ORIGINAL RESEARCH

Three Dimensional Assessment of the Palate and Palatal Contoural changes in Orthodontically treated cases using Reverse Engineering 3-D LASER scanner

Dr. Madhavi Naidu¹*, Dr. Raghunath N²

*Corresponding Author Email: ortho.madhavi@gmail.com

Contributors:

1. Senior Lecturer, Department of Orthodontics, Faculty of Dental Sciences, M S Ramaiah University of Applied Sciences, Bengaluru, Karnataka

2. Professor, Department of Orthodontics, J.S.S Dental College and Hospital, Mysuru, Karnataka.

ABSTRACT

Previous studies of the morphologic changes of the maxilla after orthodontic treatment have used 2-dimensional methodologies. In the present study, we used a 3-dimensional surface laser scanning technique and computerized cast analysis for assessment of palatal contour in sagittal, transverse and vertical dimensions. Maxillary pre and post treatment casts were duplicated and scanned using 3-D FARO laser scanner. The following landmarks were identified: Medial points of third palatal rugae; Point A (Intersection of the midsagittal plane with a line passing over the widest point of incisive papilla); Point B (Intersection of the midsagittal plane with a plane passing through most distal points of the upper first permanent molars); Point C (Cervical aspect of the mesiolingual cusp at the junction of the right permanent first molar tooth and gingival margin); Point D (Cervical aspect of the mesiolingual cusp at the junction of the left permanent first molar tooth and gingival margin). Length of the palate measured from Point A to Point B; width of the palate measured from Point C to Point D; height of the palate measured from Point C/Point D to the highest point of the palatal vault were evaluated. Cast analysis demonstrated that, palatal contour reacted differently when treated with extraction and non-extraction. A significant difference was found in palatal contour treated by extraction in the sagittal and transverse dimension. However a significant change was observed in the length and vertical height of the palate when treated without extractions. Intergroup analysis revealed a statistically significant difference in post treatment anteroposterior length of palate between extraction and non-extraction cases.

INTRODUCTION:

In recent decades three dimensional virtual study models have made headway into dentistry. Digital study models were introduced commercially in 1999 by OrthoCad and have given way to the most recent reverse engineering technology used to capture and recreate three dimensional images. The replacement of plaster orthodontic models with virtual models has potential benefits including instant
accessibility without need for retrieval of plaster models from storage area, ability to perform accurate and simple diagnostic set ups of various extraction patterns, virtual images can be transferred anywhere in the world for referral and consultation.

Superimposition of orthodontic study models is of a greater significance since they are the only evidence of pretreatment occlusion, which is irreversibly altered by the treatment. The records are essential for retrospective reference and analysis of treatment outcome, success and failure. However superimposition of dental casts has inherent limitations due to the lack of anatomic reference points or areas for superimposition.

Stability of anatomic references point for superimposition of orthodontic casts was established from the result of a study conducted Marco Antonio Almeida et al which it concluded that the medial rugae appear to be suitable anatomic points for the construction of stable reference planes for longitudinal cast analysis. A clinical aid of imaging of plaster casts with a flatbed scanner was presented by Akhter Husain as an alternative to conventional photography. Orthodontic plaster casts could be imaged with a simple flatbed scanner for the purposes of record keeping.

However, the scanned images from a flatbed scanner was also a two-dimensional representation of a three-dimensional structure.

Knowledge of the normal rugae of palatal shape can act as a baseline to study certain oral developmental abnormalities. It is commonly alleged that muscle activity plays an important role in determining the shape of the dental arches. An accurate method for assessing the contour, symmetry and stability of the dental arches is a prerequisite for investigations of this form-function relationship. The tongue that is centrally located within the oral cavity is a powerful muscular organ which has the ability to affect the position of the teeth and surrounding structures. The palatal vault in its lateral dimension and its apical contour is of great importance in the function of the tongue. Generous vault width and smooth non-furrowed contours of the mucous membrane enable the tongue to perform swallowing, speaking and chewing motions easily. Conversely, a narrow or constricted palatal vault not only necessitates greater tongue effort to perform various functions, but also generates tongue hyperactivity and in its most extreme state, encourages and induces detrimental habits.

