Palatal Growth Rates in *Macaca nemestrina* and *Papio cynocephalus* [1]

DARIS R. SWINDLER AND JOYCE E. SIRIANNI [2]
Department of Anthropology and The Regional Primate Research Center, University of Washington, Seattle, Washington 98195

KEY WORDS Growth rate · palate · monkeys.

ABSTRACT A longitudinal study consisting of 38 unrelated *Macaca nemestrina* and 16 *Papio cynocephalus* monkeys are investigated for palatal changes during the first two and a half years of life. The central problem is to ascertain whether there are any significant differences between the two genera regarding their relative growth rates. In order to examine this question, the amount of sexual dimorphism in absolute size was determined. There was no sex difference in palatal dimensions within the species but there were marked size differences between the groups. The relative growth rates present another story. There are no significant sex or intergeneric differences in growth rates. The genera are different in absolute size but they grow at about the same relative rates. These rates represent a decelerating curve in both genera.

During the past several decades the monkey, which has usually meant any nonhuman primate between prosimians and anthropoid apes, has received a great deal of scientific attention as a research animal. The majority of work, however, has centered around the Old World monkeys, and in particular two genera, *Macaca* and *Papio*. Growth studies of the cephalo-facio-dento complex in these taxa have concentrated mainly on the developing teeth, i.e., tooth formation and eruption sequences (Krogman, '30; Hurme and van Wagenen, '53, '61; Reed, '65; Swindler and Gavan, '62; Gavan, '67). To date, there is little information regarding the growth of the dental arches in these two nonhuman primates. Zuckerman ('26) in his study of the growth of the baboon skull mentioned palatal growth as did Freedman ('62). To our knowledge the most extensive study of the palate was that of Baume and Becks ('50). In all of these studies, the investigators were unfortunately limited to cross-sectional data. Indeed, the majority of growth studies among nonhuman primates have had to utilize cross-sectional information, because as Gavan recently noted, "there has been little opportunity to study the same animals throughout their total growth period" ('71).

The present study is primarily concerned with relative growth rates of several dimensions of the palate in *Macaca* and *Papio* from approximately three months to two and a half years of age. The problem is to determine whether or not there are any significant differences between the two genera regarding their relative growth rates.

MATERIALS AND METHODS

The monkeys were born at the Regional Primate Research Center Field Station in Medical Lake, Washington. The colony was established for the investigation of longitudinal growth and development of the pig-tail monkey, *Macaca nemestrina* and the Olive baboon, *Papio cynocephalus*. The parents of all of the animals used in the study were captured in the field and brought to the Primate Center.

The sample consists of 16 unrelated *Papio cynocephalus* and 38 unrelated

[1] Recent studies of baboon taxonomy indicate that all savanna baboons represent a single polytypic species (Buettner-Janusch, '66; Thorington and Grooves, '70; Maples, '72). The legitimate name for the Olive baboon is, therefore, *Papio cynocephalus* (Linneaus, 1766). The continued use of *anubis* and *doguera* for the specific name of the Olive baboon should be discouraged.

[2] Present address: Ms. Joyce E. Sirianni, Department of Anthropology, State University of New York at Buffalo, New York.

Macaca nemestrina. The monkeys were weaned around three months and henceforth raised together in bisexual groups for the next several years. Their diet consisted of monkey chow supplemented with green vegetables and fruit. The protocol stated that each animal was to be studied every three months for the first two years of life and, thereafter, biannually for the remainder of its growth period. As is characteristic of most longitudinal growth studies, strict adherence to the schedule was not always possible. We believe the final result, however, will be the accumulation of a creditable amount of longitudinal growth data.

The basic data presented in this paper consists of measurements of dental casts. The casts were poured within minutes after the impressions were taken, minimizing the possibility of any dimensional change. *Measurements taken on dental casts are directly comparable to measurements of the original specimens* (Swindler et al., '63). All measurements were taken by (D.R.S.). The caliper points were sharpened for greater accuracy. Palatal arch lengths and breadths were taken as follows (fig. 1).

a. Palatal arch length, the distance between the tangent to the labial surfaces of the deciduous central incisors and a plane tangent to the distal surface of the second deciduous molars, parallel to the occlusal plane.

b. Anterior palatal length, the distance between the tangent to the labial surfaces of the deciduous central incisors and a plane through the bicanine breadth parallel to the occlusal surface. The dimension corresponds approximately to the anteroposterior length of the premaxillary bone.

c. Posterior palatal length, the distance between the tangent to the distal surfaces of the second deciduous molars and a plane through the bicanine breadth parallel to the occlusion plane.

d. Bicanine breadth, the distance between the labial crown surfaces at the gingival level.

e. Bimolar breadth, the greatest distance between the buccal surfaces of the second deciduous molars.

