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The Morphological Aspects of the Mandibular Fossa: A Method for Reconstructing Food Texture in Antiquity

Abdel Halim al-Shiyab*, Abdulla al-Shorman *

Abstract

This study analyzes the variables of slope length, angle, width and depth of the mandibular fossa in archaeological populations to test the impact of consuming hard food items on them. Using those variables, the study suggests a new method for reconstructing the food texture of ancient populations, which is applied to a sample of 27 skulls from the Queen Alia International Airport (QAIA) and 30 skulls from Wadi Faynan (WF): two late Roman archaeological sites. The fossae were molded using a special paste, cut longitudinally and imprinted on tracing paper in order to measure those variables. The results show that the people of WF had consumed harder food stuffs than the people of Queen Alia International Airport. Seen in longitudinal section, consumption of hard food appears to increase the angle of the mandibular fossa relative to those eating softer food.

Keywords: Paleodiet, Jordan, Wadi Faynan, QAIA, Late Roman, Mandibular Fossa.

Introduction

Recent anthropological literature abounds in studies on paleodiet that use a wide array of methods, including stable carbon and nitrogen isotope analyses (Quade et al. 1995; Cerling, et al. 1997; Barrett et al. 2001, Keenleyside et al. 2006; Kundson et al. 2007), trace element analyses (Ambrose and Krigbaum 2003; Radosevich 1993; Djingova et al. 2004; Sponheimer et al. 2005) as well as dental wear and caries studies (Grine et al. 2006; Caglar et al. 2007; Polo-Cerdá et al. 2007). Other studies have identified the ratio of food types like protein and carbohydrates (Oudemans and Boon 1991; El-Najjar and Al-Shiyab 1998), social status (Privat et al. 2002; Al-Shorman 2003; Vodanović et al. 2005) and indirectly

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* Anthropology Department, Faculty of Archaeology and Anthropology, Yarmouk University.
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subsistence strategy (Katzenberg et al. 1995; Louwagie et al. 2006). Unfortunately very few studies have been concerned with the physical properties of diet (hardness) especially in the region of Jordan even though archaeological human remains are very abundant.

Continuous and prolonged consumption of hard food requires greater forces of mastication and consequently enhances the process of dental wear (Bourdiol and Mioche 2000). Strong forces of mastication were believed to modify contours and depth of the mandibular fossa at the base of the skull (Hinton 1981). Consequently the morphology of the mandibular fossa may indicate the texture of the consumed food. The mandibular fossa is located in the base of the squamous portion of the temporal bone; it is a depression forming the cranial part of the temporo-mandibular joint. The mandibular fossa is divided into two halves by the squamo-tympanic fissure. In living individuals, the mandibular fossa contains the mandibular condyle and the articular disc. It is concave with a rounded apex directed toward the middle cranial fossa (fig. 1).