Various approaches to the study of arch shape have been described but they were either best suited for simple visual analysis where requirement for maximal accuracy was left desired. The cost and complexity of the techniques and the equipment employed for assessing the arch shape preclude their general application.

The present study included using three-dimensional assessment of the palate and palatal contoural changes using a reverse engineering 3-D laser scanner since the palate, due to its morphology and position, is one of the key anatomic structures in determining the type of skeletal pattern and most importantly, the palate can be influenced by orthodontic treatment procedures. This study evaluates the changes in palate and palatal contour in orthodontic cases treated with extraction and non-extraction using three-dimensional digital scanning which provides accurate measurement of palatal changes post orthodontic treatment in anteroposterior, sagittal and vertical dimensions.

**Materials and methodology**

Forty pretreatment and posttreatment maxillary casts of twenty completed cases in permanent dentition phase managed with fixed mechanotherapy were included in the present study. Out of the twenty pairs of casts selected ten were of patients treated with extraction of premolars and nonextraction each.

The maxillary casts were selected from the records of treated cases, who underwent treatment in the outpatient Department of Orthodontics and Dentofacial Orthopaedics, J.S.S Dental College and Hospital.

**INCLUSION CRITERIA**

- Patients undergoing orthodontic treatment with need for extraction of any teeth.
- Mixed dentition
- Patients with jaw discrepancies
- Skeletal malocclusion
- Patients with cleft lip and palate

**EXCLUSION CRITERIA**

- Patients with cleft lip and palate who underwent orthodontic treatment without need for extraction of any teeth.
- Patients requiring orthodontic treatment with extraction of bilateral pre molar extractions.
- Patients requiring orthodontic treatment with completed active growth period, who underwent orthodontic treatment.

Pretreatment and post-treatment maxillary casts of the same cases were taken (Figure 1) and were duplicated using Biostar machine using Biostar material of 1mm thickness. All the 20 pairs of pretreatment and posttreatment maxillary casts were poured in Orthokal. (Figure 2)

**Figure 1 - Occlusal view of maxillary cast**

**Figure 2: Duplicate of the maxillary cast**
The noncontact surface laser scanner (FARO300) operates by the principle of light-stripe triangulation range-finding, whereby the position of an illuminated surface point relative to the viewpoint is obtained by triangulation. The resolution in x and y coordinates is 200 X 200 range points view per scan. The camera was angled approximately 45° to the cast, to achieve the ideal geometry for the incidence of the laser stripes. The casts were scanned from top to bottom, with the occlusal face of the teeth and the palate vault facing the camera lens and laser beams. The images were stored in a personal computer and analyzed with the Geosoft computer software programs. (Figure 3) The reliability of this method has been tested and found to be accurate.

The following landmarks were identified on the maxillary cast and were marked using Geosoft software (Figure 4):
1) Medial points of third palatal rugae.
2) Point A: Intersection of the midsagittal plane with a line passing over the widest point of incisive papilla.
3) Point B: Intersection of the midsagittal plane with a plane passing through most distal points of the upper first permanent molars.
4) Point C: Cervical aspect of the mesiolingual cusp at the junction of the right permanent first molar tooth and gingival margin.
5) Point D: Cervical aspect of the mesiolingual cusp at the junction of the left permanent first molar tooth and gingival margin.

The three dimensional changes in palatal contour due to orthodontic tooth movement were assessed using the following parameters:
The antero-posterior length of the palate was measured from Point A to Point B. The transverse width of the palate was measured from Point C to Point D. (Figure 5). The depth of the palate measured from Point C / Point D to the highest point on the palatal vault. (Figure 6)
The three dimensional measurements of palatal contour in pretreatment and posttreatment scanned maxillary casts were compared.

