Original Article

Three-Dimensional Palatal Development between 3 and 6 Years

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ABSTRACT

Objective: To measure palatal landmarks of healthy nonpatient children aged 3 to 6 years with a normal deciduous dentition and to evaluate palatal shape independent of size.

Materials and Methods: Fifty-eight dental casts of children with a normal and complete deciduous dentition were obtained and digitized with a computerized 3D instrument. At all ages, male and female data did not differ (Student's *t*-test), so the pooled values were considered. Dimensions were compared between ages by analyses of variance.

Results: Palatal slope and height increased significantly as a function of age ($P < .001$). Palatal length did not change with age (average: 23.1 mm). In the frontal plane, the intermolar width increased slightly with age by about 1.8 mm at the second molars, 1.1 mm at the first molars, and 0.9 mm at the canines. Palatal height in the frontal plane did not change in the posterior part of the palate, but decreased anteriorly. The intercanine distance increased by 0.9 mm with age. However, this change did not reach statistical significance.

Conclusions: Between 3 and 6 years of age, palatal shape changed and became proportionally higher in both the frontal and sagittal planes.

KEY WORDS: Palate; Growth and development; Deciduous dentition, 3D

INTRODUCTION

The quantitative and qualitative study of craniofacial morphology in the individual patient and its comparison with normal reference subjects represents the first step in the diagnosis of facial dysmorphology and a determination of the effect of therapy. There are several studies regarding palatal dimension assessment; most have focused on craniofacial syndromes.[1–4] Such investigations have not produced a consistent view of the values for palatal height and width in healthy children.

The mathematical description of a biologic structure allows quantifying of shape independent of size. New sophisticated methods for the noninvasive determination of the three-dimensional (3D) morphology of human structures have been developed. These include laser scanning, stereophotogrammetry, optical electronic systems, electromagnetic digitizers, and 3D digital computer-aided procedures.[5–10]

Oral parafunctions or harmful habits can affect normal palatal growth. Breathing, sucking, mastication, swallowing, and sound pronunciation are part of the neuromuscular functional system. Respiratory performance is of great importance for stimulating and maintaining a balance during and after craniofacial development. All of these functions represent natural mechanisms of growth control, and any sustained alteration in their performance may lead to the appearance of structural anomalies of the osseous bases. Westling and Mohlin[11] showed that there were no relationships at early ages between parafunctions and palatal dimensions. Nevertheless, their data about palatal posterior dimensions did not supply information on palatal shape.

During an orthodontic or orthognathic-surgical treat-

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ment, palatal dimensions often need to be changed. For example, more than 100 years ago rapid and slow palatal expansion was introduced, a method that is currently applied in clinical orthodontics as a solution for maxillary contraction.[12]

In the present investigation, an electromagnetic 3D computerized digitizer was used to measure several landmarks on the palates of healthy children with normal deciduous dentition, and mathematical equations of palatal shape, independent of size, were developed. The analysis was restricted to children free from oral parafunctions and without respiratory problems, to provide a set of normative data.

MATERIALS AND METHODS

Patients

Fifty-eight dental casts were obtained from children between 3 and 6 years of age (38 boys, 20 girls) with a complete deciduous dentition. The children were selected by a screening done in a public structure in Milan, Italy. Only healthy children with a normal anteroposterior canine and molar relationship (Angle Class I), no anterior open bite, no crossbite, without parafunction, and without any respiratory or phonetic problems were included in the study. In addition, subjects were excluded if any permanent teeth had erupted.

The parents or legal guardians were informed in full about the adopted procedures and gave their written agreement to the investigation, which had been approved by the local ethics committee.

Digitization of Palates

A standardized set of palatal landmarks was digitized with a computerized 3D instrument (3Draw Polhemus Inc, Colchester, Vt). The method was derived from the original description made by Ferrario et al.[13]

On each cast, the following landmarks were identified and marked: the intersections of the palatal sulci of the first ($M1_r$, $M1_l$) and second ($M2_r$, $M2_l$) deciduous molars with the gingival margin, the intersection of gingival margin and the point of maximum convexity of the canines (C_r, C_l), the posterior limit of the palatal raphe (RP), incisive papilla (IP), and the cusps of the deciduous canines (A_r, A_l) (Figure 1). The intermolar ($M1_{r\ to\ l}$, $M2_{r\ to\ l}$) and intercanine lines and the line perpendicular to the second intermolar line starting from IP were traced, and approximately 15 points were marked on each line.

