# Maxillary and Mandibular Jaw Size in Pre-Columbian Peru

DANNY R. SAWYER, D.D.S., PH.D.

*Department of Pathology, Medical College of Virginia, Health Sciences Division of Virginia Commonwealth University, Richmond, Virginia*

MARVIN J. ALLISON, PH.D.

*Department of Pathology, Medical College of Virginia, Health Sciences Division of Virginia Commonwealth University, Richmond, Virginia*

RICHARD P. ELZAY, D.D.S., M.S.D.

*Department of Oral Pathology, Medical College of Virginia, Health Sciences Division of Virginia Commonwealth University, Richmond, Virginia*

DENNIS G. PAGE, D.D.S., M.S.

*Department of Oral Pathology, Medical College of Virginia, Health Sciences Division of Virginia Commonwealth University, Richmond, Virginia*

ALEJANDRO PEZZIA, PH.D

*Curator, Regional Museum of Ica, Ica, Peru*

## Introduction

Varying techniques of measurement coupled with lack of sufficient data have presented great difficulties in the comparison of dental arch dimensions obtained by different workers. Several authors[1-7] have attempted to delineate the arches. Lavelle et al[7] measured the dental arches of adults from several different ethnic groups and found little difference between the modern British Caucasian, Australian aborigines, and North American Indians. They did, however, see considerable differences between these modern populations and a group of Anglo-Saxons and a group of West Africans.

Several studies[8-10] have shown that there has been a reduction in the dimensions of the maxilla and mandible in modern times, although no reduction in tooth size was reported. A variety of explanations have been put forth to explain this reduction in jaw size, among them evolutionary change[11] and consistency of diet.[12] Others[13-16] have shown that bone size is affected by mechanical stress or the lack of it. Since the modern diet is softer than that of past periods, it is reasoned that the soft diet requires less mechanical force to masticate and thus less mechanical stress on the bone. This reduction in mechanical stress is assumed then to lead to reduction of jaw size.

Supported by a grant from the National Geographic Society and a NIDR, NIH Fellowship No. IF 32 DE 05091-01.

Correspondence and reprint requests to Dr. Danny R. Sawyer, Department of Pathology, Medical College of Virginia, Richmond, VA 23298.

The present study was undertaken to investigate any changes in jaw size that occurred within the time period (2300 years) encompassed by the six pre-Columbian Peruvian cultures studied, and from that period to modern times.

**Materials and Methods**

Measurements were made on 84 adult maxillae and 114 adult mandibles from the pre-Columbian Peruvian material housed in the Museo Regional de Ica, Ica, Peru; these were made up of the following number of specimens from each of the six cultures: Paracas, 33 maxillae and 33 mandibles; Nazca, 6 maxillae and 20 mandibles; Huari, 10 maxillae and 14 mandibles; Ica, 19 maxillae and 24 mandibles; Inca, 1 maxilla and 2 mandibles; and Colonial, 15 maxillae and 21 mandibles. These six cultures flourished during the following periods: Paracas, 600 BC–AD 100; Nazca, 100 BC–AD 800; Huari, AD 800–AD 1200; Ica, AD 1200–AD 1450; Inca, AD 1450–AD 1532; and Colonial, AD 1534–AD 1700. The dating of this material was carried out by both archaeological and C-14 dating. Sex determinations were carried out as outlined by Allison and Gerszten,[17] although these could not be made accurately on some of the material; the values for this unsexed material appear in the tables under the heading "unknown."

