Original Article

Three-dimensional longitudinal evaluation of palatal vault changes in growing subjects

Jasmina Primoziča; Giuseppe Perinettib; Stephen Richmondc; Maja Ovsenikd

ABSTRACT
Objective: To evaluate palatal vault change in children and to assess the reliability of two palatal parameters in assessing growth modifications.

Subjects and Methods: A group of 26 healthy white children aged 5.3 ± 0.3 years (15 boys, 11 girls) were randomly selected. Impressions of the upper dental arches were obtained at baseline and at 12, 18, and 30 months follow-up. Three-dimensional digital images of study casts were obtained using a laser scanning device. Palatal surface area and palatal volume were measured on the digital study casts at each time point. Effect size (ES) coefficients were calculated for both parameters as indices of diagnostic reliability in individual subjects when at least equal to 1.0.

Results: Significant increases in palatal surface area and volume were seen over the observation period (P < .001). ES coefficients for palatal surface area were greater than those for palatal volume. However, even for the former parameter, only the value taken at 30 months was above the threshold.

Conclusions: Growth of the palatal vault was significant during the observation period, which coincides with primary and mixed dentition stages. Palatal surface area appears to be more reliable than palatal volume in assessment of growth modifications in individual subjects. (Angle Orthod. 2012;82:632–636.)

KEY WORDS: Three-dimensional; Palatal growth; Palatal surface area; Palatal volume

INTRODUCTION

Growth of the upper jaw is influenced by genetic and/or environmental factors.1–4 It has been suggested that growth in width is completed first, then growth in length, and finally growth in height. Growth in width, including width of the dental arches, tends to be completed before the adolescent growth spurt and is affected minimally, if at all, by adolescent growth changes.5 However, as the maxillary bone grows posteriorly, it also grows wider. Growth in length and height of the maxillary bone continues through the period of puberty. Human growth and development are not uniform; accelerations and decelerations are seen in the growth velocity of different skeletal components at various developing maturational stages.6–9

Studies of maxillary growth and maturation of the intermaxillary sutural system10–13 and growth of the mandible9,14–16 have been conducted. However, different methods have been used for assessment of growth of the upper jaw.

Histologic examination of maturation of the midpalatal suture at different developmental stages has been done on autopsy material.10,11 In the “infantile” stage (up to 10 years of age), the suture was broad and smooth, whereas in the “juvenile” stage (from 10 to 13 years), it had developed into a more typical squamous suture with overlapping sections. Finally, during the adolescent stage (13 and 14 years of age) the suture was wavier and showed increased interdigitation. Observations of the adult stage11 of the suture revealed synostoses and numerous bony bridge formations across the suture. Implant studies15,17,18 have demonstrated that the transverse growth pattern...
of the maxilla follows distance and velocity curves similar to those for body height with similar times of growth spurt and growth completion. Implant studies have also been used to show vertical growth of the hard palate on lateral cephalograms. However, both of these methods are invasive and therefore are ethically questionable for use in small children.

Until recently, growth and changes in the upper jaw were studied on plaster casts by direct measurement of arch width and length, palatal height, or palatal volume. Although reliable, the methods used are very time-consuming. To overcome these problems, a laser scanner can be used to obtain three-dimensional (3D) images of study casts. 3D images of study casts can be used to measure linear dimensions, palatal surface area, and palatal volume.

Given the poor available data on growth of the upper jaw in different dentition stages, the aim of the present study was to assess dimensional palatal vault changes in children on 3D digital images of study casts in primary dentition and mixed dentition stages.

MATERIALS AND METHODS

Study Design and Data Recording

Before the investigation was begun, approval for this study design was received from the local Institutional Review Board, along with a signed informed consent from the parents of all subjects. A group of 26 healthy white children aged 5.3 ± 0.3 years (4.9–6.1 years) were randomly selected from a local kindergarten. The group consisted of 15 boys and 11 girls in primary dentition without malocclusion and having good general health with no nutritional problems. All subjects had no respiratory, deglutition, or masticatory problems and had undergone no previous or concomitant orthodontic treatments. Impressions of the dental arches were obtained at baseline and at 12, 18, and 30 months follow-up. Study casts were scanned at a distance of 60 cm with a Konica/Minolta Vivid 910 laser scanner (Konica/Minolta Holdings, Tokyo, Japan) using a lens with a focal distance of 25 mm. With this lens, the scanner has a reported accuracy of 0.22 mm.

