THE RELATIONSHIP OF FORCEFUL CHEWING AND PALATAL FORM IN THE VERVET MONKEY (CERCOPITHECUS AETHIOPS)

by

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In this study, palatal growth with respect to masticatory forces was examined. Normative and experimental data about palatal growth were collected from three different populations on the vervet monkey (Cercopithecus aethiops): (1) a control sample of anatomic specimens of different ages; (2) an experimental sample fed a hard-food diet; and (3) an experimental sample fed a soft-food diet, nutritionally similar to the hard-food diet.

Three measurements were taken on each specimen: (1) intermolar width; (2) intercuspid width; and (3) palatal length. Ratios of intermolar width versus palatal length and intercuspid width versus palatal length were calculated and compared.

It was found that the control specimens were generally smaller than the experimental specimens. The change in the experimental groups initial versus final measurements showed a statistically significant decrease in permanent intercuspid width versus palatal

length in the soft diet specimens. The hard diet specimens showed an increase in permanent intercuspid width versus palatal length.

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Introduction

In this study, the post-natal normal development of occlusion and its related effects on the palate, with respect to masticatory forces, was examined. Palatal growth of hard-food and soft-food diet monkeys was compared.

The effects of function on anatomical form have been studied for many years, resulting in numerous and diverse theories. There are those who believe that function has little to do with development, and that it was due to inherent developmental, or genetic factors. Others believe that function plays an important role in development. Today it is understood that genetics, function, nutrition, and numerous other environmental factors all have varying degrees of effect on form.

Little is known about the functional relationships and development of the palate outside the species _Homo sapiens_. Most of the literature focuses on embryology and pathology of the palate (e.g., Wood et al., 1969; Lavelle and Moore, 1970; Laugman, 1975; Mauser et al., 1975; Bhaskar, 1976), and few studies on the morphogenesis of the palate in non-human primates have been reported.

According to a review by Oyen (1984), Schultz (1948) showed that size on the canine diastema was not wholly tied to canine size. Moore (1949) and Craven (1956) commented on remodeling patterns of the palate seen in their vital stain studies of growing macaques. Sarnat (1958) demonstrated in macaques that unilateral surgical removal of the hard palate has no discernable effect on the development of the maxillary dentition.

Freedman (1962 a, b) incorporated palate length into his biometric studies of monkeys. Reed (1965, 1967, 1973) included some information about the length of the palate in his descriptions of growth in olive baboons. More recently, Beecher and Corruccini (1979) measured length and breadth of the palate of Rhesus macaques. In Oyen's study (1984), he described changes in palatal length and breadth in a cross-sectional collection of olive baboons.

Several studies have been completed to show the relationship between dietary consistency and the development of occlusion. The effects of the physical consistency of food on the growth and development of the masticatory apparatus have been of interest since Watt and Williams (1951) demonstrated that weanling rats fed a soft diet developed a more narrow arch compared to weanling rats fed a hard diet. Because the rat is a poor analogy for the human masticatory system (Weijs, J., 1975), Beecher and Corruccini (1979) performed a similar experiment with 17 Rhesus macaques.

They also showed a decrease in maxillary arch width in the soft diet animals.

Dietary consistency and palatal growth is of interest, also, because of the analog between experimental findings and maxillary arch collapse in humans described by Kelly and Harvey (1977), where the maxillary arch width decreases in comparison to arch length, allowing for a posterior dental crossbite.

Begg and Kesling (1965) suggested that consistency of diet has much to do with periodontal disease, occlusal malrelationships, and changes in the bony architecture of the face. Many studies have shown that populations raised on processed foods have developed variable occlusal patterns compared to their ancestors who were raised on harder, tougher foods which required more forceful chewing. In 1925, Keith did a study to compare people of the Neolithic Period with the British population of his day. He noted a tendency of modern man to have an increased incidence of crowding in the dentition. Also, there was a tendency towards a narrow nose, a high vaulted and constricted palate. The dentition in the Neolithic man had an edge to edge incisor relationship, while modern man has an overlapping of the maxillary incisors over the mandibular incisors.

A study by Price (1936) had similar findings. He observed Eskimos that became civilized, and noted a 50%

increase of malocclusion. Clinch (1951) reported a 100% increased incidence of malocclusion in Australian aboriginals living on a reservation, when compared to the free-ranging nomadic aboriginals.

