Preplanning Contemporary Incisor Positioning using Inclinometer: A Clinical and Cephalometric Study

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ABSTRACT

Introduction: The purpose of the present study is to link the fields of cephalometric assessment of incisor inclination with that of contemporary orthodontic incisor inclination correction, in order to enhance the applicability of well-accepted cephalometric standards.

Materials and methods: The sample of the study consists of 120 subjects, 53 males and 67 females pretreatment lateral cephalograms and corresponding dental casts with proper inclusion criteria. Upper (U1) and lower (L1) axial incisor inclinations were assessed using inclinometer with reference to the cephalometric planes NA (nasion to point A) and NL (palatal plane), and NB (nasion to point B) and ML (mandibular plane: tangent to the lower border of the mandible) respectively. Sagittal and vertical skeletal relationships were classified using SNA (SNB) and NSL (SN plane)—ML (NSL-NL) angles. Third-order angles [U1TA (upper incisor torque angle) and L1TA (lower incisor torque angle)] were derived from direct dental cast measurements using an incisor inclination-recording appliance (inclinometer).

Results: Cephalometric assessments of upper incisor inclination showed a range of 31 ± 5.27° for U1NA/degree and 32 ± 5.84° for the U1NL. Lower incisor inclination showed a variation of 28.5 ± 6.58 (L1NB/degree) and 36.75 ± 7.2 to the L1ML respectively. Third-order angles varied between 31° for U1TA and 35° for L1TA. In the upper arch, U1TA assessments underscored U1NA/degree values with a mean of 14.43° and U1NL data at a mean of 104.63°.

Conclusion: Third-order measurements using inclinometer device can offer a simple way to get an objective and rapid vision of the incisors inclination and might be a helpful guideline to the choice of low or high torque brackets. Incisor inclination is strongly correlated with skeletal-sagittal data, but little with skeletal-vertical findings.

Keywords: Incisor inclination, Inclinometer, Tooth inclination protractor, Cephalometrics.


Source of support: Nil
Conflict of interest: None
Received on: 2/4/13
Accepted after Revision: 25/6/13

INTRODUCTION

Incisor inclination has traditionally been assessed by lateral cephalometric radiographic analysis. However, lateral cephalometric radiograph derived axial inclinations of incisors are prone to relatively large digitizing errors.1

Satisfactory molar and canine occlusion with acceptable incisor relationship can be found naturally in a majority of subjects with very differing craniofacial properties. In these untreated ideal occlusion cases, varying incisor inclination plays an essential part in achieving dentoalveolar compensation of skeletal discrepancies. One of the most important aspects of ideal occlusion is the labiobuccal inclination of maxillary and mandibular incisors. Downs and Steiner suggested that the concept of ideal or standard inclination for upper and lower incisors.2,3 In addition to playing a vital functional role in the determination of overbite stability, correct incisor inclination contributes to an attractive facial appearance.4

Detailed descriptions of this dental compensation mechanism have been provided, including regression equations for calculating definite incisor positions on the basis of craniofacial properties, such as ANB angle.5 This compensation mechanism should be used as a guideline for correcting incisor inclination during orthodontic treatment in compliance with naturally occurring standards.6,7

Orthodontic correction of inadequate incisor relationships is usually performed using fixed orthodontic appliances. However, torque or third-order prescriptions of brackets do not refer to cephalometric lines, but to the occlusal plane. Despite previous studies regarding the natural range of incisor inclination in subjects with ideal occlusal relationships, there
is a lack of information in the orthodontic literature regarding how to adjust teeth according to skeletal data using straight wire appliances.8-10

The correlation between vertical and sagittal craniofacial patterns, incisor inclination and third-order angles were investigated initially in an untreated ideal occlusion sample with natural dentoalveolar compensation of skeletal discrepancies.11 Subsequently, these correlations will provide the basis for the development of a method for determining individual recommendations for third-order corrections based on natural standards.

So, the aims and objectives of this study were: (1) to link the fields of cephalometric assessment of incisor inclination with that of contemporary orthodontic incisor inclination correction, in order to enhance the applicability of well-accepted cephalometric standards in Indian population, (2) draw the correlation between sagittal craniofacial patterns, incisor inclination, and third-order angles, (3) develop a method for determining individual recommendations for third-order corrections based on natural standards, (4) draw regression equations for the obtained correlations between sagittal craniofacial patterns, incisor inclination, and third-order angles for Indian population.