The relative growth rates used in this paper were calculated using the method of Fisher ('21). The procedure for calculating relative growth rates as well as their utility in growth studies has been discussed by Gavan and Swindler ('66). Briefly, relative growth rates were calculated for each animal as follows:

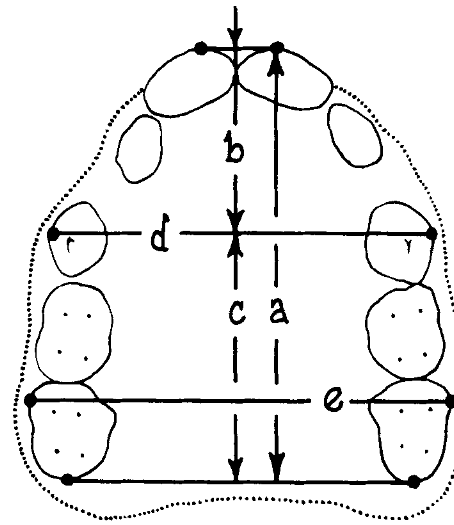

Fig. 1 Palatal measurements.

$$\frac{\ln S_2 - \ln S_1}{T_2 - T_1}$$

where lnS is the natural logarithm of size (measurement) and T is time. These were calculated for each pair of adjacent measurements taken on an animal through time. An average age $(T_2 + T_1)/2$ was calculated for each rate. Relative growth rates of the palatal dimensions were compared by sex within each taxa for each age range and the significance of sex differences was determined using the "t-test."

In addition, coefficients of correlations were calculated for the two palatal segments and the two breadth dimensions to determine whether or not the dimensions were independent. Regression coefficients (b in the regression equation $y = a + bx$) were calculated for the same dimensions. The b function measures the increase in the dependent variable (e.g., bicanine breadth, etc.) compared to that of the independent variable (time). All measurements were taken in millimeters and time recorded in thousandths of a year.

TABLE 1

Generic comparison of palatal lengths

Age range	Anterior palatal length						Posterior palatal length					
	Macaca			Papio			Macaca			Papio		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
0.250–0.499	15	9.7	0.669	12	12.1	1.238	—	—	—	—	—	—
0.500–0.749	17	10.8	0.641	6	12.5	0.534	16	18.2	0.610	2	22.5	0.556
0.750–0.999	21	11.2	0.783	4	13.4	0.594	21	18.4	0.893	4	24.7	0.745
1.000–1.249	19	11.5	1.024	14	14.1	0.782	19	18.5	0.836	14	24.8	1.043
1.250–1.499	18	11.6	0.883	10	14.5	0.890	18	18.7	0.718	10	25.2	0.727
1.500–1.749	18	11.8	1.285	10	14.8	0.932	18	18.8	0.763	10	25.4	0.872
1.750–1.999	11	11.9	0.889	4	14.9	0.661	11	18.9	0.961	4	25.7	0.665
2.000–2.249	11	12.2	1.034	2	15.8	0.141	12	18.9	0.654	2	25.9	0.424
2.250–2.499	4	12.3	1.846	—	—	—	4	19.0	0.561	—	—	—

TABLE 2

Generic comparison of palatal breadths

Age range	Bicanine breadth						Bimolar breadth					
	Macaca			Papio			Macaca			Papio		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
0.250–0.499	15	23.6	0.993	12	27.7	1.215	—	—	—	—	—	—
0.500–0.749	17	24.8	1.276	6	28.6	1.042	16	27.7	0.883	—	—	—
0.750–0.999	21	25.6	1.349	4	31.1	2.234	21	28.7	1.131	4	34.8	1.235
1.000–1.249	19	26.2	1.125	14	31.3	1.397	19	29.2	1.103	14	35.4	1.139
1.250–1.499	18	27.1	1.027	10	31.9	1.456	18	30.3	1.117	10	36.6	1.139
1.500–1.749	18	27.4	1.092	10	32.0	1.383	18	31.1	1.223	10	36.9	1.312
1.750–1.999	11	27.9	1.101	4	33.7	2.043	11	31.4	0.866	4	37.9	1.533
2.000–2.249	12	28.4	0.948	2	35.9	2.616	12	31.8	0.937	2	40.6	1.768
2.250–2.499	4	29.1	1.245	—	—	—	4	33.4	0.451	—	—	—