The x-, y-, and z- coordinates of the landmarks were obtained with the electromagnetic 3D digitizer[13–15] and used to derive a mathematical model of palatal form.

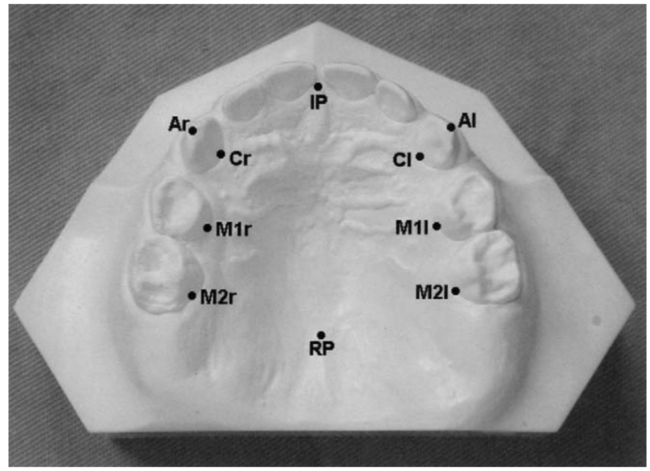

Figure 1. Landmarks identified on a palatal cast.

Mathematical Calculations

For each palate, the following measurements were obtained.

Sagittal plane.

Palatal length: horizontal projection of the line from IP to M2 (mm)
Palatal slope: slope of the maximum palatal height versus the horizontal axis (degrees)
Maximum palatal height (mm)

Horizontal plane.

Angle of RP, between the IP-RP line and the IP-M line (degrees)

Frontal plane.

Palatal width ($M2_r$ to $M2_l$; $M1_r$ to $M1_l$; C_r to C_l) (mm)
Intercanine distance (A_r to A_l) (mm)
Palatal height at the first and second molars and at the canines (mm)

Palatal shape (size independent) was assessed by four-order polynomials in sagittal-plane (from IP to a line connecting the second deciduous molars) and frontal-plane (a curve corresponding to the second deciduous molars) projections. In the frontal-plane projections, the origin of the axis was set at M2; the x-axis corresponded to the $M2_r$ to $M2_l$ line, and the y-axis corresponded to its vertical perpendicular. In the sagittal plane projection, the origin of the axis was set at IP; the x-axis corresponded to the horizontal projection of the IP–M2 distance and the y-axis corresponded to its vertical perpendicular.

Statistical Analyses

Palatal casts were divided according to the children's chronologic ages, and five non-overlapping age

Table 1. Palatal Dimensions and Maxillary Intercanine Distance as a Function of Age

Measurement	3.0–4.0 y (n = 5) Mean	SD	4.0–4.5 y (n = 10) Mean	SD	4.5–5.0 y (n = 14) Mean	SD	5.0–5.5 y (n = 18) Mean	SD	5.5–6.0 y (n = 11) Mean	SD	P^a
Sagittal plane											
Length (mm)	22.9	1.8	23.6	1.3	23.0	2.4	22.8	1.3	23.1	2.1	ns
Slope (deg)	23.5	1.3	24.0	1.3	24.5	1.3	25.5	0.8	26.1	1.0	.001
Height (mm)	10.4	1.5	10.8	1.7	10.7	1.2	11.1	1.4	11.4	1.0	
Horizontal plane											
Raphe angle (deg)	1.4	0.7	1.6	0.5	2.0	0.4	2.0	0.4	1.3	0.3	.001
Frontal plane											
Widths (mm)											
$M2_r$–$M2_l$	27.8	1.3	28.0	1.5	29.1	1.9	29.0	1.8	29.6	2.2	ns
$M1_r$–$M1_l$	24.2	1.0	24.4	1.6	25.0	1.4	25.2	1.5	25.4	1.4	ns
C_r–C_l	21.6	1.3	21.8	1.8	21.8	1.4	22.1	1.6	22.5	1.2	ns
Heights (mm)											
$M2_r$–$M2_l$	10.7	1.7	11.0	2.1	10.9	1.6	11.6	1.6	12.0	1.2	ns
$M1_r$–$M1_l$	9.6	0.6	10.1	1.4	96	1.1	9.9	1.4	9.8	1.3	ns
C_r–C_l	4.1	0.7	4.5	1.6	3.7	1.2	3.8	0.9	3.2	0.7	ns
A_r–A_l (mm)	27.56	0.77	28.72	1.45	29.18	1.11	28.23	1.80	28.48	1.84	ns