In 1981, Corruccini and Whitley studied an isolated rural Kentucky population, which still maintained in part a more traditional diet. Until recently, these Caucasian people cultivated tobacco, gardens, and orchards. Also, important in their diet were dried pork and fried, thick crusted corn bread providing stressful chewing. Hunting was still common. Within the past 25 years, industry and mechanized farming has moved into the area causing grain crops to replace the traditional ones as their primary cash crops. Recently, some of the younger residents had become part of the industrial work force and were not cultivating their own food. However, for some of the older residents, life style has not changed significantly.

Corruccini and Whitley found that members of the community raised on softer and more cariogenic foods were more variable from ideal in their occlusal patterns. Sex was not shown to be associated with any of their occlusal variables, however, diet and age showed a significant association. Occlusal variation increased steadily with decreasing age, or increasing amounts of softer components to the food. Arch length and width measurements showed no significant correlations.

Because so few American people possess a homogeneous occlusion, many dental theorists have concluded that malocclusion is numerically normal. While this may be true of Westernized people, malocclusion is still rare in many ethnic peoples who have not yet become accustomed to eating canned foods and refined sugars. The possibility of a relationship between occlusion and dietary consistency promotes the concept of prevention in orthodontics related to food toughness.

Today it is understood that genetics, function, nutrition, and numerous other environmental factors all have varying degrees of influence on form. One of the factors which is considered to affect craniofacial development, physical consistency of food, was considered in this project.

Statement of Thesis

This study assesses the relationship between forceful chewing and palatal growth. The specific objective was to analyze the effects of variation in diet consistency in the growing vervet monkey (*Cercopithecus aethiops*) and anatomic specimens on patterns of palatal growth.

Normative and experimental data on growth of the maxilla and its dentition were collected from three different populations on the vervet monkey: (1) a control sample of anatomic specimens of different ages; (2) an experimental sample fed a hard-food diet; and (3) an experimental sample fed a soft-food diet, nutritionally similar to the hard-food diet.

Materials

The control sample was a collection of 36 dried skulls of wild-caught African vervet monkeys (*Cercopithecus aethiops*) with unknown data about health and diet. The group consisted of both males and females and approximately equal numbers of infants, juveniles, adolescents, and adults.

The experimental sample consisted of 15 male vervet monkeys (*Cercopithecus aethiops*) captured on St. Kitts Island as infants or adolescents. Ten were fed a hard-food diet, and five were fed a soft-food diet.

The hard-food diet consisted of Purina Monkey Chow (nutritionally balanced biscuits) and controlled amounts of fruits and some vegetables.

The soft-food diet required no mastication and had the consistency of soft fudge. It consisted of 35% liquified Purina Monkey Chow, 25% powdered milk, 2% vitamin supplement, and 8% applesauce or pureed bananas.

Nutritionally, the hard-food and soft-food diets were comparable, and each animal had water available *ad libitum* through a pressurized watering valve.

Methods (Data Collection)

Both control, and anatomic specimens, were measured with a micrometer, as follows (Diagram 1): (1) width across the palate from lingual of maxillary right cuspid to lingual of maxillary left cuspid; (2) width across the palate from the lingual of the maxillary right first molar to lingual of the maxillary left first molar; (3) length of palate from a point bisecting a line tangent to the mesial most aspect of the maxillary first molars to a point bisecting a line tangent to the lingual most aspect of the contact point between the maxillary central incisors.

Whole palatal impressions of the experimental groups were taken every three months. The models were measured in the same manner as the control specimens.

Methods (Data Analysis)

Maxillary length and breadth were used to measure palatal growth in a similar manner as done in the studies be Beecher and Corruccini (1981) and Oyen (1984). The specimens of the control and experimental groups were catagorically separated as to presence of primary or permanent cuspids. Because of the general size difference between the control specimens and the experimental specimens, ratios of intermolar width vs. palatal length, and intercuspid width vs. palatal length were used for comparisons. Each pair of groups was subjected to student t-tests, and level of significance determined.

The control specimens were measured and compared with the measurements of the experimental specimens at the time of final records. Because of some missing teeth, some specimens did not have all the measurements taken, and were eliminated from the testing prodecures.

The initial measurements of the experimental specimens were compared with the final measurements. Any missing data were depleted in a parallel fashion.

Results

The mean ratios of the variables in the control group and the final measurements of the experimental groups are provided in Tables 2, 3 and 4.