TABLE 3

Relative growth rates of palatal dimensions

Age range	Palatal length						Bicanine breadth						Bimolar breadth					
	Females			Males			Females			Males			Females			Males		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
Macaca nemestrina																		
0.250–0.499	—	—	—	—	—	—	2	0.252	0.004	2	0.269	0.067	—	—	—	—	—	—
0.500–0.749	2	0.101	0.046	4	0.087	0.062	7	0.126	0.077	10	0.165	0.046	2	0.100	0.019	4	0.232	0.033
0.750–0.999	6	0.105	0.087	8	0.065	0.037	7	0.166	0.057	9	0.137	0.057	7	0.201	0.071	8	0.116	0.022
1.000–1.249	7	0.043	0.031	10	0.063	0.040	5	0.167	0.018	10	0.113	0.030	6	0.116	0.035	10	0.124	0.059
1.250–1.499	11	0.053	0.040	7	0.045	0.033	10	0.089	0.057	7	0.094	0.020	10	0.110	0.034	7	0.093	0.064
1.500–1.749	5	0.040	0.042	8	0.045	0.039	6	0.069	0.046	8	0.079	0.064	5	0.107	0.054	8	0.099	0.030
1.750–1.999	8	0.052	0.040	4	0.030	0.024	8	0.068	0.046	4	0.082	0.022	8	0.105	0.042	4	0.105	0.025
2.000–2.249	4	0.024	0.018	5	0.080	0.061	4	0.047	0.048	5	0.082	0.020	4	0.101	0.021	5	0.090	0.040
2.250–2.499	2	0.050	0.060	—	—	—	2	0.079	0.034	—	—	—	2	0.079	0.030	—	—	—
Papio cynocephalus																		
0.250–0.499	—	—	—	—	—	—	2	0.186	0.200	1	0.192	—	—	—	—	—	—	—
0.500–0.749	—	—	—	—	—	—	3	0.130	0.025	5	0.192	0.077	—	—	—	—	—	—
0.750–0.999	2	0.076	0.022	1	0.056	—	4	0.130	0.025	3	0.119	0.018	3	0.142	0.045	1	0.163	—
1.000–1.249	4	0.081	0.018	3	0.055	0.045	4	0.099	0.032	3	0.091	0.014	2	0.103	0.025	3	0.095	0.032
1.250–1.499	7	0.065	0.020	5	0.069	0.028	7	0.095	0.027	5	0.082	0.028	7	0.092	0.030	5	0.087	0.010
1.500–1.749	6	0.028	0.010	6	0.047	0.018	7	0.068	0.032	5	0.082	0.030	7	0.093	0.027	5	0.119	0.018
1.750–1.999	4	0.047	0.022	3	0.043	0.014	5	0.074	0.045	3	0.078	0.045	5	0.086	0.027	3	0.072	0.014
2.000–2.249	3	0.031	0.032	2	0.042	0.039	3	0.093	0.022	2	0.098	0.018	3	0.084	0.027	2	0.092	0.020
2.250–2.499	—	—	—	1	0.008	—	—	—	—	1	0.061	—	—	—	—	1	0.047	—

