TWO-DIMENSIONAL ASSESSMENT OF MORPHOLOGICAL CHANGES OF MAXILLA INDUCED BY RAPID MAXILLARY EXPANSION: A NEW METHOD

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ABSTRACT
The aim of the present study was to introduce a new technique for the evaluation of transverse and vertical changes in the palate, induced by rapid maxillary expansion (RME). Using barium sulfate solution with a paintbrush, a thin line was drawn on and between the first molars of the maxillary stone casts. Then, radiographic images of the stone casts were obtained. Transverse and vertical changes in palate were evaluated on these images by means of a computerized imaging software program. This new evaluation technique is inexpensive, simple and reliable for visualizing and evaluating the amount of transverse expansion and vertical depth of the palate.

Keywords: Rapid maxillary expansion, palate, skeletal, dentoalveolar, palatal depth, barium sulfate, radiography

Introduction
Separation of the two maxillary halves by means of a fixed appliance including a jackscrew was first hypothesized and applied to a patient by Angell (1), the pioneer orthodontist in this idea, in 1860. However, this spectacular treatment modality was rejected by the authorities of those days since Angell had no chance to show the skeletal effects of the appliance by radiography. Landsberger (18) was the first to visualize the skeletal effect of rapid maxillary expansion (RME) with occlusal radiograph of an opened midpalatal suture in 1908. RME had a silent period for a half century after this time point. This treatment approach was reintroduced and popularized during the 1960s by Haas (10, 11).

It has been known that the transverse maxillary dimension represents the sum of the skeletal maxillary base, the inclination of buccal teeth, and the surrounding alveolar bone (27). Transversal maxillary discrepancies involving the skeletal base should be treated by skeletal expansion, whereas dentoalveolar discrepancies could be corrected by increasing the inclinations of teeth and alveolar walls. Main object of RME is to widen the constricted maxilla transversely in a short period, but some tipping in buccal teeth and alveolus is inevitable. For this reason, it is important to know the amount of skeletal and dentoalveolar expansion.

Posteroanterior (PA) radiographs have been routinely used to determine the amount of real skeletal expansion caused by RME (3, 20). Timms et al (29) were the first to use computed tomography (CT) for the assessment of skeletal maxillary changes induced by RME, but these tomographic evaluations were neglected from the orthodontists for a long time. In recent years, CT utilization for the assessment of treatment changes of RME became popular among orthodontists, and a lot of articles appeared in literature (8, 9, 12, 25, 28). Some authors (5, 23) also used stone casts to evaluate the same changes in the palate.

The evaluation methods mentioned above have some shortcomings such as being expensive and requiring another expert (9, 12, 25, 28, 29), needing model duplication (23), being exposed to additional X-rays (9, 12, 25, 28, 29), not showing the real skeletal maxillary expansion (9, 28), and necessitating extra laboratory work (5).

Recently, Oktay and Kilic (22) introduced a new imaging method to obtain radiographic images of the palatal area on orthodontic stone casts. These authors suggested that detailed cross-sectional views of molar crowns and palatal vaults could be obtained as is the case in 3-D methods.

The aim of the present study is to introduce a new, easy, and reliable technique for evaluating dentoalveolar and skeletal morphology of palate in transverse and vertical dimensions.

Materials and Methods
Obtaining radiographic images
Drawing lines with barium sulphate solution on stone casts and obtaining radiographic images of the barium sulfate lines were adapted from the study of Oktay and Kilic (22). Barium sulphate lines were drawn on orthodontic models and their radiographic images were obtained according to the rules as explained by the authors.

Digitizing the images
The radiographs were scanned with a scanner (Epson Expression 1860 Pro, Seiko Epson Corp., Naganoken, Japan) under a magnification of 100% and the images were saved on the computer. They were then digitized with Quick Ceph 2000 software program (Quick Ceph Systems, San Diego, CA) and “Custom Analysis” was used to evaluate the changes in the dentoalveolar structures.
Landmarks and distances used in this evaluation

Landmarks and distances used in the present technique were adapted from the study of Oliveira et al. (23) and Oktay and Kiliç (22). The points and linear distances used in this evaluation method (Fig. 1) included:

**The points:** Right and left mesio-palatinal cusps (points 1 and 2); right and left upper alveolar tipping points (points 3 and 7); right and left lower alveolar tipping points (points 4 and 6); deepest point in palatal raphe (point 5); intersection point (point 8) described by the junction of palatal depth and upper palatal width.

**The Linear Distance Measurements:**
1) **Dental expansion:** Determined by intermolar distance (Between points 1 and 2);
2) **Dentoalveolar expansion:** Determined by upper palatal width (Between points 3 and 7);
3) **Skeletal expansion:** Determined by lower palatal width (Between points 4 and 6);
4) **Palatal depth:** The perpendicular distance from the upper palatal width to the deepest point of the palate (Between points 5 and 8);

**Reliability of the method**

In order to test the reliability of this evaluation method, 15 treated cases were randomly selected from the files of our department, and their stone casts were evaluated by this technique. All procedures such as landmark identification, digitizing, and measurement were repeated 2 weeks later by the same author. Correlation coefficients were computed to assess the reliability of the measurements as described by Houston (15).

