Evaluation and Comparison of Accuracy of Measuring the Position of Miniscrew Implants using Two-dimensional Orthopantomogram and a Three-dimensional Imaging with Direct Method on Dried Skull

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ABSTRACT

Introduction: The accuracy of position of miniscrew implants is utmost important for implant success. In this study, we investigated whether the routine 2D ortopantomogram can be used to assess the accuracy in the placement of miniscrews as compared with 3D radiography and direct measurements on a dried skull.

Methods: Miniscrew implants were placed in between premolar and molar areas at an angulation of 40° to 50° for maxilla and 10° to 20° for mandible on dried skull. Linear and angular measurements were taken on these dried skulls using direct method, ortopantomogram and 3D radiography. Analysis of variance (ANOVA) and multiple comparison Tukey’s test were used to test for differences in three methods.

Results: The results shows 20% vertical magnification for maxilla and mandible whereas horizontal measurements shows 54.2% of variations in maxilla and 27.1% of variations in mandible on panoramic radiographs as compared to direct method and 3D radiography. Angular measurements show 9° to 10° of variation on panoramic radiographs as compared to direct method and 3D radiography for both maxilla and mandible.

Conclusion: Ortopantomogram shows more variations on linear and angular measurements as compared to direct method and 3D radiography whereas direct method and 3D radiography show no difference. But, we can calculate the angulations of miniscrew implant placement by angular regression model.

Keywords: Miniscrew implants, Craniostat, Panoramic imaging, 3D imaging.

INTRODUCTION

One of the most important factors in successful orthodontic treatment is optimal anchorage control. Absolute anchorage is difficult to achieve. Miniscrew implants provide absolute anchorage, if properly placed in desired position. Mini-implants are placed in many anatomic sites, depending on the indication and the biomechanics used. Popular implant sites appear to be the palate, the lingual aspect of the maxillary alveolar process, the retromolar area in the mandible, and the buccal cortical plate in the maxilla and the mandible.

Proper angulations of implants are important factors considered before providing maximum anchorage. It is generally recommended to apically incline the insertion path to avoid possible root injuries and increase cortical bone support. To optimize the position and angulation of the implants, many technological and diagnostic aids are widely used. The most commonly used radiographs are being periapical radiographs, lateral and posteroanterior cephalometrics, ortopantomogram (OPG), hand-wrist radiographs. Assessment of the position of the miniscrew implant site before placement using panoramic radiograph and 3D radiography is a well-known procedure. But the accuracy in assessment of the position of implant is questionable on ortopantomogram. Therefore, the study was carried out to evaluate whether the routine 2D OPG radiograph can be used to assess the accuracy in the placement of miniscrews as compared with 3D radiography and direct measurements on a dried skull.

MATERIALS AND METHODS

The study consists of 10 dried skull. Four miniscrew implants, two in maxilla and two in mandible were placed. A point was marked 5 to 7 mm apical to the alveolar crest on buccal side in
between premolar and molar region of both sides of maxilla and mandible. A special inclinometer was designed for the placement of miniscrew implants at a proper angulation for respective areas in the maxilla and mandible. Angulations of implants were measured relative to the reference lines constructed in the maxilla and mandible respectively. Miniscrew implants were placed on dried skull using inclinometer at an angulation of 40° to 50° for maxilla and 10° to 20° for mandible directed apically (Fig. 1).

Reference lines on skull were drawn as mentioned below.

For Vertical Plane

Maxilla: Reference line was taken from the lower border of orbit.

Mandible: Reference line was taken from lower border of mandible.

For Horizontal Plane

Maxilla: The reference line was drawn perpendicular over lower border of orbit passing through outermost point on the lateral margin of the orbit.

Mandible: The reference line was drawn perpendicular over lower border of mandible passing through anterior border of coronoid process.

DIRECT MEASUREMENTS ON DRIED SKULL

Direct linear measurements were done on the dried skull using digital vernier caliper (Dentaurum).

Vertical Measurements

The perpendicular distance between the head of the miniscrew implant and the respective horizontal reference line was measured using vernier caliper for maxilla and mandible.

Horizontal Measurements

The distance between the head of the miniscrew and the respective vertical reference line was measured using vernier caliper for maxilla and mandible.

PANORAMIC IMAGING

A special craniostat was designed for the orientation of dried skull in panoramic X-ray machine for standardization (Fig. 2). Ortopantomogram of each sample was taken using Planmeca Proline CC Panoramic X-ray unit. The exposure parameters used in this study were as follows:

- 64 kVp, 4 mA and exposure time of 0.9 seconds.
- Panoramic image was traced using lead acetate tracing paper. Respective horizontal and vertical reference lines for the maxilla and mandible were traced on the ortopantomogram. The miniscrew implants in the respective quadrant were traced on the ortopantomogram (Fig. 3).