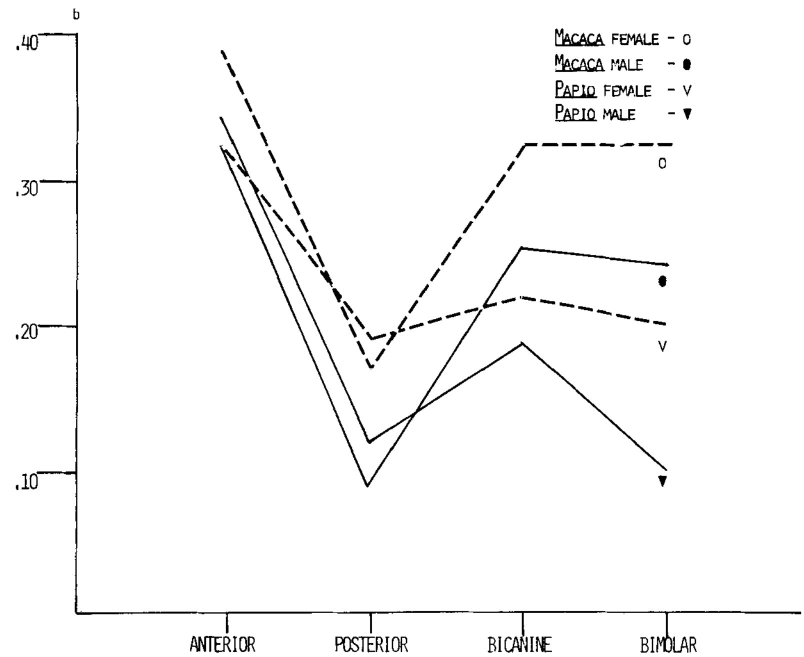

Fig. 2 Values of b for palatal dimensions.

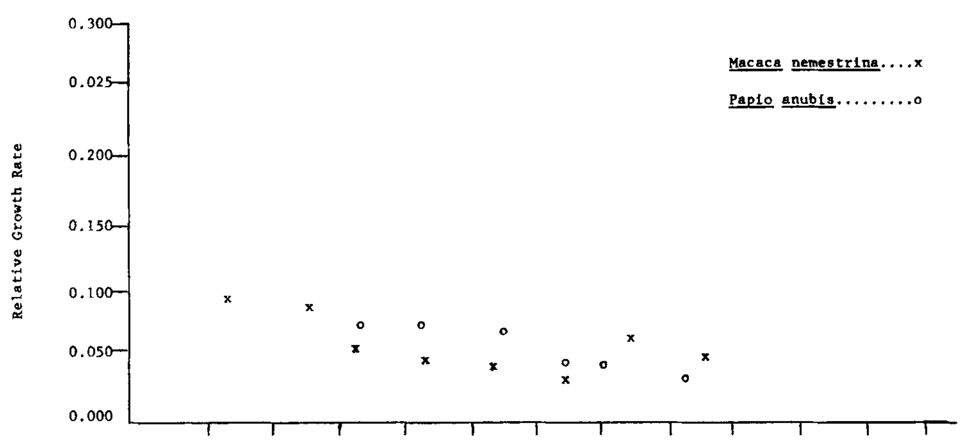

Fig. 3 Genera comparison of palatal length rate with age.

RESULTS AND DISCUSSION

The measurements for each age period (sexes combined) are shown in tables 1 and 2. Sexes are combined since there are no significant differences within the genera. After grouping the sexes a "t-test" was calculated for each age level. Significant intergeneric differences are found for each age category. Thus, *M. nemestrina* and *P. cynocephalus* are significantly different but as shown below, their relative growth rates express no major contrasts. *Papio cynocephalus* is a larger animal at birth and continues to be larger in absolute size during the growth period.

The relative growth rates are similar between males and females indicating

TABLE 4

Generic comparisons of palatal growth rates

Age range	Palatal length						Bicanine breadth						Bimolar breadth					
	Macaca			Papio			Macaca			Papio			Macaca			Papio		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
0.250–0.499	—	—	—	—	—	—	4	0.260	0.038	3	0.188	0.142	—	—	—	—	—	—
0.500–0.749	6	0.092	0.053	—	—	—	17	0.150	0.068	8	0.169	0.067	6	0.188	0.078	—	—	—
0.750–0.999	14	0.082	0.063	3	0.069	0.013	16	0.150	0.057	7	0.125	0.021	15	0.156	0.066	4	0.145	0.037
1.000–1.249	16	0.055	0.037	7	0.070	0.029	15	0.131	0.105	7	0.095	0.024	16	0.120	0.051	5	0.094	0.025
1.250–1499	18	0.049	0.037	12	0.067	0.020	17	0.091	0.045	12	0.090	0.026	17	0.103	0.040	12	0.090	0.025
1.500–1.749	13	0.043	0.039	12	0.046	0.029	14	0.075	0.035	12	0.074	0.029	13	0.102	0.039	12	0.104	0.026
1.750–1.999	12	0.038	0.031	7	0.045	0.019	12	0.073	0.039	8	0.075	0.038	12	0.105	0.030	8	0.081	0.022
2.000–2.249	9	0.055	0.053	5	0.035	0.026	7	0.062	0.041	5	0.094	0.019	9	0.095	0.030	5	0.087	0.022
2.250–2.499	2	0.050	0.060	—	—	—	4	0.080	0.030	—	—	—	10	0.079	0.030	—	—	—