A total of 12 jaw dimensions were measured; 4 of the maxilla and 8 of the mandible. The dimensions of arch width were measured between the centers of the corresponding teeth on each side of the dental arch at the first premolars, first molars and second molars in both the maxillae and mandibles. Maxillary arch length was measured as outlined by Moyers.[18] All measurements of the maxilla were made using dial calipers with an accuracy of 0.1 mm. Measurements of the mandible were taken[19] using dial calipers with an accuracy of 0.1 mm and a mandibular board. While the measurements of the maxillary and mandibular arch widths at the first premolar and the first and second molars have been explained, the maxillary arch length and the other mandibular measurements must be defined. Maxillary arch length was measured by laying a bar across the central fossae of the first molars and measuring from the midline point along this bar to the incisal edge of the central incisors. The mandibular angle is the angle between the standard horizontal plane and the ramal planes. The height of the ramus is from the most superior point on the left condyle to the standard horizontal plane (base of mandibular board) measured in the vertical plane. The body length is from the most anterior point in the symphysis area to the intersection of the standard horizontal and ramal planes. Bigonial width is the maximum width between the right and left gonion of the mandible. Bicondylar width is the maximum width between the lateral points of the right and left condyles. Although Hrdlička[4] states that bicondylar measurement is completely useless as the width is affected by the width of the skull at its base, many other authors have used bicondylar measurement to define the mandibular arch and it is, therefore, included in this study.

While 84 adult maxillae and 114 adult mandibles were measured, all totals for each of these measurements will not come to these numbers because of missing teeth, fractured condyles, and other factors.

**Results**

Females in all cultures shown in Table 1 have the larger maxillary arch size in three of the four measurements made. Maxillary arch width at the first premolar is larger in males in all cultures except the Ica. No reduction of maxillary arch size is seen during the approximately 2300-year period studied in this pre-Columbian Peruvian culture except in the width of the arch at the first molar; a reduction is seen here from the most ancient cultures studied to the most modern. The Inca culture exhibited the smallest maxillary arch length while the Huari culture, followed closely by the Nazca, showed the greatest. The smallest arch width at the maxillary first premolar was seen in the Inca culture and the Colonial exhibited the largest width. The largest arch width at the maxillary first molar was seen in the Nazca culture; the Colonial had the most narrow arch at the first molars. The Huari displayed the smallest and the Ica the largest arch widths at the maxillary second molars.

Table 2 gives five mandibular jaw measurements. The males of this pre-Columbian Peruvian population exhibited the larger arch width at the first mandibular molar, the larger bigonial width, and the larger bicondylar width; other measurements presented (mandibular arch width at the first premolar and second molar) were similar in both sexes. A trend toward smaller mandibular jaw size was evident by a reduction in jaw size at the first molar, second molar, and bigonial widths. The Nazca culture and the Paracas culture had the largest mandibular arch widths at the first premolars. The arch width at the first and second mandibular molars and the bigonial width