The vertical measurements were taken from the head of the miniscrew implant to the horizontal reference lines constructed on the maxilla and the mandible in the respective quadrants.

The horizontal measurements were taken from the head of the miniscrew implant to the vertical reference lines for maxilla and for mandible in the respective quadrants.
The angular measurements were taken from angle formed between long axis of the miniscrew implant and the respective horizontal reference line on the maxilla and mandible in the respective quadrant.

3D RADIOGRAPHY

A 3D radiographic camera was used for recording images from an image intensifier tube (Allura Exper FD20) which can record images from 1 to 30 films per second. 15 films per second speed was used to evaluate the skull, and information of the dried skull along with miniscrew implants in 3D were obtained. The kVp was 60 to 65 and 130 to 140 mA current was used.

Three-dimensional radiographic images were obtained with 12 inch intensifier and with appropriate collimation, so that images of the entire skull could be obtained. The three-dimensional radiographic images were transferred and stored onto the three-dimensional radiographic software.

Using software program, respective horizontal and vertical reference lines for the maxilla and the mandible were marked (Figs 4A to C).

The vertical, horizontal and angular measurements were obtained using same parameter as described previously.

STATISTICAL ANALYSIS

Analysis of variance (ANOVA), multiple comparison Tukey’s test and percentage variations in three methods were used to test for differences in three methods.

RESULTS

Results showed that significant difference between direct method and ortopantomogram, and ortopantomogram and 3D image. However, no statistically significant results were obtained when direct method was compared with 3D radiography in both maxilla and mandible.

Percentage variations in three methods showed that there was 19.7% of variations in maxilla and 20.9% of variations in mandible in vertical plane and 54.2% of variations in maxilla and 27.1% of variations in mandible in horizontal plane, between direct method and ortopantomogram.

Variations in angulation in three methods showed that there was 9.1° of variations between direct method and ortopantomogram in maxilla and 9.2° of variations in mandible. Same result was obtained using ortopantomogram and 3D radiography. There was no percentage variations in direct method and 3D radiography (Tables 1A to 2B).

Thus, the angular regression model was prepared for prediction of implant angulation from their panoramic values.

DISCUSSION

In this study, the results show 20% vertical magnification for maxilla and mandible whereas horizontal measurements show 54.2% of variations in maxilla and 27.1% of variations in mandible on panoramic radiographs as compared to direct method and 3D radiography. Angular measurements show 9° to 10° of variation on panoramic radiographs as compared to direct method and 3D radiography for both maxilla and mandible.

This study showed that vertical measurements are reliable with 20% of magnification on ortopantomogram but horizontal measurements are unreliable because of larger variations in the same region on both maxilla and mandible with ortopantomogram.
Table 1A: Mean and 95% confidence interval for measurements on direct method, ortopantomogram and 3D radiography in maxilla

<table>
<thead>
<tr>
<th>Linear measurements in vertical plane</th>
<th>Linear measurements in horizontal plane</th>
<th>Angular measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean 95% confidence interval for mean</td>
<td>Mean 95% confidence interval for mean</td>
<td>Mean 95% confidence interval for mean</td>
</tr>
<tr>
<td>Lower bound</td>
<td>Upper bound</td>
<td>Lower bound</td>
</tr>
<tr>
<td>Direct method</td>
<td>24.65 23.60 25.69</td>
<td>8.30 7.54 9.05</td>
</tr>
<tr>
<td>Ortopantomogram</td>
<td>29.50 27.60 31.30</td>
<td>12.80 11.79 13.80</td>
</tr>
<tr>
<td>3D radiography</td>
<td>24.74 23.69 25.78</td>
<td>8.30 7.54 9.05</td>
</tr>
</tbody>
</table>

Table 1B: Multiple comparison: Tukey's test and percentage variations for measurements on direct method, ortopantomogram and 3D radiography in maxilla

<table>
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<th>Angular measurements</th>
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</thead>
<tbody>
<tr>
<td>p-value</td>
<td>Percentage variations</td>
<td>p-value</td>
</tr>
<tr>
<td>Direct method</td>
<td>0.000</td>
<td>19.67</td>
</tr>
<tr>
<td>Ortopantomogram</td>
<td>0.994</td>
<td>0.36</td>
</tr>
<tr>
<td>Ortopantomogram</td>
<td>0.000</td>
<td>19.24</td>
</tr>
</tbody>
</table>