that sexual dimorphism in palatal growth rates is negligible between the sexes during the time period covered by this study. There are three rates which are statistically significant at the 0.05 level. These are in *M. nemestrina* and include one bicanine (1.000 to 1.249) and two bimolar (0.500 to 0.749 and 0.750 to 0.999) rates. Since there are so few significant sex differences and no chronological pattern represented by the data the sexes again are combined for each genera. In a recent paper, Gavan and Swindler ('66) were unable to detect any significant differences in sitting height rates in rhesus monkeys. Many of their monkeys had passed through puberty and had offspring. It will be interesting to see if the monkeys used in this study develop sexual differences in palatal size as they continue to grow.

In table 4, the intergeneric rate comparisons are presented. Of the 20 comparisons, *M. nemestrina* has a slightly faster rate in 13 age categories, although none is significant. In other words, palatal growth rates are very similar between these two groups of Old World monkeys during the time period investigated. The data presented in figures 3 through 5 are quite informative. In both groups of monkeys, the palates are broadening at approximately the same rate. During the first one and one-half years the palatal length is increasing at a much slower rate than either breadth dimension. Figure 3 shows that from three months to one year the rate of growth in palatal length in *M. nemestrina* decreases by about one-half. Although the rate is slower than observed in *P cynocephalus* during much of the second year, there is an increase in the rate by the end of the second year. *Papio cynocephalus* displays no such increase at this time period. The acquisition of the maxillary permanent incisors might explain, at least in part, this acceleration in rate. The growth rate presented in figures 4 and 5 decrease steadily throughout the first year and a half and then level off. In general, the relative growth rates of palatal length, bicanine breadth and bimolar breadth gradually decelerate as both genera increase in age. A decelerating growth curve was also characteristic of the sitting

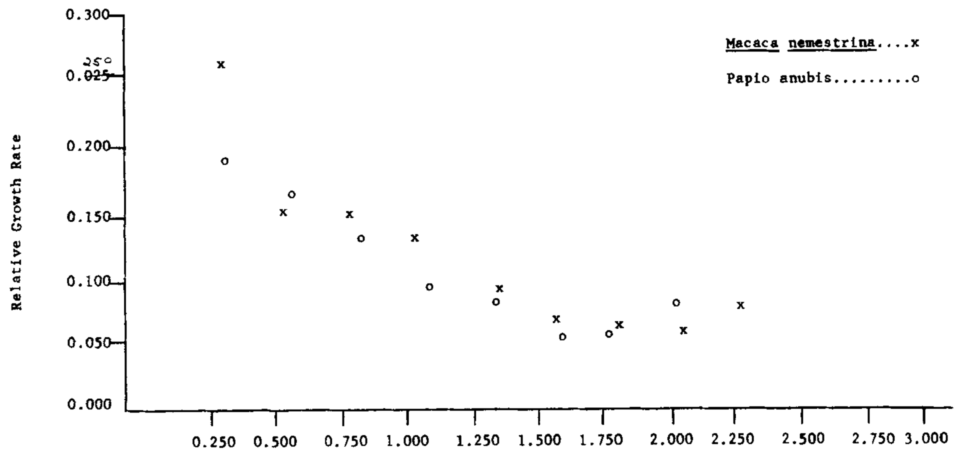

Fig. 4 Genera comparison of bicanine breadth rate with age.

