress placed on the post-cranial skeleton can result in a significant difference between dental age and post-cranial age. This study will test out the differences between dental and post-cranial aging for juveniles from the site of Tepe Hissar located in modern day Iran.
Tepe Hissar Site

The site of Tepe Hissar is located in northeastern Iran in the Salt Desert, near the southeastern border of the Caspian Sea at ca. 36° 10' N Lat., 54° 30' E. Long (Nowell 1971). In the 1931-1933 archeological seasons, a joint expedition to Persia between the University of Pennsylvania and the Pennsylvania Museum of Art excavated the site of Tepe Hissar (Krogman 1940, Nowell 1971). In 1935, skeletal materials were sent to Wilton Krogman at the Western Reserve University in Cleveland, Ohio in order to be examined.

Three layers are identified at the site, each containing its own sets of remains: Tepe Hissar I dates to before 4000 B.C. to ca. 3500 B.C.; Tepe Hissar II dates from ca. 3500 B.C. to ca. 3000 B.C.; and Tepe Hissar III dates from ca. 3000 B.C. to ca. 2000 B.C. (Schmidt, 1937). Further discussions of the site and excavation of Tepe Hissar may be found in Schmidt's 1933 and 1937 monographs.

Dental Aging Techniques

Prior to 1962, the current knowledge of dental aging was limited to the eruption sequences in juveniles. But, in 1962, Miles published his revolutionary article, "Assessment of age from the dentition" in which he subsequently proved the ability to accurately assess age based wear patterns and dental sequence eruption (Miles, 1962). The article subsequently became the basis of almost all future dental aging studies. Nevertheless, relatively stringent requirements must be met in order to properly apply the Miles' Method to a population sample.
First and foremost, the Miles’ Method requires the establishment of a baseline derived from sub-adult dentitions. This baseline consists of wear patterns on newly erupted teeth relative to previously erupted teeth. For example, the relative pattern of wear, visible on an $M_1$ when $M_2$ has just erupted would be very similar to the pattern of wear visible on $M_2$ when $M_3$ erupts. Establishment of the relative amounts of wear on the three molars in a baseline estimation can then be extrapolated to older individuals for a near accurate age assessment. Without an established baseline, ages determined for adults would be consistent, relative to each other, but have the potential of being years off the true age.

A second requirement of the Miles’ Method exists in the sample requirement. A large enough sample must be present for the baseline wear pattern determination so as to rule out discrepancies due to individual pathologies and differential dental developments. Similarly, a sample must consist of individuals of all ages and age ranges so as to properly associate degree of wear to a reflective age.

The final requirement of the Miles’ Method is the presence of the permanent dentition, particularly the molars. The method is not used very often for age assessment of the deciduous, milk, dentition for the following reasons. First, the posterior milk dentition consists of first and second pre-molars, with the first molar appearing posterior to the second pre-molar. Wear patterns would be established based on these two pre-molars. Secondly, the transition into the permanent dentition occurs at a young enough age, primarily between the ages
of 6 and 14, that the viable usages of wear patterns on milk dentition for juvenile aging are extremely limited.

For these reasons, the Miles' Method is not a viable technique for aging immature individuals and so another method must be employed. The simplest and, most accurate, is to measure the eruption times of the deciduous and permanent dentitions. Not only is the dental eruption sequence relatively consistent in nature, in that certain teeth erupt in a certain order at certain times, it is also conserved across all populations. With this in mind, Ubelaker has put together one of the definitive assays on immature dental development. The methodology consists of observing the teeth present in a given dentition, whether immature or mixed, as well as the degree of crown and root formation in non-erupted teeth. The observation is then compared to pre-made dentition charts (see Chart A). While there is a high degree of accuracy in this simple comparison, it is important to understand that there is a degree of variation between populations; and, though there is also a strong genetic predisposition for dental eruption sequence and timing, this genetic predisposition can and does vary across populations. For example\(^1\), a juvenile in New Guinea may be subject to eruption of \(M_1\) between the ages of 6 and 7, whereas one in Zambia may exhibit \(M_1\) eruption between the ages of 4 and 6. It is also important to note that certain environmental factors can also affect dentition eruption. The child born and raised in New Guinea would again experience \(M_1\) eruption between the ages of 6 to 7, but the same child raised in New York City, may experience \(M_1\) eruption

\(^1\)This example is purely intended to convey a point; there is no basis for the conclusion that juveniles in New Guinea and Zambia exhibit \(M_1\) eruption at ages 6-7 and 4-6, respectively.
at an earlier age due to the strong environmental effects of a high paced city atmosphere.