When comparing intermolar width versus palatal length ratios (Table 2), a statistically significant difference was shown between the control group and both experimental groups. In both situations, the control animals had a more narrow intermolar width in relation to palatal length than the experimental groups. The hard diet experimental group has a larger intermolar width to palatal length ratio than the soft diet experimental group; however, the difference was not statistically significant.

When comparing primary intercuspid width versus palatal length ratios (Table 3), a statistically significant difference was found between the control group and the soft diet experimental group. Both experimental groups had a larger primary intercuspid width to palatal length ratio than the control group, but the difference was not statistically significant between the control and hard diet experimental groups. The soft diet experimental group had a larger primary intercuspid width to palatal length ratio compared to the hard diet experimental group, but, the difference was not statistically significant.

Comparisons of permanent intercuspid width versus palatal length showed no statistically significant differences between control and experimental groups (Table 4). The control group had a smaller permanent intercuspid width to palatal length ratio than both experimental groups. The hard diet experimental group showed a larger permanent intercuspid width to palatal length ratio than the soft diet experimental group.

Tables 5 and 6 show the mean ratios of the variables of the initial and final measurements of the experimental groups.

The hard diet experimental group showed a decreasing intermolar width to palatal length ratio, an increasing primary intercuspid width versus palatal length ratio, and an increasing permanent intercuspid width to palatal length ratio. None of the changes was statistically significant, however.

The soft diet experimental group showed an increase in primary intercuspid width to palatal length ratio. However, there was a decrease in both the permanent intercuspid width to palatal length, and the intermolar width to palatal length. The change in permanent intercuspid width to palatal length is statistically significant.

Discussion

A factor that must be taken into consideration in the interpretation of the data obtained in this study is the use of ratios of maxillary dentoalveolar dimensions to express anything other than a palatal shape. To use these measurements and ratios to depict growth changes would be inaccurate. Measurements taken directly from the palate would be necessary to do this.

In order to understand why there are shape changes to the palate, and differences in palatal shape between hard-food and soft-food animals we must discuss some possible mechanisms of bony remodeling in the palate and alveolar bone.

One such machanism could be a change due to factors suggested by Enlow (1975), where compressive and tensile forces acting on bone can cause deposition or resorbtion of bone, respectively. The occlusion in the vervet monkey is such that the lingual cusps of the maxillary teeth are in line with the central grooves of the mandibular teeth. Also, there is a concave surface of bone formed when the buccal surface of the alveolar bone meets the maxilla, and eventually bends upward and outward to connect with the zygomatic arch. As the masticatory muscles contract pulling the maxillary and mandibular teeth into contact, the concave surface of bone will be under a compressive force, giving rise to bone deposition here. At the same time, the inner surfaces of the same bone will be under tensile forces causing bone resorbtion. The net effect will be to expand the maxillary arch in a lateral dimension. This sort of mechanism corresponds well with our idea that animals generating more force upon mastication should develop a wider palate. While our results favor this conclusion, we show no statistically significant evidence.

Another reason for a palatal shape change is due to the nasal passage located directly above the palate. As the animal increases in body size and increases its amount of activity, there is an increased need for oxygen. To take in more oxygen, the air passage can increase in size. One of the changes can be an increase in lateral dimension.

Differences in certain measurements were observed between the control specimens and the experimental specimens. The control specimens were generally smaller in intermolar width versus palatal length, primary intercuspid width versus palatal length, and permanent intercuspid width versus palatal length (refer to mean values in Tables 2, 3 and 4). The control specimens were all wild-caught African animals, and their dietary habits and other history are unknown. Although the experimental specimens were all wild-caught from St. Kitts Island, their diets and living conditions are known.

There are several possible reasons for the observed differences in measurements. The experimental specimens were all males, while the control specimens were a mixture of males and females. Females are usually smaller in size than males and thus contributing to the general smallness of the control group. The experimental specimens were all raised on a nutritionally balanced diet, while the control animals had to survive on their own. The experimental specimens were fed their respective diets for at least 15 months, while the control animals survived their entire lifetime on a wild diet. Also, the control monkeys had to be fast and light to climb high in the trees to avoid predators, while the experimental specimens had no natural predators on St. Kitts Island.

A reduced variance was found in the experimental population in relation to the control population. From a genetic standpoint, this is to be expected since the experimental specimens came from St. Kitts Island which developed from a small founder population from Africa.