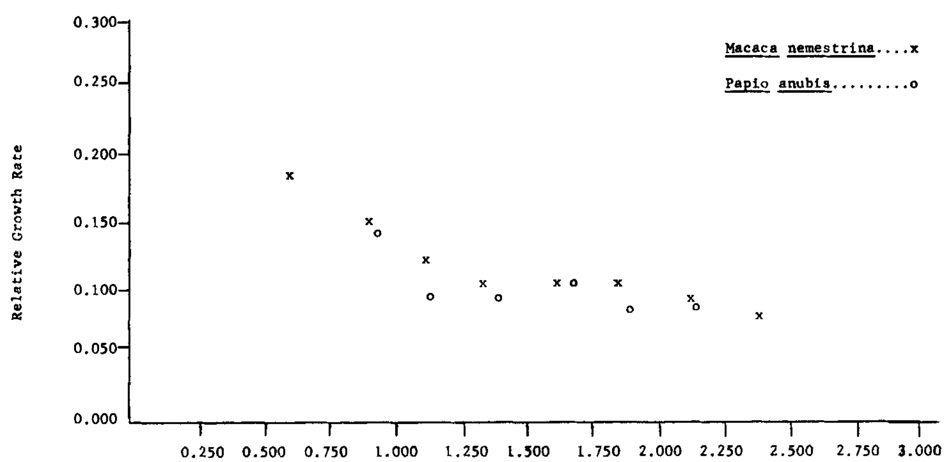

Fig. 5 Genera comparison of bimolar breadth rate with age.

height rate in rhesus monkeys, chimpanzees, man and dairy cattle (Gavan and Swindler, '66). These authors did not find any indication of a puberal growth spurt in sitting height in rhesus monkeys or chimpanzees. In fact they stated, "as far as sitting height is concerned, this spurt is the new feature in human ontogeny."

At the present time there is little information regarding age at menarche in *M. nemestrina*. We are collecting such information and it appears that menarche begins at about two years. This is well within the range for rhesus monkeys, one and one-half to two and one-half years (van Wagenen, '52). Evidently, *P. cynocephalus* is somewhat later as Napier gives three and one-half to four years for baboons (Napier and Napier, '67). The evidence from *M. nemestrina* appears to support the finding discussed above even though the samples are rather small. The baboons are not old enough to provide an answer to the question.

The palate is divided into two segments. The anterior portion (fig. 1a) corresponds to the premaxillary bone while the posterior segment (fig. 1b) includes the region of the palatine process of the maxilla. The premaxillary suture remains patent in cercopithecoid monkeys for several years after birth. Correlation coefficients between the anterior and posterior palatal segments do not differ significantly from

TABLE 5

Coefficients of correlations of palatal dimensions

Palatal dimensions	Macaca		Papio	
	Female	Male	Female	Male
Anterior palatal length / Posterior palatal length	0.28 [1] df = 64	0.13 df = 58	0.29 df = 24	0.18 df = 18
Bicanine / Bimolar	0.88 [2] df = 64	0.87 [2] df = 58	0.90 [2] df = 24	0.82 [2] df = 18

[1] P = 0.05.
[2] P = 0.01.

zero in either *M. nemestrina* or *P. cynocephalus*, table 5. Thus, indicating the independence of these two palatal segments during this growth period. A similar condition was found in rhesus monkeys (Swindler and Sassouni, '62). It is interesting to note that in both genera, the females have a higher correlation coefficient than the males (table 5). As might be expected, the palatal breadth dimensions (fig. 1c,d) are highly correlated demonstrating the close harmony between the breadth of the anterior and posterior portions of the palate.

Regression coefficients, b, were calculated for these four palatal dimensions against age. The results are presented in figure 2. The anterior palate has a higher rate of growth than the other segments, while the posterior palate displays the slowest rate of growth.

That the premaxillary bone is an active area of independent growth in cercopithecoids was suggested by Moore ('49). He studied head growth in rhesus monkeys by alizarin red S injection and concluded that the premaxillary element "apparently enjoys a prolific, independent growth." Except for the baboon males, the bicanine and bimolar dimensions express similar rates. Note the lower correlation for these two parameters in baboon males. The pig-tail females show faster rates in all dimensions except posterior palate where they are slightly lower than baboon females. With the possible exception of bimolar breadth these data again elucidate the similarity of palatal increase in these two genera.

CONCLUSIONS

The data presented in this paper cover approximately the first two and a half years of life. During this time period in both the taxa, the deciduous dentition erupts, the first permanent molars are acquired, and frequently the permanent incisors commence emergence. Tooth formation, eruption and palatal growth characterize the facio-dental region in these two genera during this dynamic period.