**TABLE 1**
**Maxillary Arch Measurements**

| | Maxillary arch length | | | | Maxillary arch width at first premolar | | | | Maxillary arch width at first molar | | | | Maxillary arch width at second molar | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Culture | M | F | U | T | M | F | U | T | M | F | U | T | M | F | U | T |
| Paracas | | | | | | | | | | | | | | | | |
| N | 0 | 0 | 6 | 6 | 0 | 0 | 22 | 22 | 0 | 0 | 33 | 33 | 0 | 0 | 28 | 28 |
| Mean | — | — | 25.4 | 25.4 | — | — | 39.6 | 39.6 | — | — | 48.8 | 48.8 | — | — | 53.6 | 53.6 |
| S.E. | — | — | 0.9 | 0.9 | — | — | 0.6 | 0.6 | — | — | 0.6 | 0.6 | — | — | 2.8 | 2.8 |
| Nazca | | | | | | | | | | | | | | | | |
| N | 1 | 0 | 3 | 4 | 1 | 1 | 4 | 6 | 1 | 0 | 5 | 6 | 1 | 1 | 3 | 5 |
| Mean | 22.7 | — | 27.2 | 26.1 | 36.1 | 36.1 | 39.9 | 39.8 | 53.4 | — | 49.6 | 50.3 | 57.0 | 51.4 | 54.3 | 54.3 |
| S.E. | 0.0 | — | 1.1 | 1.4 | 0.0 | 0.0 | 0.7 | 1.0 | 0.0 | — | 0.3 | 0.7 | 0.0 | 0.0 | 1.8 | 1.3 |
| Huari | | | | | | | | | | | | | | | | |
| N | 1 | 0 | 4 | 5 | 1 | 1 | 4 | 6 | 1 | 2 | 7 | 10 | 1 | 2 | 6 | 9 |
| Mean | 27.0 | — | 26.8 | 26.8 | 40.3 | 36.3 | 39.9 | 39.4 | 47.2 | 48.0 | 47.8 | 47.8 | 52.3 | 52.8 | 53.1 | 52.9 |
| S.E. | 0.0 | — | 1.0 | 1.0 | 0.0 | 0.0 | 0.8 | 0.8 | 0.0 | 2.5 | 1.1 | 0.8 | 0.0 | 2.9 | 1.0 | 0.8 |
| Ica | | | | | | | | | | | | | | | | |
| N | 1 | 9 | 4 | 14 | 1 | 13 | 1 | 15 | 1 | 11 | 7 | 19 | 1 | 7 | 2 | 10 |
| Mean | 25.3 | 27.0 | 26.2 | 26.7 | 39.4 | 39.7 | 39.0 | 39.6 | 50.7 | 48.7 | 45.8 | 47.8 | 52.7 | 54.6 | 56.7 | 54.8 |
| S.E. | 0.0 | 0.7 | 0.9 | 0.5 | 0.0 | 0.5 | 0.0 | 0.4 | 0.0 | 0.8 | 1.9 | 0.9 | 0.0 | 0.7 | 0.7 | 0.6 |
| Inca | | | | | | | | | | | | | | | | |
| N | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| Mean | — | — | 24.8 | 24.8 | — | — | 36.9 | 36.9 | — | — | 47.9 | 47.9 | — | — | 54.2 | 54.2 |
| S.E. | — | — | 0.0 | 0.0 | — | — | 0.0 | 0.0 | — | — | 0.0 | 0.0 | — | — | 0.0 | 0.0 |
| Colonial | | | | | | | | | | | | | | | | |
| N | 0 | 12 | 3 | 15 | 2 | 12 | 0 | 14 | 1 | 10 | 2 | 13 | 1 | 11 | 0 | 12 |
| Mean | — | 24.9 | 25.9 | 25.1 | 42.4 | 40.0 | — | 40.3 | 45.6 | 48.3 | 46.4 | 47.8 | 52.3 | 53.6 | — | 53.5 |
| S.E. | — | 0.4 | 1.2 | 0.4 | 0.3 | 0.6 | — | 0.5 | 0.0 | 0.6 | 1.0 | 0.5 | 0.0 | 0.7 | — | 0.7 |

M = male
F = female
U = sex unknown
T = total
N = number
S.E. = standard error

were larger in the Nazca culture. The Huari, followed closely by the Nazca culture, had the greatest bicondylar width. The mandibular jaw size measurements presented in Table 2 were consistently smaller in the Inca culture, although this figure can be misleading due to the small sample size.

For three other mandibular jaw measurements (mandibular angle, ramus height, and body length) presented in Table 3, the male specimens in this study have the larger measurements, although no reduction in jaw size is seen from the most ancient to the most modern cultures. The Paracas culture exhibits the largest mandibular angle and the Nazca the smallest in this pre-Columbian Peruvian population. The Paracas culture shows the smallest ramus height and the Colonial has the greatest. In examining the body length measurements, the Nazca culture specimens have the longest mandibular body and the Inca have the shortest.