Each scan of the study cast was preprocessed to remove unwanted data. To measure palatal surface area and calculate palatal volume, the boundaries of the palate must be defined. The gingival plane and a distal plane were used as boundaries for the palate. The gingival plane was created by connecting the midpoints of the dentogingival junction of all primary teeth. The distal plane was created through two points at the distal surface of the second primary molar perpendicular to the gingival plane (Figure 1). Palatal surface area (Figure 1A) and palatal volume (Figure 1B) were then calculated.

Sample Size Calculation and Method Error Analysis

A sample size of at least 21 subjects was set to detect an effect size coefficient of 0.8 for either palatal parameter (surface area and volume) between any two paired comparisons of values at 12, 18, and 30 months vs baseline values, with an alpha set at .01 and a power of 0.8. The effect size (ES) coefficient is the ratio of the difference between the recordings of two different time points (eg, 12 months vs baseline), divided by the within-subject standard deviation (SD). An effect size of at least 0.8 was considered a reliable index of a large effect, that is, clinically relevant growth as detected through current parameters. Method error for each palatal parameter was calculated using interclass correlation coefficients on a random sample of 10 replicate measurements, yielding values of at least 0.95.

Statistical Analysis

The Statistical Package for the Social Sciences (SPSS) software, version 13.0 (SPSS Inc, Chicago, III), and Comprehensive Meta-Analysis, version 2 (Biostat, Englewood, NJ), were used to perform the statistical analyses. After the normality of the data was tested with the Shapiro-Wilk test and Q-Q normality plots, and equality of variance among datasets was assessed with a Levene test, nonparametric methods were used for data analysis. Nevertheless, means ± SDs are reported for descriptive purposes. A Friedman test was used to assess the significance of the differences in both palatal parameters over time. A Bonferroni-corrected Wilcoxon test was used for pairwise comparisons.

Moreover, as indices of potential diagnostic accuracy of each palatal parameter, ES coefficients (as Hedges’s g coefficients), along with the 95% confidence intervals (CIs), have been calculated at each time point, as previously described. In this regard, a threshold of 1.0 was used to assess potentially good diagnostic accuracy.

RESULTS

At baseline, all of the children had a complete primary dentition, but at 12 months follow-up, eruption of the permanent teeth was seen in most cases. At 18 months follow-up, all of the children were in the early mixed dentition stage, with all first permanent molars and permanent incisors erupted. Because no significant differences were seen between the genders in any parameter, merged data are shown herein.

Results regarding palatal surface area and palatal volume are shown in Table 1. Longitudinally, significant
differences in palatal surface area and volume were seen (all differences, $P < .001$). At pairwise comparisons with baseline values, the two parameters were greater at each time point as compared with baseline values. No significant differences were observed between boys and girls (not shown).

Results regarding the ES coefficients for both palatal parameters are shown in Table 2. ES coefficients for palatal surface area were greater as compared with those for the palatal volume parameter. ES coefficients greater than 1.0 were seen for palatal surface area at 18 and 30 months, and for palatal volume at 30 months. However, among these coefficients, only those for palatal surface area at 30 months with full 95% CIs (1.11–2.30) showed a statistically significant value above the threshold.

**DISCUSSION**

Prediction of growth of the upper jaw, particularly in the transverse direction, is important for treatment planning of maxillary transverse deficiency, to achieve an orthopedic effect and a stable result. Growth of the maxillary bone has been studied with the implant method on cephalograms or on plaster study casts by measuring length, width, and height of the upper arch.