**Post-Cranial Aging Techniques**

Dentition is not the only feature by which age assessments can be made; various aspects of the post-cranial skeleton can also be used to determine age. In order to understand the rationale for post-cranial aging techniques, it is important to first note the nature of long bone growth and development.

In juveniles, there is a need for long bones to be able to continually reshape themselves in order to grow in proportion to the rest of the body. Nature fulfilled this need by designing long bones that grow in three different, yet closely interacting segments: the proximal articular end (proximal epiphysis), the bone shaft (diaphysis), and the distal articular end (distal epiphysis). While each is separated by a small gap, or growth plate, they all grow together in concert and never out of proportion to each other (White 1991).

When an individual physically reaches adulthood, between the ages of 17 and 21, the three components of a long bone fuse together in a process known as epiphyseal union. However, by noting the occurrence of epiphyseal union one can only come to one of three conclusions: 1) the individual is immature, if union has not occurred; 2) the individual is between the ages of 17 and 21, since epiphyseal union is occurring; and 3) the individual is an adult if epiphyseal union has already occurred. The process of epiphyseal union reveals very little other information in terms of age identification outside of marking maturation and
adulthood. Therefore, other means must be used to assess ages from immature post-cranial materials.

In any given population, children sustain relatively stable patterns of growth and development. If the chronological age of a sample of children is known, it is then possible to quantify their ages into increments based on measurements of unfused long bones. For example, a femur measuring 234.3 mm long can be correlated to an individual between the ages of 4.5 to 5.5 years (Ubelaker 1978). However, as with any sample study, a baseline must be established so as to minimize the effects of individual variation and to quantify the mean value of long bone lengths for associated ages. The above example of 234.3 mm is the mean value of femoral lengths correlating to individuals between the ages of 4.5 to 5.5 years, while the range of values for individuals in this age increment is 225.0 mm to 243.0 mm with a standard deviation of 9.0mm. Ideally, a baseline would be established for juveniles in a population; however, this would require knowledge of the chronological ages of at least part of the sample. If this data is unavailable, it is possible to adapt Ubelaker’s measurement increments to the population at hand, provided the acknowledgement that there exists potential for variation (Ubelaker, 1978).

The Sample

The sample for this study consisted of immature individuals from Tepe Hissar that were available for study in the "Bone Room”. According to Krogman, a total of 35 children from all three layers at Tepe Hissar are represented by cranial and mandibular specimens; the present researcher has established the
presence of 46 cranial bones, including maxillae and mandibles. Nevertheless, only 30 sets of immature post-cranial bones were present. Nowell describes the possibility of excavator bias against females and juveniles due to the large disproportionate ratio of males to females and adults to children. Nowell also points out the possibility of researcher bias towards the best preserved bones over ones that were poorly or adequately preserved (Nowell 1971).

In spite of this bias, it is still possible to study a subset of the sample. At least 4 individuals are represented by single sets of bones, including phalanges, clavicles, and ischia, none of which can accurately be used in a post-cranial to cranial age comparison for juveniles. Even so, within the set of 46 crania and set of 26 of remaining post-cranial remains, this study uncovered only 10 matching sets of post-cranial bones to dentition (See Table I).

Methodology

Post-cranial bones were selected on the basis of their fusion status. Any bones not having undergone or were currently undergoing epiphyseal union were included whereas any that had, with no visible evidence of the growth plate were excluded. 82 post-cranial long bones representative of 26 individuals were measured in millimeters in order associate an accurate age range. The measurements represent the maximum length of unfused diaphyses. Bones in the process of epiphyseal union were not measured for two reasons. First, bones undergoing epiphyseal union are not represented very well in Ubelaker's assessment. Measurements would not accurately represent the age of the individual, as the added length of proximal and distal epiphyses would result in
the bone being placed within a length range correlating to a higher age than is actually representative by the bone itself. Therefore, ages for these bones were determined on the biological timing of epiphyseal unions as described in numerous osteology texts.