MATERIALS AND METHODS

The sample consisted of pretreatment upper and lower dental casts and corresponding lateral cephalograms of 120 subjects (53 males and 67 females) between 19 and 30 years of age were selected with neutral (angle Class I) molar and canine relationships and an incisor relationship that was sagittally and vertically considered as ideal, i.e. well supported by the antagonistic teeth and without the need for either deep or open bite correction.

The following inclusion criteria were as follows: (1) neutral (angle Class I) molar and canine relationship, (2) ideal incisor relationship, (3) ideal symmetrical arches with minor rotations or marginal lower arch crowding which did not affect axial incisor inclination.

The following exclusion criteria were as follows: (1) Gross facial imbalance or asymmetry, (2) history of previous orthodontic treatment, (3) presence of primary teeth, (4) missing permanent teeth, (5) presence of crowns on teeth, (6) presence of morphological tooth anomalies.

Cephalometric Measurements

Sagittal (SNA, SNB and ANB) and vertical, sella-nasion—mandibular plane (NSL-ML) sella-nasion—palatal plane (NSL-NL) skeletal structures were analyzed on digital lateral cephalogram using VistaDent OC (GAC Orthodontic Software solutions, Birmingham, USA) cephalometric software (Fig. 1).

Upper (U1) and lower (L1) incisor angulations were assessed with reference to the lines NA and NL (palatal plane) \([U1NA/degree \& U1NL/degree]\) and NB and ML (mandibular plane) \([L1NB/degree \& L1ML/degree]\) respectively. Each analysis was performed digitally by two examiners on two occasions with 3 weeks interval to reduce the error analysis.

Fig. 1: Digital cephalometric analysis done using VistaDent OC

Figs 2A and B: (A) 180° protractor and (B) inclinometer device
Third-order angles were derived from pair of the dental casts, created in parallel with the corresponding lateral radiograph. The most proclined upper and lower central incisors were chosen and prepared for third-order assessment by marking the middle of the facial axis of the incisor clinical crown (FACC), i.e. on the center of the clinical crown. The measurements were performed using an incisor inclination gauge. The measuring device consisted of a table with a centric slot and an 180° protractor mounted beneath it.

**Design of the Inclinometer**

The inclinometer is made of an acrylic table with a centric slot and an 180° protractor having an extension to measure the angulations was attached to it (Figs 2A and B). For the assessments, the dental casts were mounted on a glass slab which could move freely on the acrylic platform. For third-order measurements, the plane of occlusion, used as the reference plane, is of particular importance. It was maintained by positioning the dental casts on the glass slab contacting the molars and the premolars.

**Measuring the Third-order Angles**

The dental casts were then horizontally adjusted with the edge of the incisor perpendicular to the table’s protractor and then guided forward against the extension of the protractor until contacting the center of clinical crown so that the extension of the protractor served as a tangent to the FACC at the center of the clinical crown (Figs 3 and 4).

The excursion of the extension on the protractor then indicated the third-order angle of the incisor (U1TA and L1TA), which is the inclination of the facial surface of the incisor to the occlusal plane. Third-order values were defined as positive if the gingival portion of the facial tangent as marked by the protractors extension was lingual to the incisal portion and negative if the incisal portion was lingual.

**STATISTICAL ANALYSIS**

**Assessment of Reliability**

Systematic differences between replicate measurements performed by two examiners on two occasions with a 3 weeks interval were tested. Intraexaminer error was
assessed using method error (ME) = (∑d^2/2n)^1/2, where ‘d’ is the difference between single measurement and the mean of the single measurements and ‘n’ the number of measurements. To assess inter-examiner error, the Student’s paired t-test was used setting the \( \alpha \) error at 0.05. There were no significant differences (\( \alpha = 0.05 \)) either between the replicate U1TA and L1TA measurements or the cephalographic assessments.

The cephalometric readings obtained were then correlated to the readings obtained from the inclinometer device and statistical analysis was performed using the SYSTAT (Version 12.0, Cranes Software International Ltd.) statistical software. Correlation and regression analysis was performed and the results were then tabulated in Microsoft Office Excel 2010, and the regression equations were derived.

RESULTS

Cephalometric assessments of upper incisor inclination showed a range of 31° for U1NA/deg (mean 25.68, SD 5.27°) and 32° for the U1NL (mean 115.88°, SD 5.84°). Lower incisor inclination showed a variation of 28.5 (L1NB/deg) and 36.75° (U1NL; mean: 94.2°, SD 7.2°) respectively. Third-order angles varied between 31° for U1TA and 35° for L1TA. In the upper arch, U1TA assessments underscored U1NA/deg values with a mean of 14.43° and U1NL data at a mean of 104.63°. Lower incisor third-order measurements were a mean of 27.53° smaller than L1NB data and deviated at a mean of 98.45° from L1ML data (Table 1).