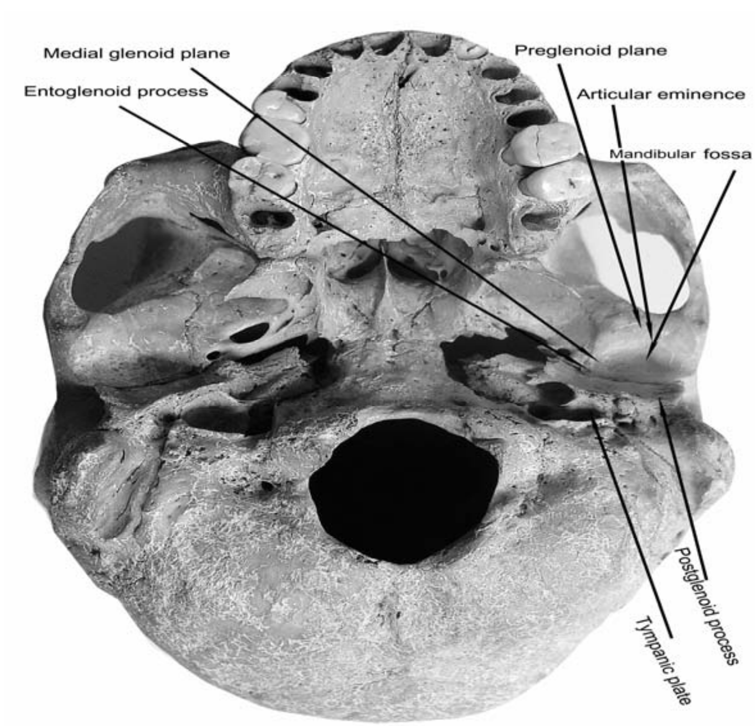

Fig. 1: Position and anatomical landmarks of the mandibular fossa

Previous studies on the morphology of the mandibular fossa ended with contradictory results probably due to instrumentation and personal errors. Hinton (1981) found that a stress imposed on the mandible contributes to the changing slope and depth of the mandibular fossa. Knowles (1915) stated that the tough food consumed by Eskimos made the mandibular fossa shallow but he was contradicted by Dimirjian (1967). Nevakari (1960) found no differences in the depth between males and females (although the impinged forces of mastication are different), while Lindblom (1960) found significant statistical differences. Granados (1979) found that the higher angulations of the mandibular fossa contribute to tooth loss and attrition.

This study examines the morphological features of the mandibular fossa from two archaeological sites in Jordan: the Queen Alia International Airport (QAIA) and Wadi Faynan (WF). Those morphological features are slope length, angle, width and height. After identifying statistically the most significant variable that could be affected by food type, the paper reconstructs the food type consumed by people in these sites.

The Queen Alia International Airport (QAIA)

The QAIA site is located about 25km south of the city of Amman and east of the city of Madaba in a broad plain between the Wadi al-Quleib/Wadi al-Manshiya on the west and the Wadi al-Matabba on the east. The west area of the site is very fertile, while the eastern area is semiarid. The altitude of the site is about 730m above sea level and the annual amount of precipitation is about 110mm (Ibrahim and Gordon 1987). In 1978, a team from the Department of Antiquities in Jordan conducted a salvage excavation at the site and dated it to Late Roman period. The team recovered 52 human skeletal remains in very good state of preservation. The orientation of the graves was east-west at a depth of about 160cm below the surface.

Wadi Faynan (WF)

The WF site is located approximately 300km to the southwest of the city of Amman. The site is situated on the eastern side of Wadi Arabah, 5km to the east of the village of Qurayqira. It is one of the most important but least explored archaeological sites in Southern Jordan. The region was first visited and surveyed in the 19th century, by Frank (1991), Glueck (1935) and Kind (1965). Recently, survey work has been carried out by MacDonald (1992), Raikes (1980) and King (1989). The first season of systematic excavation took place in 1995 and 1996. The site appears to have been used or occupied from at least the 7th millennium BC. With the evidence of many settlements still in existence, the main activities of the people of WF were copper mining and agriculture. The altitude of the site varies from 140 to 300m above sea level. The area is hot and dry in summer but cold in winter with annual precipitation of about 80mm. The site was abandoned between 2500 and 3000 BC, and then the mines were reopened during the Roman period for copper ores that had not been exploited by the Bronze Age miners (Hauptmann 1986). Fifty-five human skeletons were recovered, of which 90% are complete. The skeletons are dated to the Late Roman period. The biological and pathological features of those skeletons have been analyzed by El-Najjar and Al-Shiyab (1998), who stressed the presence of osteoarthritis.

Material and methods

The sample from the QAIA archaeological site numbers 27 skulls (15 males and 12 females). The sample from WF numbers 30 skulls (20 males and 10 females). Dating was based on artifact assemblage (Late Roman). The selected samples were in a very good state of preservation with intact skull bases, which preserved the detailed morphological features of the mandibular fossae. Skulls with damaged bases and unidentifiable sex were excluded from the sample.

QAIA and WF represent two different environmental and climatic settings, and subsistence economies. They also vary in their topography which in turn would have affected subsistence strategies or food acquisition and preparation techniques. The mandibular fossae (right and left) of every skeleton in both sites were molded using a mixture of cloxane base and catalyst. The molds were then dissected longitudinally parallel to the squamo-tympanic fissure for measurement purposes (fig. 2). A print for each fossa was produced using Indian ink on tracing paper. The slope length, height, width and slope angle were measured as shown in figure 4. Sexing and aging were recorded following the methods of Buikstra and

Ubelaker (1994), based on the anatomical features of the skull and pelvis.