**Results**
Comparison of pretreatment and posttreatment maxillary arch parameters of cases managed with non extraction and extraction of teeth was done using paired samples t test. The results of the present study will be discussed under the following headings.

**EXTRACTION GROUP:**
Changes in anteroposterior length, transverse width and vertical height: (Table 1)
The pretreatment value of anteroposterior length of 29.80 ± 1.22 was found to be increased to 30.92 ± 1.32 with a mean difference of 1.12. Pretreatment value of transverse width of 34.80 ± 3.39 was found to be decreased to 32.67 ± 3.49 with a mean difference of 2.13. these differences in the palatal length and width were statistically significant since p value was less than 0.05.

The pretreatment value of vertical height of 15.09 ± 1.99 was found to be increased to 15.31 ± 1.37 with a mean difference of 0.22. This comparative difference was found to be of no statistical significance since p value was more than 0.05.

**NON-EXTRACTION GROUP:**
Changes in anteroposterior length, transverse width and vertical height: (Table 2)
The pretreatment value of transverse width of 33.77 ± 2.76 was found to be decreased to 32.86 ± 2.67 with a mean difference of 0.90. This comparative difference was found to be of no statistical significance since p value was more than 0.05.
The pretreatment value of anteroposterior length of 30.62 ± 0.61 was found to be increased to 31.13 ± 0.75 with a mean...
difference of 0.51. The pretreatment value of vertical height of 14.69 ± 1.42 was found to be increased to 15.55 ± 1.55 with a mean difference of 0.86. These comparative differences were found to be of statistical significance since p value was less than 0.05.

Comparison of pretreatment and posttreatment maxillary arch anteroposterior length, transverse width and vertical height of cases managed by extraction and non-extraction was done using Repeated measure ANOVA test. The results were as follows:

Comparison of pretreatment and posttreatment maxillary arch anteroposterior length of cases managed by extraction and non-extraction:

In the analysis the mean length irrespective of the groups was found to be 30.21 which was increased to 31.03. An overall increase of 0.81 was found to be significant as the P value was less than 0.05. However, group wise reading revealed 1.12 increase for extraction group and 0.51 increase for non-extraction group indicating a differential increase which is statistically significant as the P value is was more than 0.05. In other words the there is a statistically significant increase in the anteroposterior length of extraction group as compared to non-extraction group.

(Table 3)

Comparison of pretreatment and posttreatment maxillary arch transverse width of cases managed by extraction and non-extraction:

In the analysis the mean width irrespective of the groups was found to be 34.29 which was reduced to 32.77. An overall reduction of 2.01 was found to be significant p was less than 0.05. However, group wise reading revealed 2.13 decrease for extraction group and 0.90 decrease for non-extraction group indicating a differential decrease which statistically non-significant as the P value is was more than 0.05 indicating the decrease in the transverse width is statistically same for both extraction and non-extraction groups.

Table 1: EXTRACTION GROUP: Changes in anteroposterior length, transverse width and vertical height

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Treatment</th>
<th>Mean</th>
<th>SD</th>
<th>SE of Mean</th>
<th>Mean difference</th>
<th>T</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anteroposterior length</td>
<td>Pre</td>
<td>29.80</td>
<td>1.22</td>
<td>0.273</td>
<td>1.123</td>
<td>7.014</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>30.92</td>
<td>1.32</td>
<td>0.295</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transverse width</td>
<td>Pre</td>
<td>34.80</td>
<td>3.39</td>
<td>0.759</td>
<td>2.132</td>
<td>5.676</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>32.67</td>
<td>3.49</td>
<td>0.780</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical height</td>
<td>Pre</td>
<td>15.09</td>
<td>1.99</td>
<td>0.446</td>
<td>0.228</td>
<td>0.712</td>
<td>0.485</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>15.31</td>
<td>1.37</td>
<td>0.308</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Table 2: NON-EXTRACTION GROUP: Changes in anteroposterior length, transverse width and vertical height