Similarly, the mandibulae and maxillae representative of 46 individuals were assessed for age based on dental eruption status as well as comparison to Ubelaker's dental eruption chart (See Chart A). Mandibulae and maxillae that have not reached the classical signs of adulthood, more appropriately, complete eruption of the permanent dentition including third molars, were included in the sample.

The preliminary sampling yielded the above numbers of 26 individuals represented via post-cranial specimens and 46 individuals represented via cranial specimens. However, the integration of the two data sets to find those individuals represented by both cranial and post-cranial specimens yielded a value of ten (see Table I). Nine out ten were physically present in the room while the tenth individual is a comparison of available post-cranial specimens to an age estimate made by George Nowell in his 1971 Master's Thesis (Nowell, 1971, see also Table II).

In any study, a researcher must be aware of the potential for sample biases. The bone quality bias has been discussed earlier. In this study there is potential for age bias. If post-cranial and dental specimens belonging to the same individual were aged together, it is possible for the determined age of one set to influence the assessed age of the other set. For this reason, the dental
and post-cranial specimens were aged individual of each other. Secondly, if there is more than one post-cranial bone available to age a particular individual, the determined age of one bone may influence the determination of the age of other bones from the same individual. For this reason, post-cranial bones from a given individual were measured together, but were aged individually.

Sample Results

The sample results are depicted in Table II. On average, the dental age was either on par with, or greater than the post-cranial age. There were a few individuals whose dental age range lay outside the post-cranial age range, probably due to environment stressors and malnutrition during the individual's life resulting in stunted post-cranial growth, but had little or no effect on dental maturation.

The data sample is plotted on Graph I in a correlation curve. In this sample of ten individuals, there is a correlation of \((r) = 0.921\) between dental and post-cranial ages. The statistical calculations of \(r\) are shown in Appendix I. The value of \((r)\) is rather high for such a small sample size. The reason for this is the variation in the range of post-cranial specimens undergoing epiphyseal union. As discussed earlier, measurements were not taken for these bones; instead, the accepted age range for epiphyseal union was applied to the aforementioned specimens for the purposes of accuracy. However, this application was not without side effects. The increased value of the post-cranial specimens of the applied range had an effect on the mean and standard deviations of the post-cranial specimens (Appendix I), which ultimately led increased the value of \((r)\).
thus giving a falsely high correlation between dental and post-cranial ages. While a positive correlation is expected, one as high as \( r = 0.921 \) is not, instead, an \( r = 0.75 \) is probably more accurate for the study at hand.

**Interpretation of results and \( r \)**

The results yielded from the study indicate that there were few extreme stressors working on the sample population. This is indicative by the fact that there were few extreme differences between post-cranial and dental ages. Any truly damaging environmental stressors would have left indicators would be visible in the post-cranial skeleton. Growth of the post-cranial skeleton, while under some degree of genetic control, is very susceptible to environmental influence. A lack of resource availability would have caused a degradation of nutritional status, which would ultimately slow post-cranial growth. Unless corrected, this degraded nutritional status would result in slower growth and development comparative to dental growth and development. In terms of aging, the post-cranial age would be smaller than the dental age; with the degree of this difference based on the level of influence placed on the individual by environmental stress. A measure of this influence is seen in \( r \).

\( r \) is the correlation coefficient between two associated variables. In this study, the established value of \( r \) was 0.021. Therefore, in this juvenile sample, the value of dental age is closely correlated with the value of post-cranial age. As a result, it is possible then to infer the dental condition of existing post-cranial bones, and vice-versa. However, making such inferences should be cautioned against due to the small sample size and unusually high correlate of \( r \).
Conclusion

The study was performed on a sample of ten individuals from the site of Tepe Hissar. Skeletal data measurement techniques, in particular the Miles’ Method for dentition and Ubelaker’s post-cranial comparison, were described in order to provide background information for the methodology. Based on the two collection methods, two data sets were obtained: the first involving measurements of post-cranial long bones; the second involving dental maturation measurements and observations. Measurements of bone length and dental maturation were made independent of each other, and in the case of multiple long bones, each bone was assessed independently so as to remove bias from the assessed ages. These two data sets were then sorted in a manner that would pair up post-cranial and cranial bones from the same individual. Once paired, the correlation coefficient (r) was ascertained at a value of 0.921, indicating a high degree of association between post-cranial and dental ages.