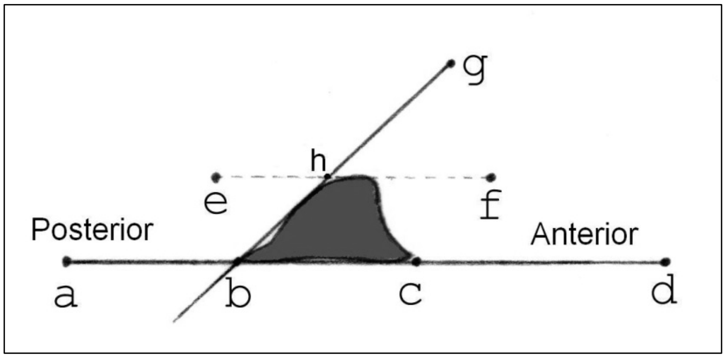

Fig. 2: A schematic print of a longitudinal section of a left mandibular fossa: gbc is the angle, ef is the maximum depth measured from ad, bc is the width, bh is the slope length.

Results and discussion

Four morphological variables of the mandibular fossa were identified by the previous studies: slope length, angle, width, and depth (fig. 2). After reviewing the literature, we expected to find statistical differences in the slope length of the mandibular fossa between the left and the right side in each site. That expectation was based on the assumption by Dimirjian (1967) that tooth loss modifies the morphology of the fossa. We hypothesized that there would be no uniform tooth loss in any given skull on both sides (it is not necessary, for example, to have a first molar antemortem loss on the right side and left side at the same time) and thus running ANOVA (Analysis of Variance) on the above variables between the right and left fossa would test the hypothesis. At QAIA, ANOVA shows that there is no significant statistical difference between the mean of the right slope length and the mean of the left slope length in the male population (table 1):

Table 1: ANOVA between right and left slope length at QAIA

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F critical*
Between groups	0.30	1	0.30	0.08	0.77	4.21
Within groups	101.66	27	3.76			
Total	101.96	28				

H_0: the mean of slope length left = the mean of slope length right… at P = 0.05

H_1: the mean of slope length left ≠ the mean of slope length right… at P = 0.05

H_0 is accepted since the P value (0.77) is larger than 0.05 and H_1 is rejected, meaning that the slope length on both sides were the same, eliminating the effect of tooth loss. The same ANOVA results were achieved using the angle and depth but not width (table 2). So H_0, which states that the mean width in the right fossa is equal to the mean in the left fossa, is rejected, as the calculated P value (0.007) is smaller than 0.05. Variation in width might be related to the habit of chewing on one side triggered by tooth loss on the other side. The absence of differences among the right and left fossa in QAIA could be related to the lower mean age, which is 40.6 years for males and 41.1 years for females. It could also be related to the lower number of cases of antemortem tooth loss. The female population of QAIA shows the same ANOVA results.

Table 2: ANOVA on right and left width at QAIA

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	39.10	1	39.10	8.48	0.007	4.21
Within Groups	124.45	27	4.61			
Total	163.55	28				

ANOVA results from the male population of Wadi Faynan also show that the mean values for right and left fossae were the same, except for the width. The female population shows the same results as males and also indicates that the intra-population variation in skull size is large as well. The standard deviation of the width in QAIA is 2.25 for the male population and 1.5 for the female population. The higher standard deviation in males and the lower standard deviation in females may indicate intra-population variation and sexual dimorphism. In WF the standard deviation in the width measurements is 2.4 for the male population and 1.2 for females.

We compared the mean values of the previous four variables (slope length, slope angle, height and width) between QAIA and WF using ANOVA analysis (tables 3-6). We hypothesized that the mean value of each variable in QAIA is equal to that in WF. We performed ANOVA analysis for comparing the left fossa only because it was previously demonstrated that left and right fossa measurements were statistically the same in each site.

Table 3: ANOVA between the slope length of QAIA and that of WF

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	4.58	1	4.58	1.54	0.22	4.21
Within Groups	80.16	27	2.97			
Total	84.74	28				

H_0 is accepted: the mean slope length at QAIA is not statistically different from the mean slope length of WF.

Table 4: ANOVA between the height of QAIA and that of WF

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	1.294	1	1.294	1.745	0.19	4.21
Within Groups	19.90	27	0.74			
Total	21.19	28				

H_0 is accepted: the mean height at QAIA is not statistically different from WF.

Table 5: ANOVA between the width of QAIA and that of WF

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	0.003	1	0.003	0.0005	0.98	4.15
Within Groups	175.68	32	5.49			
Total	175.68	33				

H_0 is accepted: the mean width in QAIA is not statistically different from the mean width of WF.