[a] Analyses of variance; ns, not significant, $P > .05$.

groups were made, each covering 6 months. At all ages, male and female data did not differ (Student's *t*-test for independent samples), and pooled values were considered. Dimensions were compared between ages by analyses of variance, with a level of significance set at 5% ($P < .05$).

Error of Method

The intraoperator repeatability of the measurements was assessed in two different ways: (1) landmark identification, and (2) repeated digitization of the same cast.[14]

To assess the error in landmark identification, five randomly selected casts were traced twice and digitized by the same operator within a 1-week interval. To asses digitization error, five casts were digitized twice by the same operator within a 1-week interval.

For each linear and angular measurement, the Dahlberg error was calculated[13,16] (error $= \sqrt{\Sigma\, d^2/2N}$, where N is the number of casts digitized). For each measurement, the error percentage[16] was calculated as the percentage ratio between the variance of the method error and the population variance of that measurement. In both tests, the palates were also interpolated with the four-order polynomial equation (frontal and sagittal plane projections).

In all repeated analyses, the four-order polynomials used to interpolate the palatal curves of the same cast were superimposed, with coefficients of correlation ranging between 0.97 and 1.00.

For landmark identification, the error of the method was always less than 10% of the total biologic variance. For landmark digitization, the error percentage ranged between 1.76% (horizontal projection of the distance between IP and M2) and 8.26% (maximum palatal height in the frontal plane).

RESULTS

Palatal slope and height increased significantly as a function of age ($P < .001$; Table 1). Palatal length (distance between IP and a line connecting the second deciduous molars) did not change with age (average, 23.1 mm). In the frontal plane, intermolar width increased slightly with age by about 1.8 mm at the second deciduous molars, 1.1 mm at the first deciduous molars, and 0.9 mm at the canines. Palatal height in the frontal plane did not change in the posterior part of the palate but decreased anteriorly. Also, the angle of RP varied significantly in the analyzed children ($P < .001$).

With age, intercanine distance increased by 0.9 mm (Table 1). However, this change did not reach statistical significance. Between 3 and 6 years of age, palatal shape changed; the palate became proportionally higher in both the frontal and sagittal planes (Figure 2).

DISCUSSION

Assessment of the normal range of palatal size and shape can be used as a baseline for studies of oral developmental abnormalities. To the best of our knowledge, the present study is the first to provide a complete set of quantitative data on palatal size and

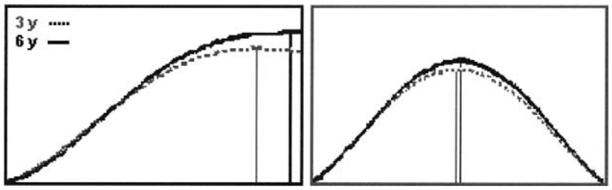

Figure 2. Comparison of palatal shape (size independent) between 3 and 6 years of age in sagittal and frontal plane projections.

shape in children with healthy, normal deciduous dentitions who are also free from oral parafunctions and respiratory problems.