## Discussion

The size and shape of the dental arches are subject to considerable variation.[3] Factors such as growth[20] and the location of the teeth in relation to

**TABLE 2**
**Mandibular Jaw Width**

| | Mandibular arch width at first Premolar | | | | Mandibular arch width at first Molar | | | | Mandibular arch width at second Molar | | | | Bigonial width | | | | Bicondylar width | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Culture | M | F | U | T | M | F | U | T | M | F | U | T | M | F | U | T | M | F | U | T |
| Paracas | | | | | | | | | | | | | | | | | | | | |
| N | 0 | 0 | 19 | 19 | 0 | 0 | 18 | 18 | 0 | 0 | 14 | 14 | 1 | 1 | 28 | 30 | 1 | 1 | 30 | 32 |
| Mean | — | — | 34.9 | 34.9 | — | — | 44.8 | 44.8 | — | — | 49.8 | 49.8 | 96.0 | 96.0 | 93.3 | 93.5 | 121.5 | 112.0 | 116.9 | 116.9 |
| S.E. | — | — | 0.5 | 0.5 | — | — | 0.6 | 0.6 | — | — | 0.7 | 0.7 | 0.0 | 0.0 | 1.4 | 1.3 | 0.0 | 0.0 | 1.7 | 1.6 |
| Nazca | | | | | | | | | | | | | | | | | | | | |
| N | 1 | 1 | 10 | 12 | 1 | 1 | 14 | 16 | 1 | 0 | 13 | 14 | 1 | 1 | 18 | 20 | 1 | 1 | 18 | 20 |
| Mean | 35.5 | 35.4 | 34.8 | 34.9 | 48.2 | 43.7 | 46.5 | 46.4 | 55.7 | — | 51.4 | 51.7 | 90.0 | 81.5 | 95.0 | 95.8 | 111.0 | 118.0 | 118.5 | 118.1 |
| S.E. | 0.0 | 0.0 | 0.5 | 0.4 | 0.0 | 0.0 | 0.4 | 0.4 | 0.0 | — | 0.4 | 0.6 | 0.0 | 0.0 | 2.1 | 2.4 | 0.0 | 0.0 | 1.3 | 1.3 |
| Huari | | | | | | | | | | | | | | | | | | | | |
| N | 1 | 2 | 8 | 11 | 1 | 1 | 7 | 9 | 1 | 0 | 6 | 7 | 2 | 2 | 9 | 13 | 2 | 2 | 9 | 13 |
| Mean | 32.5 | 33.8 | 34.1 | 33.9 | 42.6 | 42.3 | 45.9 | 45.2 | 47.0 | — | 51.6 | 50.9 | 101.5 | 85.8 | 93.4 | 93.5 | 124.0 | 120.5 | 118.1 | 118.6 |
| S.E. | 0.0 | 0.4 | 0.6 | 0.5 | 0.0 | 0.0 | 0.4 | 0.6 | 0.0 | — | 1.2 | 1.2 | 0.0 | 0.2 | 1.7 | 1.7 | 1.0 | 2.5 | 2.3 | 1.8 |
| Ica | | | | | | | | | | | | | | | | | | | | |
| N | 2 | 14 | 4 | 20 | 1 | 11 | 8 | 20 | 1 | 10 | 1 | 12 | 4 | 16 | 7 | 27 | 4 | 17 | 7 | 28 |
| Mean | 37.2 | 35.0 | 33.3 | 34.9 | 49.2 | 45.5 | 44.4 | 44.9 | 52.4 | 49.8 | 56.3 | 50.4 | 94.1 | 93.6 | 90.4 | 92.8 | 119.3 | 118.9 | 117.2 | 118.5 |
| S.E. | 2.5 | 0.5 | 1.2 | 0.5 | 0.0 | 0.8 | 1.1 | 0.7 | 0.0 | 0.6 | 0.0 | 0.8 | 3.0 | 1.3 | 2.2 | 1.4 | 1.8 | 1.2 | 3.0 | 1.1 |
| Inca | | | | | | | | | | | | | | | | | | | | |
| N | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 2 | 0 | 1 | 1 | 2 |
| Mean | — | — | 31.3 | 31.3 | — | — | 42.6 | 42.6 | — | — | 48.1 | 48.1 | — | 94.0 | 88.0 | 91.0 | — | 118.5 | 111.0 | 114.8 |
| S.E. | — | — | 0.0 | 0.0 | — | — | 0.0 | 0.0 | — | — | 0.0 | 0.0 | — | 0.0 | 0.0 | 3.0 | — | 0.0 | 0.0 | 3.8 |
| Colonial | | | | | | | | | | | | | | | | | | | | |
| N | 3 | 16 | 1 | 20 | 1 | 9 | 0 | 10 | 0 | 10 | 0 | 10 | 3 | 18 | 2 | 23 | 3 | 17 | 1 | 21 |
| Mean | 34.3 | 35.0 | 32.8 | 34.7 | 43.8 | 43.3 | — | 43.3 | — | 48.6 | — | 48.6 | 95.2 | 90.0 | 80.8 | 88.0 | 121.7 | 116.7 | 115.0 | 117.3 |
| S.E. | 0.8 | 0.4 | 0.0 | 0.4 | 0.0 | 0.2 | — | 0.2 | — | 0.6 | — | 0.6 | 2.6 | 1.7 | 1.8 | 1.6 | 3.4 | 1.0 | 0.0 | 1.0 |