Correlation between Radiographic Incisor Inclination Data and Skeletal Findings

A strong negative correlation with upper axial incisor inclination (U1NA/deg) and a positive correlation with lower incisor inclination (L1NB/deg) was found (Table 2), but comparatively weaker correlations with cephalometric U1NL, L1ML and third-order angles (U1TA and L1TA). There were also rather weak correlations between vertical-skeletal structures and axial inclination data (Table 3); the correlation 0.28 between palatal plane inclination (NL-NSL) and U1NL being the highest within this aspect (see Table 3).

Correlation between Skeletal-sagittal and Skeletal-vertical Findings

The geometric influence of upper and lower jaw inclination on the sagittal position of the landmarks A and B can be seen (Table 4), according to which SNA and mainly SNB were correlated with the vertical position of the mandible (ML-NSL angle), but less to the cant of the palatal plane (NL-NSL angle).

Correlation between Radiographic Incisor Inclination Findings and Third-order Angles

Highly significant coefficients of correlation were found for third-order angles (U1TA and L1TA) and cephalometrically assessed incisor inclination (Graphs 1A to D).

The linear regression equations for the cephalographic assessed incisor inclination were:

\[
\begin{align*}
U1NA &= 28.96 – (1.86 \times ANB) \quad R = –0.7585 \quad SE = 3.446 \\
L1NB &= 27.046 + (1.37 \times ANB) \quad R = 0.4447 \quad SE = 5.922 \\
U1NL &= 117.8 – (1.125 \times ANB) \quad R = –0.4115 \quad SE = 5.349 \\
L1ML &= 98.015 + (1.34 \times ANB) \quad R = 0.4304 \quad SE = 6.030
\end{align*}
\]

The linear regression equations for the cephalographic assessed for third-order measurements were:

\[
\begin{align*}
U1TA &= –10.05 + (0.83 \times U1NA) \quad R = 0.9174 \quad SE = 1.904 \\
L1TA &= –22.83 + (0.84 \times L1NB) \quad R = 0.9330 \quad SE = 2.145 \\
U1TA &= –59.09 + (0.607 \times U1NL) \quad R = –0.4115 \quad SE = 5.349 \\
L1TA &= –64.36 + (0.66 \times L1ML) \quad R = 0.4304 \quad SE = 6.030
\end{align*}
\]

R is the coefficient of correlation and SE is the standard error of estimate.

Table 1: Distribution of the mean and SD values of all parameters under study (n = 120)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Max.</th>
<th>Min.</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
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<td>–5</td>
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</tr>
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<tr>
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<td>91</td>
<td>73</td>
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</tr>
<tr>
<td>SNB</td>
<td>91</td>
<td>71</td>
<td>79.25</td>
<td>2.77</td>
</tr>
<tr>
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<td>6</td>
<td>3</td>
<td>1.75</td>
<td>2.13</td>
</tr>
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<tr>
<td>NSL-ML</td>
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<td>16</td>
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<td>4.55</td>
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<td>Upper incisor angulations</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>U1NA</td>
<td>40</td>
<td>9</td>
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<td>5.27</td>
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<tr>
<td>U1NL</td>
<td>135</td>
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<td>115.88</td>
<td>5.84</td>
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<tr>
<td>Lower incisor angulations</td>
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<td></td>
<td></td>
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<tr>
<td>L1NB</td>
<td>50</td>
<td>10</td>
<td>29.45</td>
<td>6.58</td>
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<td>L1ML</td>
<td>121</td>
<td>85</td>
<td>100.37</td>
<td>6.65</td>
</tr>
</tbody>
</table>

Table 2: Karl Pearson’s correlation coefficients (R) between upper and lower incisor inclination vs sagittal-skeletal dimension (n = 120)