The social implication for this correlation suggests that there weren’t many extreme environmental stressors in this juvenile population. However, one must be careful of making such an assumption, as there is still the initial excavator bias towards the collection and preservation of only the highest quality bones.

The sample of juveniles from Tepe Hissar is grossly under populated, potentially due to either the collection biases or the misplacement and/or mishandling of materials. However, with the data available, it is the opinion of this researcher that an accurate correlation between post-cranial and cranial ages was reached.
Acknowledgments

I would like to thank Dr. Alan Mann for advising me for this research project, as well as for the near infinite amount of knowledge I have gained from his classes over the past two years. I would also like to thank Dr. Janet Monge for her advice on this project and for allowing me access to the skeletal materials at Tepe Hissar.
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* Comparison to Nowell's Data

33-23-210
33-23-226
33-23-242
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<td>326</td>
<td>9 - 10</td>
<td>8.67</td>
<td>man</td>
<td>M1 erupted, M2 in crypt crown complete, P2 pres</td>
<td>8 - 10</td>
<td>9.0</td>
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<td></td>
<td>L Fib</td>
<td>243</td>
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<td></td>
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<td></td>
<td></td>
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<td>7 - 8</td>
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<tr>
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<td>6.5 - 7.5</td>
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<td></td>
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<tr>
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<td>L Tib</td>
<td>237</td>
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<td>246</td>
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<td>M2's erupting, M3 crown visible in crypt</td>
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<td>215</td>
<td>7.5 - 8.5</td>
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<td>R Hum</td>
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<td>7.5 - 8.5</td>
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<td>33-16-091</td>
<td>L Hum</td>
<td>167</td>
<td>4.5 - 5.5</td>
<td>5.0</td>
<td>man</td>
<td>M1 erupted</td>
<td>6 - 8</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td>R Hum</td>
<td>170</td>
<td>4.5 - 5.5</td>
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<td>33-16-103</td>
<td>L Fem</td>
<td>316</td>
<td>8.5 - 9.5</td>
<td>8.33</td>
<td>man</td>
<td>M2 about to erupt</td>
<td>8 - 10</td>
<td>9.0</td>
</tr>
<tr>
<td></td>
<td>L Tib</td>
<td>249</td>
<td>7.5 - 8.5</td>
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<tr>
<td></td>
<td>L Fib</td>
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<td>293</td>
<td>12 - 13</td>
<td>12.5</td>
<td>man</td>
<td>M2 Fully erupted; M3 Crown forming</td>
<td>12 - 14</td>
<td>13.0</td>
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<td></td>
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<td>12 - 13</td>
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<td>273</td>
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<td>man</td>
<td>M1 just erupted, I1 about to erupt, P1, P2 Pres, M2</td>
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### Table II
**Dental vs Post Cranial Aging**

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<th>Individual</th>
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<th>Length (mm)</th>
<th>Age Range</th>
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<td>-</td>
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<td>16.75</td>
<td>man</td>
<td>M3 Crown partially formed</td>
<td>14 - 18</td>
<td>16.0</td>
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<tr>
<td></td>
<td>R Tib</td>
<td>-</td>
<td>14 - 18</td>
<td></td>
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<td>M2's recently erupted</td>
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<td>L Fem</td>
<td>-</td>
<td>15 - 18</td>
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<td></td>
<td>R Fem</td>
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<td>-</td>
<td>14 - 18</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>R Hum</td>
<td>-</td>
<td>14 - 20</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>R Rad</td>
<td>-</td>
<td>16 - 20</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>R Ulna</td>
<td>-</td>
<td>16 - 20</td>
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</tbody>
</table>

---

Comparison to Nowell's Data (Nowell 1971, Appendix I)

The Dental ages below come from George Nowell's aging study of the Tepe Hissar Sample. His data is provided due to the lack of availability of dental correlates to present post-cranial materials.