When comparing the initial measurements of the experimental groups to their final measurements, an increase in almost all dimensions was found (Tables 5 and 6). However, both the hard and soft diet experimental groups showed less of an increase in molar width in relation to the increase in palatal length (this is reflected by decreasing ratios of molar width to palatal length). The specimens with primary cuspids showed an increase in intercuspid width in relation to palatal length. The more interesting changes, however, were noted in permanent intercuspid widths in relation to palatal length. The soft diet experimental group showed a statistically significant decrease in this ratio, while the hard diet group showed an increase. We believe this difference is due to the difference in the consistency of diet between the two experimental groups. With all of the other possible variables held constant, consistency of diet is the one variable to which we can most easily attribute this difference.

Because all of the experimental animals have not developed to their full maturity and these specimens have been restricted to there respective diets for only the past 15 months, we expect to see more significant changes due to the difference in dietary consistency when the animals are all full grown.

Although this study suggests that dietary consistency has an effect on maxillary dentoalveolar dimensions, it must be noted that the sample sizes were quite small. Because of this, the study may best be viewed as a pilot study, and show the need for further exploration in this area.

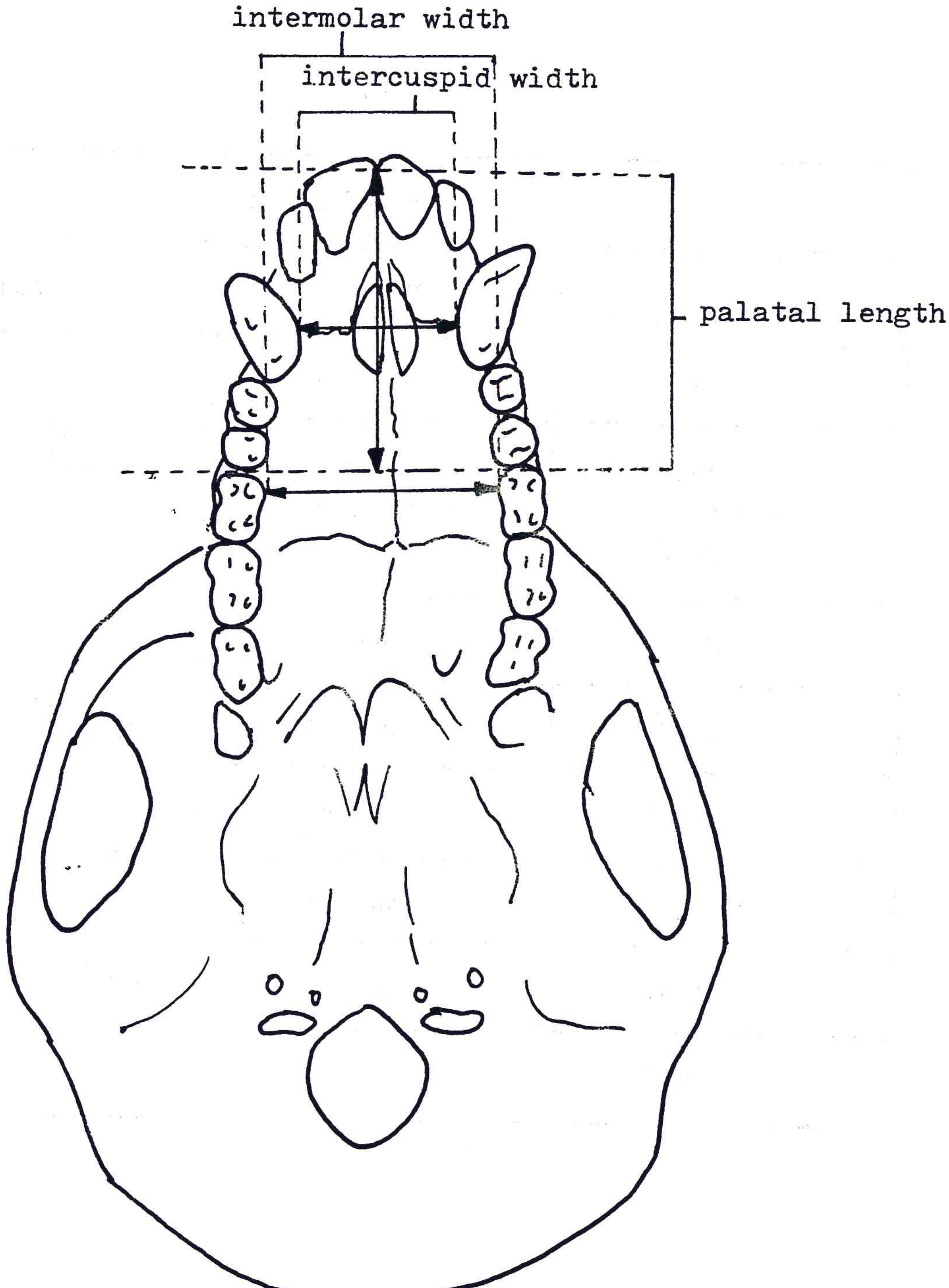

Diagram 1

Table 7

Raw Data of Control Specimens

Animal #	dentition	length	width (m)	width (c)
2	MO	22.8 mm	13.5 mm	13.8 mm
3	MO	25.5	13.9	14.4
4	MO	23.2	15.4	15.2
5	MO	25.0	16.8	16.8
6	MO	22.9	14.0	missing
7	MO	21.7	13.7	14.3
8	M1	20.0	14.4	14.7
9	MO	22.4	14.6	14.2
10	M1	18.7	13.5	14.9
11	M1	20.6	14.2	14.3
12	M1	20.6	12.3	13.7
13	M1	19.5	14.3	14.5
14	M1	25.4	14.5	16.0
15	M1	22.5	13.9	15.0
16	M1	24.2	14.6	16.1
17	M1	23.2	15.1	16.1
18	M1	21.0	14.4	15.5
19	M1	21.4	13.9	missing
20	M1	21.5	14.6	missing
21	M1	23.2	14.7	16.0
22	M1	21.9	15.6	16.5