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Treatment</th>
<th>Mean</th>
<th>SD</th>
<th>SE of Mean</th>
<th>Mean difference</th>
<th>T</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anteroposterior length</td>
<td>Pre</td>
<td>30.62</td>
<td>0.61</td>
<td>0.137</td>
<td>0.512</td>
<td>5.932</td>
<td>0.000</td>
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<tr>
<td></td>
<td>Post</td>
<td>31.13</td>
<td>0.75</td>
<td>0.168</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transverse width</td>
<td>Pre</td>
<td>33.77</td>
<td>2.76</td>
<td>0.618</td>
<td>0.902</td>
<td>1.775</td>
<td>0.092</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>32.86</td>
<td>2.67</td>
<td>0.598</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical height</td>
<td>Pre</td>
<td>14.69</td>
<td>1.42</td>
<td>0.318</td>
<td>0.863</td>
<td>4.399</td>
<td>0.000</td>
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<tr>
<td></td>
<td>Post</td>
<td>15.55</td>
<td>1.55</td>
<td>0.348</td>
<td></td>
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</tbody>
</table>

Table 3: Comparison of pretreatment and posttreatment maxillary arch anteroposterior length of cases managed by extraction and non-extraction using Repeated measure ANOVA test.

<table>
<thead>
<tr>
<th>Group</th>
<th>Pretreatment</th>
<th>Posttreatment</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraction</td>
<td>29.80±1.223</td>
<td>30.92±1.323</td>
<td>1.121</td>
</tr>
<tr>
<td>Non-extraction</td>
<td>30.62±0.615</td>
<td>31.13±0.753</td>
<td>0.513</td>
</tr>
<tr>
<td>Total</td>
<td>30.21±1.041</td>
<td>31.03±1.068</td>
<td>0.817</td>
</tr>
</tbody>
</table>

Table 4: Comparison of pretreatment and posttreatment maxillary arch transverse width of cases managed by extraction and non-extraction using Repeated measure ANOVA test

<table>
<thead>
<tr>
<th>Group</th>
<th>Pretreatment</th>
<th>Posttreatment</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraction</td>
<td>34.80±3.397</td>
<td>32.67±3.490</td>
<td>2.133</td>
</tr>
<tr>
<td>Non-extraction</td>
<td>33.77±2.764</td>
<td>32.86±2.678</td>
<td>0.903</td>
</tr>
<tr>
<td>Total</td>
<td>34.29±3.101</td>
<td>32.77±3.072</td>
<td>2.018</td>
</tr>
</tbody>
</table>
Conclusion

A significant difference was found in the anteroposterior length of the palate post treatment within the two groups. However, the change in palatal width and depth between both the groups were found to be statistically non significant. Since literature comparing the change in palate in three dimension post fixed orthodontic mechanotherapy treated by extraction with non extraction is inadequate this study requires to be supported by further similar researches.

The present study also evaluated and compared the change in post treatment anteroposterior length, transverse width and palatal depth of extraction group with non extraction group. A differential difference was found in the anteroposterior length of the palate post treatment within the two groups. However, the change in palatal width and depth between both the groups were found to be statistically non significant. Since literature comparing the change in palate in three dimension post fixed orthodontic mechanotherapy treated by extraction with non extraction is inadequate this study requires to be supported by further similar researches.

Table 5: Comparison of pretreatment and posttreatment maxillary arch vertical height of cases managed by extraction and non-extraction using Repeated measure ANOVA test

<table>
<thead>
<tr>
<th>Group</th>
<th>Pretreatment</th>
<th>Posttreatment</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraction</td>
<td>15.091 ± 1.995</td>
<td>15.319 ± 1.379</td>
<td>0.228</td>
</tr>
<tr>
<td>Non-extraction</td>
<td>14.690 ± 1.422</td>
<td>15.554 ± 1.556</td>
<td>0.864</td>
</tr>
<tr>
<td>Total</td>
<td>14.891 ± 1.722</td>
<td>15.436 ± 1.456</td>
<td>0.545</td>
</tr>
</tbody>
</table>

Discussion

Orthodontic study models are essential diagnostic records which help to study the occlusion and dentition in all three dimensions. They are accurate plaster reproductions of the teeth and their surrounding soft tissues. However superimposition of dental casts has inherent limitations due to the lack of anatomic reference points or areas for superimposition.