In the current study the increase in palatal slope in the sagittal plane could have been caused by the changes in swallowing patterns that take place from childhood to adulthood.[17] This functional modification could also be the reason for the shape modification, as well as for the decrease in palatal height at the canines. Despite the fact that previous reports indicated that palatal shape at 6 years of age would become less flat,[17] no quantitative data were found. Some changes in the position of RP relative to the dental arches were observed, with greater palatal symmetry in children aged 4.5 to 5.5 years. The effect, although it was statistically significant, was limited (up to 2 degrees). Overall, this effect could explain the discrepancies found between the maximum height of the palate in the frontal projection (between the deciduous second molars) and the maximum height of the palate in the sagittal projection.

Overall, comparison of the present results with those of other studies is difficult, because studies of palatal size and shape in children between 3 and 6 years of age are scarce. Hung-Huey and Ching-Ting[18] analyzed 150 ''normal'' children and found sex-related differences in size; all linear measurements were uniformly larger in boys than in girls. This sexual dimorphism contrasts with the current findings, but racial or ethnic differences, as well as different inclusion criteria, might account for the difference. Nevertheless, notwithstanding the different methods used (2D photographic vs 3D direct assessment), the values for intermolar width and palatal depth were similar to the current data (Table 2).

De Freitas et al[19] compared the transverse and vertical palatal dimensions of two groups of children with a mean age of 5 years. One group had allergic rhinitis and the other had no respiratory pathology. In the group without any respiratory pathology, the intercanine distance from the palatal surfaces of the maxillary deciduous canines at the cervical margin was 23.7 mm, showing good agreement with the present palatal intercanine width (C_r to C_l). Overall, the intercanine distance measured in the current group of children is in good agreement with the values reported by Abu Alhaija and Qudeimat[20] from a study of randomly selected 4- to 5-year-old children, and by Warren and Bishara[21] from a study of children of comparable age but with different sucking behaviors. Intermolar width and maximal palatal height also correlated well with the current data (Table 2).

In the present investigation, no significant age-related modifications were found for the maxillary intercanine distance, but further studies are required to confirm this observation. Indeed, according to Bishara et al,[22] intercanine and intermolar widths increase significantly between 3 and 13 years of age, but arch width does not change in the deciduous dentition between 4 and 6 years of age. The largest increase (3 mm) was observed during the eruption of the maxillary and mandibular incisors, with subsequent stabilization.

Among the main limitations of the present study are the reduced number of children and its cross-sectional nature, which prevented the assessment of individual growth patterns.[15] Nevertheless, the study provides a complete set of data regarding hard tissue palatal dimensions in children 3 to 6 years of age and used a 3D method that did not destroy the casts.

In children with a complete deciduous dentition, the lack of age-related modifications in maxillary intercanine width implies careful consideration of treatment timing of patients with crossbites. When a functional cause has been ruled out, the diagnosis of a crossbite at the deciduous canines should be a priority, because a relatively reduced maxillary intercanine distance will probably not correct spontaneously with growth.

In the frontal plane, the increase in intermolar width was larger than the increase in intercanine width. This could be an additional important fact to considered in the timing of orthodontic treatment. Further investiga-

Table 2. Palatal Dimensions in the Primary Dentition from Literature References

				Intermolar distance ($M2_r$–$M2_l$) (mm)		Palatal height (mm)	
Authors	Sex	Age (y)	n	Mean	SD	Mean	SD
De Freitas et al[19]	M+F	4–6	22	29.6	2.2	10.0	1.2
Hung-Huey and Ching-Ting[18]	M	4–5	78	30.1	2.2	10.8	1.2
Hung-Huey and Ching-Ting[18]	F	4–5	72	28.9	2.2	10.7	1.0

tions could analyze palatal shape modifications in relation to the development of an adult pattern of swallowing.

Children with allergies or enlarged tonsils have been shown to have high palatal vaults,[23] and they could develop malocclusion in the future. A careful periodic analysis of palatal shape in growing children with respiratory problems may help to prevent future malocclusion.

CONCLUSIONS

In children with a complete deciduous dentition between 3 and 6 years of age:

a. Palatal slope and height increased with age.
b. Palatal length did not change with age.
c. With age, palatal width increased more at the second deciduous molars than at the canines.
d. Additionally, the shape of the palate changed, becoming relatively higher.

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