M = male
F = female
U = sex unknown
T = total
N = number
S.E. = standard error

**TABLE 3**
**Other Mandibular Measurements**

| | Mandibular Angle | | | | Ramus Heighth | | | | Body Length | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Culture | M | F | U | T | M | F | U | T | M | F | U | T |
| Paracas | | | | | | | | | | | | |
| N | 1 | 1 | 31 | 33 | 1 | 1 | 30 | 32 | 1 | 1 | 29 | 31 |
| Mean | 115.0 | 121.5 | 121.3 | 121.1 | 63.0 | 53.5 | 56.8 | 56.9 | 82.0 | 71.5 | 74.1 | 74.3 |
| S.E. | 0.0 | 0.0 | 1.0 | 1.0 | 0.0 | 0.0 | 1.2 | 1.1 | 0.0 | 0.0 | 1.0 | 1.0 |
| Nazca | | | | | | | | | | | | |
| N | 1 | 1 | 18 | 20 | 1 | 1 | 18 | 20 | 1 | 1 | 18 | 20 |
| Mean | 118.0 | 114.5 | 118.0 | 117.9 | 60.0 | 55.0 | 60.1 | 59.8 | 68.5 | 68.0 | 78.3 | 77.3 |
| S.E. | 0.0 | 0.0 | 1.7 | 1.5 | 0.0 | 0.0 | 1.0 | 1.0 | 0.0 | 0.0 | 1.3 | 1.3 |
| Huari | | | | | | | | | | | | |
| N | 2 | 2 | 10 | 14 | 2 | 2 | 10 | 14 | 2 | 2 | 10 | 14 |
| Mean | 123.5 | 116.5 | 119.8 | 119.8 | 60.8 | 55.8 | 59.6 | 59.2 | 76.2 | 76.3 | 73.1 | 74.7 |
| S.E. | 3.0 | 5.0 | 1.7 | 1.4 | 2.3 | 1.8 | 2.3 | 1.7 | 1.2 | 2.8 | 2.5 | 2.1 |
| Ica | | | | | | | | | | | | |
| N | 4 | 16 | 5 | 25 | 4 | 17 | 6 | 27 | 4 | 16 | 8 | 28 |
| Mean | 119.5 | 116.9 | 122.0 | 118.3 | 59.0 | 60.2 | 59.4 | 60.6 | 78.9 | 75.3 | 73.3 | 74.1 |
| S.E. | 3.8 | 1.3 | 3.5 | 2.4 | 1.7 | 0.8 | 1.8 | 0.6 | 2.1 | 1.0 | 2.4 | 1.2 |
| Inca | | | | | | | | | | | | |
| N | 0 | 1 | 1 | 2 | 0 | 1 | 1 | 2 | 0 | 1 | 1 | 2 |
| Mean | — | 121.5 | 116.0 | 118.8 | — | 54.5 | 59.5 | 57.0 | — | 71.0 | 74.0 | 72.5 |
| S.E. | — | 0.0 | 0.0 | 2.8 | — | 0.0 | 0.0 | 2.5 | — | 0.0 | 0.0 | 1.5 |
| Colonial | | | | | | | | | | | | |
| N | 3 | 17 | 2 | 22 | 3 | 16 | 2 | 21 | 3 | 16 | 2 | 19 |
| Mean | 117.0 | 117.5 | 124.5 | 118.5 | 62.3 | 60.0 | 56.3 | 60.0 | 74.8 | 75.6 | 76.0 | 75.0 |
| S.E. | 5.6 | 1.6 | 0.0 | 1.5 | 2.0 | 1.1 | 1.3 | 1.0 | 1.4 | 1.0 | 0.0 | 0.0 |