**Changes in the Palatal Vault**

In the present study, dimensional changes in the palatal vault at different dental stages were evaluated; 3D digital images of study casts showed a high degree of accuracy when different measurements were

---

Table 1. Palatal Surface Area and Palatal Volume at Each Time Point ($n = 26$)$^{a,b}$

<table>
<thead>
<tr>
<th>Palatal Parameter</th>
<th>Baseline</th>
<th>12 Months</th>
<th>18 Months</th>
<th>30 Months</th>
<th>Diff</th>
</tr>
</thead>
</table>
| Surface, mm$^2$   | 780.7 ± 83.1 | 831.0 ± 84.6$^*$ | 840.5 ± 92.2$^*$ | 878.2 ± 101.6$^*$ | $P < .001$
| Volume, mm$^3$    | 2948.9 ± 479.7 | 3139.3 ± 489.1$^*$ | 3137.0 ± 590.1$^*$ | 3306.6 ± 647.1$^*$ | $P < .001$

$^a$ Data are shown as means ± standard deviation (SD).

$^b$ Diff indicates significance of the difference over time points or between groups.

$^*$ Statistically significant difference as compared with the corresponding baseline value.
performed.\textsuperscript{26,34} In particular, growth of the maxillary bone was assessed by measuring palatal surface area and palatal volume at each time point; this has previously been demonstrated to be a valid tool for assessing skeletal changes in the maxillary bone before and after treatment.\textsuperscript{27,28,35}

Of note, growth in length may be excluded in this study because the palatal vault was delimited posteriorly by a plane passing through two points located at the distal aspects of the last erupted primary molars, even if first permanent molars were present in the oral cavity (Figure 1B). Nevertheless, an almost linear increase in palatal surface area was observed during the study, regardless of the dentition stage. However, the transition from primary to mixed dentition, with the permanent incisors erupting more labially, may have led to relocation of the boundaries of the palatal vault, influencing the size of the palatal surface area.

On the other hand, from 12 to 18 months follow-up, when all of the children had completed the transition to the early mixed dentition stage, a slight, although not significant, decrease in palatal volume was observed. Regardless of this slight decrease, maxillary growth in the transverse and vertical direction continued at almost the same rate throughout the observation period.

Although a longer period of follow-up on a larger group is needed to determine the ideal time to start orthopedic treatment\textsuperscript{36} in the maxillary bone, this study demonstrates that during the primary dentition stage, the transitional dentition stage, and the mixed dentition stage, growth of the maxillary bone was observed as an increase in palatal surface area and volume.

### Diagnostic Accuracy of 3D Digital Images of Study Casts

A further goal of the present study was to estimate the diagnostic accuracy of measurements on 3D digital images of study casts as indicators of palatal growth in individual subjects. Indeed, any diagnostic tool has to provide measurement outcomes wherein the responses obtained can be considered accurate (ie, to have high sensitivity and specificity) in terms of the presence/absence of a given condition (eg, growth). In this regard, further difficulty in appraising palatal parameters resides in intragroup variability and the number of subjects examined, on which recorded variability also depends.

Therefore, a critical approach to assessing the relevance of measurements on 3D digital images of study casts as a diagnostic aid in orthodontics has to rely on the high accuracy of measurements, and the fact that measurements recorded at two time points (eg, baseline vs 12 months) have to show notable changes as compared with corresponding variances. Indeed, a low ratio would be responsible for low sensitivity and specificity, revealing poor diagnostic performance of a given tool. A statistical approach to quantifying this ratio (taking into account the sizes of study populations) is provided by calculation of the ES coefficient.\textsuperscript{30}

The present appraisal through the ES coefficients demonstrates that palatal surface area would be more reliable than palatal volume in assessment of growth changes (Table 2). Moreover, evidence that both parameters would be capable of detecting palatal vault changes in a group of children (as shown by ES coefficients greater than 0.6) does not imply that a reliable assessment is provided on an individual basis. Therefore, only the ES coefficient for palatal surface area after 30 months reached the required threshold for this parameter (at least 1.0, considering also the full confidence interval) to reliably describe palatal growth modifications in individual subjects. Although both parameters may be successfully applied in detecting growth changes during research activity, from a clinical standpoint, palatal surface area should be preferred because it is a more reliable parameter, and follow-up activities should occur at least 30 months apart, at least in the age ranges included in the present study.

### CONCLUSIONS

- Palatal growth modifications were detected during primary dentition through early and intermediate mixed dentition stages.
- Orthopedic treatment in the upper jaw should be performed during this period to enhance treatment efficiency.
- To monitor palatal vault changes during growth, palatal surface area should be preferred over palatal volume.

\textit{Angle Orthodontist, Vol 82, No 4, 2012}
REFERENCES