There is no significant sexual dimorphism in palatal size in *Macaca* or *Papio* during the time covered by the data. This permitted combining the sexes in order to examine the degree of differences separating the two genera. In every case the difference in absolute palatal measurements are highly significant. The baboon is a larger animal than the pig-tail and this is also reflected in their palatal measurements.

When relative growth rates are considered another picture emerges. There is no appreciable sexual dimorphism in growth rates within genera, nor are there any significant differences in growth rates between genera. Thus, the genera are quite different in absolute size but they grow at approximately the same relative rates. In both taxa the relative growth rates represent a decelerating curve.

ACKNOWLEDGMENTS

We wish to thank Charles D. Wood, Medical Illustrator for preparing figure 1.

This research was supported in part by

National Institutes of Health grants DE-02918 and RR-00166, Bethesda, Maryland.

LITERATURE CITED

Baume, L. J., and H. Becks 1950 The development of the dentition of Macaca mulatta. Am. J. Orthod., *36:* 723–748.

Buettner-Janusch, J. 1966 A problem in evolutionary systematics: nomenclature and classification of baboons, genus *Papio.* Folia Primat., *4:* 288–308.

Fisher, R. A. 1921 Some remarks on the methods formulated in a recent article on the quantitative analysis of plant growth. Ann. Applied Biol., *7:* 367–372.

Freedman, L. 1962 Growth of muzzle length relative to calvaria length in *Papio.* Growth, *26:* 117–128.

Gavan, J. A. 1967 Eruption of primate deciduous dentition: A comparative study. J. Dent. Res., *46:* 984–988.

——— 1971 Longitudinal, postnatal growth in chimpanzee. In: Behavior, Growth and Pathology of Chimpanzees (The Chimpanzee, volume 4). G. H. Bourne, ed. University Park Press, Baltimore, pp. 46–102.

Gavan, J. A., and D. R. Swindler 1966 Growth rates and phylogeny in primates. Am. J. Phys. Anthrop., *24:* 181–190.

Hurme, V. O., and G. van Wagenen 1953 Basic data on the emergence of deciduous teeth in the monkey (*Macaca mulatta*). Proc. Amer. Phil. Soc., *97:* 291–315.

——— 1961 Basic data on the emergence of permanent teeth in the rhesus monkey (*Macaca mulatta*). Proc. Amer. Phil. Soc., *105:* 105–140.

Krogman, W. M. 1930 The problem of growth changes in the face and skull as viewed from a comparative study of anthropoids and man. Dent. Cosmos, *72:* 624–630.

Maples, W. R. 1972 Systematic reconsideration and a revision of the nomenclature of Kenya baboons. Am. J. Phys. Anthrop., *36:* 9–19.

Moore, A. W. 1949 Head growth of the macaque monkey as revealed by vital staining, embedding and undecalcified sectioning. Amer. J. Orthod., *35:* 654–671.

Napier, J. R., and P. H. Napier 1967 Handbook of Living Primates. Academic Press, London.

Reed, O. M. 1965 Studies of the dentition and eruption patterns in the San Antonio baboon colony. In: The Baboon in Medical Research. Volume I. H. Vagtborg, ed. University of Texas Press, Austin, pp. 167–180.

Swindler, D. R., and J. A. Gavan 1962 Calcification of the mandibular molars in rhesus monkeys. Arch. Oral Biol., *7:* 727–734.

Swindler, D. R., J. A. Gavan and W. M. Turner 1963 Molar tooth size variability in African monkeys. Hum. Biol., *35:* 104–122.

Swindler, D. R., and V. Sassouni 1962 Open bite and thumb sucking in rhesus monkeys. Angle Orthod., *32:* 27–37.

Thorington, R. W., Jr., and C. P. Groves 1970 An annotated classification of the Cercopithecoidea. In: Old World Monkeys: Evolution, Systematics, and Behavior. J. R. Napier and P. H. Napier, eds. Academic Press, New York, pp. 629–647.

van Wagenen, G. 1952 Age at menarche of the laboratory rhesus monkey. Anat. Rec., *112:* 436.

Zuckerman, S. 1926 Growth-changes in the skull of the baboon, *Papio procarius.* Proc. Zool. Soc. Lond., *2:* 843–873.