M = male
F = female
U = sex unknown
T = total
N = number
S.E. = standard error

the basal bone[21] have been shown to influence arch size and shape. Gould and Picton[22] pointed out that the equilibrium between the adjacent orofacial musculature and the arch affects its size and shape. The degree of tooth attrition or abrasion has also been noted to affect arch size and shape. Several of these factors, particularly attrition and growth, could have influenced jaw size and shape in this study, giving the wide degree of variation seen between and within the cultural groups.

Studies of Swedish maxillae and mandibles,[8] British palates[10] and dental arches,[23] and European mandibles,[24] have all shown a reduction in jaw dimensions in recent times in Europe. Several of these studies have also shown that this reduction was not accompanied by a corresponding diminution in tooth size. The present study shows a reduction in the width of the maxillary arch at the first molar during the time period studied. The most recent pre-Columbian Peruvian cultures also showed a reduction in jaw size in the mandible as noted in the diminution of arch width at the first and second molars and in the bigonial width. This reduction in jaw dimensions in more recent times was, however, accompanied by a corresponding reduction in tooth size.[25]

Many authors[26,27,12] have blamed this reduction

of jaw size on soft diet. The soft diet requires little mechanical force to masticate and thus less stimulation of the bone. If changes in the consistency of the diet were the principal factor responsible for this reduction, then the mandibular ramus would be reduced in size.[28] One should bear in mind that the mandibular ramus is the point of insertion of the muscles of mastication. In the present study, while a reduction in jaw size was exhibited by the more modern cultures as compared to the earlier ones, a reduction in the mandibular ramus was not seen. Although the presumptive evidence is strong that the reduction of the jaws is the direct result of less mechanical stress produced by the mastication of a soft diet in some studies, the possibility that genetic change may also be involved cannot be completely ruled out. Archaeological study of these cultures has shown that while differences in diet were seen between "inland" and "coastal" cultures, little change occurred in the diet within these groups over the period studied. The influx of outside groups of individuals into the cultures studied, either by conquest or peaceful assimilation, could have resulted in the acquisition of new genetic traits, which leaves open the possibility that genetic change has influenced the reduction in jaw size.

## Conclusion

In this study of 84 adult maxillae and 114 adult mandibles a reduction in jaw dimensions was seen in the more modern cultures. This reduction could not be explained by diet alone and the possibility that genetic change from gene mutation or population migration is suggested. Due to the small number of male specimens identified in this population, few, if any, valid comparisons can be made between the sexes concerning jaw dimensions. Future studies should be conducted to remedy this discrepancy.

## REFERENCES


1. THOMSEN S: Dental morphology and occlusion in the people of Tristan da Cunha. Results of the Norwegian Scientific Expedition to Tristan da Cunha, 1937–38. No. 25, Oslo, 1955.

2. AITCHISON J: Some racial contrasts in the teeth and dental arches. *Dental Magazine and Oral Topics* 82:201–205, 1965.

3. MOOREES CFA: *The Aleut Dentition. A Correlative Study of Dental Characteristics in an Eskimoid People.* Cambridge, Harvard University Press, 1957.