Table 6: ANOVA between the slope angle of QAIA and that of WF

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	136.88	1	136.88	4.65	0.04	4.21
Within Groups	794.09	27	29.41			
Total	930.97	28				

H_0 is rejected: the mean angle in QAIA is statistically different from the mean angle of WF. The mean angle value at WF (38.21°) is larger than the mean angle value at QAIA (33.68°), which means that the diet consumed by the people of WF required greater mastication forces while eating compared to the people of QAIA and consequently had increased the angulations of their mandibular fossae. Greater mastication forces are usually applied when the consumed food is harder (Hinton 1981; Granados 1979; Knowles 1915). Based on the study by Al-Saad (2003), dental wear among the people of QAIA is moderate with caries, while dental wear among the people of WF is severe with minimal caries (El-Najjar and Al-Shiyab 1998). So it is expected that the diet of the people of WF might have contained more meat and raw stables while the people of QAIA might have consumed more carbohydrates without introducing hard food items. That explanation makes sense because the landscape is not fertile at WF but is arable and fertile at QAIA.

The measurements of the mandibular fossa (especially the angle) would only be reliable if geometrically the angle (gbc) is inversely related to the slope length and height of the mandibular fossa because the three variables form a geometric triangle. Testing that relationship by applying a correlation coefficient among the four variables at the site of QAIA and WF demonstrates the reliability of the measurements, as shown in the tables below:

Table 7: Correlations among the variables of slope length, slope angle (θ) and height at QAIA

QAIA	***slope length***	***slope angle***	***height***	***width***
slope length	1			
slope angle	-0.5	1		
height	0.7	0.09	1	
width	0.25	-0.08	0.34	1

Table 8: Correlations among the variables of slope length, slope angle (θ) and height at WF

WF	***slope length***	***slope angle***	***height***	***width***
slope length	1			
slope angle	-0.5	1		
height	0.31	0.5	1	
width	0.51	-0.1	0.6	1

The results show a negative relationship between slope length and slope angle (r = -0.5) and a positive relationship between slope length and height at QAIA. A weaker relationship is noticed between height and width (r = 0.34) and another weaker relationship between width and slope length. The results of WF show strong negative relationships between slope angle and slope length (r = -0.05); between width and slope length (r = 0.51); between slope angle and height (r = 0.50) and between width and height (r = 0.6). The correlation results parallel the correlation results in the geometric triangle where the angle increases if the height and hypotenuse length increases. We found no relationship between age and any of the four variables in both QAIA and WF because the mean age in each sites is considered to be young. Females tend to have smaller measurements in both sites probably due to sexual dimorphism in the shape of the skull.

Conclusions

The prolonged consumption of hard food and/or uncooked food is strongly associated with changes in the morphology of the mandibular fossa. The most significant change is an increase in the angle of the fossa compared to people not eating hard foods on a systematic basis. It is significant that the subsistence strategy and food preparation methods have left clear marks on the mandibular fossa, and that morphology can be used to infer differences in diet. Although further study of the biomechanics of the temporo-mandibular joint is essential, the results of this research can shed light on human diet, adaptation and subsistence strategies.

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الجوانب الشكلية للحفرة الصدغية: طريقة لإعادة بناء نسيج الغذاء في المجتمعات القديمة

عبد الحليم الشياب وعبد ا الشرمان**

ملخـص

تحلل هذه الدراسة عوامل كل من الطول والميل والزاوية والعرض وعمق الحفرة الصدغية للمجتمعات الأثرية؛ بهدف فحص أثر استهلاك نوعية الغذاء في الحفرة.
بناء على العوامل السابقة تقترح الدراسة طريقة جديدة لإعادة بناء قوام الغذاء للمجتمعات القديمة، التي طبقت على مجتمعي مطار الملكة علياء الدولي ووادي فينان للفترة الرومانية المتأخرة.
تناولت الدراسة ٢٧ جمجمة من مطار الملكة علياء الدولي، و٣٠ جمجمة من وادي فينان، وقد تم صنع قالب للحفرة باستخدام معاجين خاصة قطعت طولياً، حيث تمت طباعة المقطع لأجل عمل القياسات اللازمة. دلت نتائج الدراسة على أن سكان وادي فينان قد تناولوا طعاماً أقسى من سكان مطار الملكة علياء الدولي، حيث إن استهلاك الطعام القاسي يزيد من زاوية الحفرة الصدغية.

الكلمات الدالة: الأردن، الغذاء القديم، وادي فينان، مطار الملكة علياء، الفترة الرومانية المتأخرة، الحفرة الصدغية.

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* قسم الأنثروبولوجيا، كلية الآثار والأنثروبولوجيا، جامعة اليرموك، اربد، الأردن.

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