<table>
<thead>
<tr>
<th>Individual</th>
<th>Bone</th>
<th>Length (mm)</th>
<th>Age Range</th>
<th>Age</th>
<th>Max/Man</th>
<th>Range</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R Fem</td>
<td>-</td>
<td>15 - 18</td>
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</tr>
<tr>
<td></td>
<td>L Tib</td>
<td>-</td>
<td>14 - 18</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>R Tib</td>
<td>-</td>
<td>14 - 18</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>L Hum</td>
<td>-</td>
<td>14 - 20</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>R Hum</td>
<td>-</td>
<td>14 - 20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>L Rad</td>
<td>-</td>
<td>16 - 20</td>
<td></td>
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</tbody>
</table>
Appendix I
Calculation of Correlation Coefficient (r)

<table>
<thead>
<tr>
<th>Xi</th>
<th>Xi in SU</th>
<th>Yi</th>
<th>Y in SU</th>
<th>(SU) * Y(SU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.5</td>
<td>-1.36</td>
<td>7</td>
<td>-0.86</td>
<td>1.17</td>
</tr>
<tr>
<td>7</td>
<td>-1.23</td>
<td>5</td>
<td>-1.38</td>
<td>1.70</td>
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<td>9</td>
<td>-0.71</td>
<td>8.33</td>
<td>-0.52</td>
<td>0.37</td>
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<tr>
<td>9</td>
<td>-0.71</td>
<td>8.67</td>
<td>-0.43</td>
<td>0.31</td>
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<tr>
<td>10.5</td>
<td>-0.32</td>
<td>7.67</td>
<td>-0.69</td>
<td>0.22</td>
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<tr>
<td>.2</td>
<td>0.07</td>
<td>8.25</td>
<td>-0.54</td>
<td>-0.04</td>
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<tr>
<td>.3</td>
<td>0.38</td>
<td>12.5</td>
<td>0.56</td>
<td>0.18</td>
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<tr>
<td>.6</td>
<td>1.12</td>
<td>12.5</td>
<td>0.56</td>
<td>0.63</td>
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<tr>
<td>16</td>
<td>1.12</td>
<td>16.75</td>
<td>1.66</td>
<td>1.86</td>
</tr>
<tr>
<td>16.25</td>
<td>1.70</td>
<td>16.71</td>
<td>1.65</td>
<td>2.81</td>
</tr>
</tbody>
</table>

Calculation of correlation coefficient:

\[
\begin{align*}
\text{Sum (Xi)} &= 117.25 \\
\text{Mean (Xi)} &= 117.25/10 = 11.725 \\
\text{SD (Xi)} &= 3.83 \\
\text{Conversion to SU} &= (\text{Xi} - \text{Xm})/\text{SD(Xi)} \\
\text{Sum (Yi)} &= 103.38 \\
\text{Mean (Yi)} &= 103.38/10 = 10.338 \\
\text{SD (Yi)} &= 3.86 \\
\text{Conversion to SU} &= (\text{Yi} - \text{Ym})/\text{SD(Yi)} \\
\end{align*}
\]

\[
\text{Sum (X*Y)} = 9.21 \\
r = 9.21 / 10 \approx 0.921
\]

Given the sample size, a correlation coefficient of \( r = 0.921 \) works to prove the closeness of dental and post-cranial aging techniques.
Chart A

5 months in utero (± 2 mos.)

7 months in utero (± 2 mos.)

Birth (± 2 mos.)

6 months (± 3 mos.)

9 months (± 3 mos.)

1 year (± 4 mos.)

18 months (± 6 mos.)

2 years (± 8 mos.)

3 years (± 12 mos.)

4 years (± 12 mos.)

5 years (± 18 mos.)

6 years (± 24 mos.)

7 years (± 24 mos.)

8 years (± 24 mos.)

9 years (± 24 mos.)

10 years (± 30 mos.)

11 years (± 36 mos.)

12 years (± 36 mos.)

15 years (± 36 mos.)

21 years

35 years

from Ubelaker 1989a, Figure 71
Bibliography


Glantz, Michelle., PhD Dissertation.


Krogman, Wilton Marion, "Racial Types From Tepe Hissar, From the Late Fifth To the Early Second Millennium, B.C.," 1940.