4. HRDLIČKA A: Lower jaw. Further studies. *Am J Phys Anthropol* 27:383–476, 1940.

5. HRDLIČKA A: Lower jaw. I. The gonial angle. II. The bigonial breadth. *Am J Phys Anthropol* 27:281–308, 1940.

6. LAVELLE CLB, FLINN RM, FOSTER TD, ET AL: An analysis into age changes of the human dental arch by a multivariate technique. *Am J Phys Anthropol* 33:403–411, 1970.

7. LAVELLE CLB, FLINN RM, FOSTER TD, ET AL: Differences in growth of the dental arch in some "races" of man. *J Anat* 107:182–183, 1970.

8. LYSELL L: A bometrical study of occlusion and dental arches in a series of mediaeval skulls from northern Sweden. *Acta Odont Scand* 16:177–203, 1958.

9. BRASH JC: The aetiology of irregularity and malocclusion of the teeth. Dental Board of the United Kingdom, London, 1929.

10. GOOSE DH: Reduction of palate size in modern populations. *Arch Oral Biol* 7:343–350, 1962.

11. KEITH A: Concerning certain structural changes which are taking place in our jaws and teeth. Dental Board of the United Kingdom, London, 1924.

12. WALLACE JS: *Variation in the Form of the Jaws.* London, Bailliere, Tindall, and Cox, 1927.

13. WATT DG, WILLIAMS CHM: The effects of the physical consistency of the food on the growth and development of the mandible and maxilla of the rat. *Am J Orthodont* 37:895–928, 1951.

14. GILLESPIE JA: The nature of the bone changes associated with nerve injuries and disuse. *J Bone Joint Surg* 36B:464–473, 1954.

15. MOORE WJ: Masticatory function and skull growth. *J Zool Proc Zool Soc London* 146:123–131, 1965.

16. MOORE WJ: Muscular function and skull growth in the laboratory rat (Rattus norvegicus). *J Zool Proc Zool Soc London* 152:287–296, 1967.

17. ALLISON MJ, GERSZTEN E: Paleopathology in Peruvian mummies. Application of modern techniques. Richmond, Virginia Commonwealth University, 1975.

18. MOYERS RE: *Handbook of Orthodontics,* 3 ed. Chicago, Yearbook Medical Publishers, Inc, 1973, p 198.

19. MORANT GM: A biometric study of the human mandible. *Biometrika* 28:84–122, 1936.

20. SILLMAN JH: Some aspects of individual dental development: Longitudinal study from birth to 25 years. *Am J Orthodont* 51:1–25, 1965.

21. MARTINEK CE: A comparison of various surveys on the adequacy of basal bone. *Am J Orthodont* 42:244–254, 1956.

22. GOULD MSE, PICTON DCA: A study of pressures exerted by the lips and cheeks on the teeth of subjects with Angle's class II division 1, class II division 2 and class III malocclusions compared with those of subjects with normal occlusions. *Arch Oral Biol* 13:527–541, 1968.

23. LAVELLE CLB: The British dental arch. *Am J Phys Anthropol* 41:63–69, 1974.

24. MOORE WJ, LAVELLE CLB, SPENCE TF: Changes in the size and shape of the human mandible in Britain. *Br Dent J* 125:163–169, 1968.

25. SAWYER DR: *The Oral Paleopathology and Odontology of Pre-Columbian Peruvians,* thesis. Medical College of Virginia, Richmond, 1977.

26. KLATSKY M: Etiological factors in dental degeneration. A study in physical anthropology, abstract. *J Dent Res* 24:117, 1945.

27. PICKERILL HP: *The Prevention of Dental Caries and Oral Sepsis,* 3 ed. London, Bailliere, Tindall and Cox, 1923.

28. LAVELLE CLB: A comparison between the mandibles of Romano-British and nineteenth century periods. *Am J Phys Anthropol* 36:213–219, 1972.