**Results and Discussion**

The coefficients of reliability regarding the measurements are shown in Table 1. As can be seen from the Table, the values of the reliability coefficients are above 0.90 for all measurements. Based on this result, it can be said that this method yields sufficient reliability.

The aim of maxillary expansion by orthopedic forces is to obtain skeletal changes in the subject with a skeletal-palatal deficiency. This technique called rapid maxillary expansion increases the transverse dimensions of the upper dental arch by separating the two maxillary halves by means of mid-palatal suture splitting. This treatment approach has also a bending effect on the posterior teeth and alveolar processes (2, 6, 11, 14). For this reason, the effects of RME on skeletal expansion have been searched by many authors. Orthodontic stone casts have been frequently used in diagnosis, treatment planning and evaluation of treatment efficiency (7, 22, 26).

**Table 1**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dental expansion</td>
<td>0.9685</td>
</tr>
<tr>
<td>Dentoalveolar expansion</td>
<td>0.9382</td>
</tr>
<tr>
<td>Skeletal Expansion</td>
<td>0.9256</td>
</tr>
<tr>
<td>Palatal depth</td>
<td>0.9527</td>
</tr>
</tbody>
</table>

Barium sulfate is a radiopaque agent which has been used to diagnose certain medical problems, especially in the gastrointestinal system. Because this substance does not let x-rays to pass, any tissue or organ coated with it will appear white on the x-ray films (13). This substance has also been used in orthodontics to expose skeletal asymmetries and the accompanying soft-tissue deficiencies and/or excess by means of radiographs (7).

Since computerized digitizing has some advantages (4, 30), such as accurate determination of the contours of the investigated structures by enlarging the image and changing the contrast when needed, a computer software program was incorporated into this evaluation method.

The present study aims to introduce a new method for visualization and evaluation the transverse and vertical morphological changes of the palate. This technique is very simple and practical. Using this technique, one could easily appraise the skeletal and dento-alveolar expansions of palate and the changes in palatal depth after RME. Skeletal or basal maxillary expansion induced by RME was evaluated by the distance between the deepest points in palatal concavity on right and left sides (points 4 and 6). Likewise, Oliveira et al (23) and Ciambotti et al (5) used the same points for evaluation of skeletal expansion induced by RME.

The most important feature of the present technique is that image acquisition process from stone casts has high reliability and low cost. Oktay and Kiliç (22) used the same visualization method for evaluation of the inclination in the posterior dentoalveolar structures after RME. The radiographic images obtained in this technique give detailed cross-sectional views of molar crowns and palatal vaults as in 3-D methods (22). On these images, the transverse and vertical changes of the palate can be readily measured. The parameters used in this method show the actual transverse expansions at the dental, alveolar, and basal levels of the maxilla. The flattening effect of RME on the palatal vault can also be assessed by measuring the palatal depth. Oliveira et al (23) used the same points for the
assessment of morphologic changes of maxilla by means of 3D images of the stone casts. Likewise, Garib et al (8) evaluated dento-skeletal effects of RME by means of two-dimensional tomographic images using almost the same points.

In the studies carried out on plaster models, Ciambotti et al (5) assessed the skeletal changes by means of a symmetrograph and a hard laboratory work that requires considerably special attention. Oliveira et al (23) used laser scanning in order to get superimpositions. Although laser scanning has some advantages such as high reliability, providing more comprehensive data, and giving more precise cross-sectional areas of the investigated structures (17, 23), it is rather expensive and requires extra hard laboratory work. In a recent study, Marini et al (19) assessed transverse diameters and volumetric variations of the palate by a digital photogrammetric technique before and after RME. This technique includes three operative phases which require great attentions: (i) Digital photographic acquisition, (II) optical 3D model creation, and (III) graphic rendering. Some authors (8, 9, 12, 25, 28, 29) used computed tomography for the evaluation of skeletal changes of the maxilla. Gathering computed tomographic images needs another expert (skilled radiologist) and great attention. In addition, the patients are subjected to extra radiation. Image acquisition with CT is also expensive. In a study carried out for computed tomographic assessment of transverse maxillary effects of RME, Timms et al (29) drew attention to the reproducibility of head positioning of patients and of the registration of landmarks to ensure true superimpositions. Although two-dimensional CT images have a high degree of reproducibility (24, 25) and they improve the accuracy of cephalometric measurements over conventional cephalography (21), there was no additional gain when using the images generated from the CT volumetric data set (21).

In a spiral CT study evaluating the skeletal changes induced by RME, Tausche et al (12) offered new skeletal points out of the real expansion site such as lower borders of the orbits and piriforms. Podesser et al (24, 25) introduced a new computed tomographic method for the quantitation of transverse maxillary dimensions. In this method, “cross-axis” of molars was used as reference lines for the transverse dentoalveolar and skeletal assessments. Using these reference lines may cause incorrect evaluations, since buccal inclinations of molar teeth during both bonded and banded RME are inevitable and at significant level (16).

Conclusions
It seems that the new technique introduce in this paper is an inexpensive, simple and reliable method for visualizing and evaluating the amount of the transverse expansion and vertical depth of the palate.

REFERENCES