The stability of the palatal rugae during orthodontic treatment was evaluated and the medial points of the third palatal rugae was found to be the most stable and suitable reference points for the assessment of anteroposterior tooth movement. A study evaluating the relative influence of genetics and environment on palatal dimensions in monozygotic and dizygotic twins was performed where width of the palate was measured as the minimum distance between points A and B of the upper first permanent molars at the cervical aspects of the mesiobuccal cusp at the junction of the tooth and gingival margins. The Length of the palate was measured from an anterior point defined as the intersection of the midsagittal plane with a line passing over the widest point of the incisive papilla, measured using a divider, to a posterior point defined as the intersection of the midsagittal plane with a plane passing through the most distal points of the upper first permanent molars. Height of the palate was measured from a level coinciding with points A and B of the maxillary first molars to the highest point of the palatal vault in the midline. This study conducted by Armando Riquelme et al. laid the parameters for assessing the palatal width, height and length in human twins. An advanced study was conducted for analyzing the tooth movement in extraction cases using three dimensional (3D) reverse engineering technology by Bong Kuen Cha et al. They compared the three dimensional digital model superimposition with cephalometric superimposition. It was concluded that the 3D digital orthodontic model superimposition technique used in their study was clinically as reliable as cephalometric superimposition for assessing orthodontic tooth movements.

In the present study forty pretreatment and posttreatment maxillary casts of twenty completed cases in permanent dentition phase managed with fixed mechanotherapy were included. A significant change in anteroposterior length and transverse width was found within the extraction group showing an increase in the length and decrease in the width of the palate post fixed orthodontic mechanotherapy. This was found to be in accordance with the study conducted by Wolfgang Heiser, Andreas Niederwanger, Beatrix Bancher, Gabriele Bittermann, Nikolaus Neunteufel, and Siegfried Kulmer for assessing the three-dimensional dental arch and palatal form changes after extraction and non extraction treatment. In non extraction cases change in the transverse width of the palate, post orthodontic treatment was found to be statistically insignificant. The stability of the palatal width was found to be in accordance with the study conducted by Wolfgang Heiser et al. according to which the stability of the transverse width in cases treated by non-extraction was maintained.

The present study also evaluated and compared the change in post treatment anteroposterior length, transverse width and palatal depth of extraction group with non extraction group. A differential difference was found in the anteroposterior length of the palate post treatment within the two groups. However, the change in palatal width and depth between both the groups were found to be statistically non significant. Since literature comparing the change in palate in three dimension post fixed orthodontic mechanotherapy treated by extraction with non extraction is inadequate this study requires to be supported by further similar researches.

Comparison of pretreatment and posttreatment maxillary arch vertical height of cases managed by extraction and non-extraction:

In the analysis the mean vertical height irrespective of the groups was found to be 14.89 which was increased to 15.43. An overall increase of 0.545 was found to be significant as the P value was less than 0.05. However, group wise reading revealed 0.22 increase for extraction group and 0.86 increase for non-extraction group indicating a differential increase which is statistically non significant as the P value is was more than 0.05. This implies the increase in the vertical height is statistically same for both extraction and non-extraction groups. (Table 4)
2. There is a significant difference in the pretreatment and posttreatment anteroposterior length and vertical height of the palate in non-extraction cases. Difference in pretreatment and posttreatment palatal arch transverse width, of palate was found to be statistically insignificant.

3. There is statistically significant difference in posttreatment anteroposterior length of palate between extraction and non-extraction cases.

References