S–significant; NS–non-significant

Table 2A: Mean and 95% confidence interval for measurements on direct method, ortopantomogram and 3D radiography in mandible

<table>
<thead>
<tr>
<th>Linear measurements in vertical plane</th>
<th>Linear measurements in horizontal plane</th>
<th>Angular measurements</th>
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<tbody>
<tr>
<td>Mean 95% confidence interval for mean</td>
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</tr>
<tr>
<td>Lower bound</td>
<td>Upper bound</td>
<td>Lower bound</td>
</tr>
<tr>
<td>Direct method</td>
<td>21.50 20.72 22.27</td>
<td>35.40 33.08 37.71</td>
</tr>
<tr>
<td>Ortopantomogram</td>
<td>26.00 24.69 27.30</td>
<td>45.00 40.85 49.14</td>
</tr>
<tr>
<td>3D radiography</td>
<td>21.50 20.72 22.27</td>
<td>35.40 33.08 37.71</td>
</tr>
</tbody>
</table>

Table 2B: Multiple comparison: Tukey's test and percentage variations for measurements on direct method, ortopantomogram and 3D radiography in mandible

<table>
<thead>
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<th>Linear measurements in vertical plane</th>
<th>Linear measurements in horizontal plane</th>
<th>Angular measurements</th>
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</thead>
<tbody>
<tr>
<td>p-value</td>
<td>Percentage variations</td>
<td>p-value</td>
</tr>
<tr>
<td>Direct method</td>
<td>0.000</td>
<td>20.93</td>
</tr>
<tr>
<td>Ortopantomogram</td>
<td>1.000</td>
<td>0.00</td>
</tr>
<tr>
<td>Ortopantomogram</td>
<td>0.000</td>
<td>19.67</td>
</tr>
</tbody>
</table>

S–significant; NS–non-significant

Overall study showed that ortopantomogram shows more variations as compared to direct method and 3D radiography in both maxilla and mandible.

Tronje et al (1985) found a variation in magnification factor horizontally on panoramic radiographs. He stated that the horizontal magnification varied markedly throughout the rotation of the X-ray beam but it would increase in regions where the average jaw fell outside the focal trough.

Larheim and Svanaes (1986) showed that horizontal measurements on panoramic radiographs are longer and more...
distorted than vertical measurements. The study on five dried skulls showed an image magnification of approximately 18 to 21% for the vertical variables.

Tronje et al (1981) demonstrated that a projected length of a vertically oriented object, located at the central plane within the image layer, does not exceed 10%. In the present study, same results were found with vertical magnification of 20%. The horizontal measurements were unreliable.

Brown et al (2009) demonstrated that linear measurements on 3D images and direct measurements show no differences on dry skull. They showed that the overall mean percentage measurement error for anatomic skull dimensions (0.45 mm) was significantly lower than the error for 3D images (p = 0.001; mean difference = 0.44 mm).

In the present study, the same results were obtained when direct measurements on dried skull were compared with 3D images.

Langland et al (1989) showed that despite the fact that horizontal measurements were unreliable, angular measurements might be performed reliably on panoramic radiographs.

Venta et al (1993) showed that angular measurements on panoramic radiographs were useful in determining the inclination of impacted teeth, implant site assessment, crown angulation and root alignment in orthodontics.

Present study showed similar results when compared with these studies. This study showed vertical magnification of 20% whereas horizontal measurements were unreliable. Angular measurements showed overall 9° to 10° of variation as compared to direct measurements and 3D radiography.

Yitschaky et al (2004) measured real lengths of 112 first premolars extracted for orthodontic reasons and compared with their panoramic lengths. They found that prediction of all first premolar lengths using their panoramic images is both feasible and reliable.

CONCLUSIONS

The following conclusions were drawn from the present study:

- There is no variation in vertical and horizontal measurements between direct measurements on dried skull and 3D radiography in both maxilla and mandible.
- It shows that 3D radiography is more accurate than traditional 2D ortopantomogram.
- The major finding of this study was creation of angular regression formula for prediction of implant angulations based on their panoramic angulations.

The mathematical formula for prediction of angulations from panoramic angulations is as follow:

<table>
<thead>
<tr>
<th>Angular</th>
<th>Predicted angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxilla</td>
<td>(Panoramic angle × 0.82) + 0.37</td>
</tr>
<tr>
<td>Mandible</td>
<td>(Panoramic angle × 1.003) – 9.26</td>
</tr>
</tbody>
</table>

The real angulation of implant can be easily determined by the appropriate regression model and can be helpful for predicting the angulation of implant after placement.

REFERENCES