23	M1	20.4	15.0	15.9
24	M1	22.8	16.0	16.0
25	M1	22.1	14.0	14.6
26	M1	22.9	14.7	16.8
28	M1	21.2	14.7	16.4
29	M1	21.4	13.4	missing
30	M1	21.5	15.9	16.4
31	M1	20.9	15.0	16.5

Table 8

Raw Data of Experimental Specimens (Initial)

Animal #	dentition	length	width (m)	width (c)
1 *	M1	25.9 mm	20.5 mm	19.8 mm
2	M2	28.0	24.9	22.8
3	M1	25.5	18.5	16.7
4	M1	23.9	18.9	18.3
5	M1	23.6	20.5	20.0
6	M1	22.5	10.8	17.2
7	M1	24.2	17.2	missing
8	M1	24.6	20.2	19.2
9	M2	23.7	21.5	20.5
10	M1	26.3	19.8	18.3
11 *	M1	26.0	19.4	20.3
12 *	M2	28.4	23.4	21.4
13 *	M1	21.9	18.2	16.5
15 *	M1	22.3	20.0	18.5
16	M1	21.9	18.0	16.6

M1 - permanent first molar present
M2 - permanent second molar present
* - soft diet animals

Table 9

Raw Data of Experimental Specimens (Final)

Animal #	dentition	length	width (m)	width (c)
1 *	M1	28.5 mm	23.4 mm	22.5 mm
2	M2	28.0	25.5	22.0
3	M1	26.4	19.5	17.3
4	M1	26.0	21.0	19.9
5	M1	28.0	22.0	21.3
6	M1	24.2	18.5	18.3
7	M1	24.8	18.5	missing
8	M1	26.4	21.5	20.0
9	M2	24.4	21.5	20.7
10	M1	27.8	21.4	20.6
11 *	M1	29.3	20.6	21.9
12 *	M2	30.4	24.5	24.2
13 *	M1	24.3	18.8	17.9
15 *	M1	24.4	19.3	18.8
16	M1	24.0	18.9	16.7

M1 - permanent first molar present
M2 - permanent second molar present
 * - soft diet animals

Summary

In this study, palatal growth with respect to masticatory forces was examined. Normative and experimental data about palatal growth were collected from three different populations on the vervet monkey (_Cercopithecus aethiops_): (1) a control sample of anatomic specimens of different ages; (2) an experimental sample fed a hard-food diet; and (3) an experimental sample fed a soft-food diet, nutritionally similar to the hard-food diet.

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It was found that the control specimens were generally smaller than the experimental specimens. The change in the experimental groups initial versus final measurements showed a statistically significant decrease in permanent intercuspid width versus palatal length in the soft diet specimens. The hard diet specimens showed an increase in permanent intercuspid width versus palatal length.

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