<table>
<thead>
<tr>
<th>Parameters</th>
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<th>SNB</th>
<th>ANB</th>
</tr>
</thead>
<tbody>
<tr>
<td>U1TA</td>
<td>–0.23</td>
<td>0.25</td>
<td>–0.66</td>
</tr>
<tr>
<td>U1NA</td>
<td>–0.33</td>
<td>0.21</td>
<td>–0.75</td>
</tr>
<tr>
<td>U1NL</td>
<td>0.03</td>
<td>0.36</td>
<td>–0.41</td>
</tr>
<tr>
<td>L1TA</td>
<td>0.37</td>
<td>0.11</td>
<td>0.40</td>
</tr>
<tr>
<td>L1NB</td>
<td>0.09</td>
<td>0.39</td>
<td>0.44</td>
</tr>
<tr>
<td>L1ML</td>
<td>0.35</td>
<td>0.06</td>
<td>0.43</td>
</tr>
</tbody>
</table>
DISCUSSION

The radiographic technique usually records the most prominent incisor, and there may be superimposition and lack of clarity between the apices of the six anterior teeth. In addition, it is difficult to validate a technique to assess incisor inclination as the traditionally used radiographic assessment is well-known to be less than ideal. Although, both techniques assess incisor inclination, the tooth inclinometer records incisor crown inclination only and the radiographic assessment crown/root inclination. Drawing a line between the incisor tip and apex may not reflect the inclination of the incisor in situations with diverse crown root angles.

Table 3: Karl Pearson’s correlation coefficients (R) between upper and lower incisor axial inclination vs vertical-skeletal dimension (n = 120)

<table>
<thead>
<tr>
<th></th>
<th>NSL-NL</th>
<th>NSL-ML</th>
</tr>
</thead>
<tbody>
<tr>
<td>U1TA</td>
<td>−0.03</td>
<td>0.04</td>
</tr>
<tr>
<td>U1NA</td>
<td>−0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>U1NL</td>
<td>0.28</td>
<td>0.04</td>
</tr>
<tr>
<td>L1TA</td>
<td>0.09</td>
<td>0.26</td>
</tr>
<tr>
<td>L1NB</td>
<td>0.08</td>
<td>0.22</td>
</tr>
<tr>
<td>L1ML</td>
<td>0.09</td>
<td>−0.17</td>
</tr>
</tbody>
</table>

Table 4: Karl Pearson’s correlation coefficients (R) between correlations between vertical and sagittal skeletal configurations (n = 120)

<table>
<thead>
<tr>
<th></th>
<th>NSL-NL</th>
<th>NSL-ML</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNA</td>
<td>−0.14</td>
<td>−0.27</td>
</tr>
<tr>
<td>SNB</td>
<td>−0.31</td>
<td>−0.39</td>
</tr>
<tr>
<td>ANB</td>
<td>0.19</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Though, the inclinometer records crown inclination only. However, the device can record the individual inclinations of all eight incisors allowing more detailed assessment of proclined or retroclined teeth. The assessment of the crowns to the occlusal plane may be variable, especially in the lower arch where there may be problems with a deep curve of Spee. Although, the occlusal plane variability does not seem to be a factor in reliability, it may cause a problem with validity when comparing the lower incisor to the occlusal plane and mandibular plane.

The mean axial inclination findings (U1NA, L1NB, U1TA and L1TA) as well as the wide range of 31° for the U1NA variable and 39° for L1NB in this sample are in agreement with previous studies on naturally occurring incisor inclination variation in untreated subjects with normal occlusion.5,11-13

Graphs 1A to D: Digital and inclinometer variations of upper and lower incisors: (A) Scatter plot for U1TA-U1NA, (B) scatter plot for U1TA-U1NL, (C) scatter plot for L1TA-L1NB and (D) scatter plot for L1TA-L1ML
Moreover, the sagittal-skeletal range measured (see Table 1) is nearly similar to that described by Cascio and Shepherd et al who considered a wide range of ANB, –3 to 8° as normal. The present study showed a range of –3 to 6° for ANB. Moreover, the cephalometric incisor inclinations showed slightly higher values as per Steiner’s analysis but these values are in accordance with the cephalometric norms of Steiner’s analysis stated for the Indian population. Thus, the findings of the cephalometric parameters in the present study were close to well-accepted norms in the literature and can be judged as representative.

From the results in Table 2, it is obvious that even in untreated normal occlusion subjects, the correlation of U1NA to the sagittal position of the maxilla (SNA) is significantly stronger than that to the sagittal position of the mandible (SNB). Similarly, lower incisor inclination (L1NB) to SNB is significantly stronger than to SNA. Thus, axial incisor inclination depends more on the sagittal position of the respective jaw and less on the antagonistic jaw.

Contrary to untreated malocclusion sample, the present study with untreated normal occlusion group illustrates a strong correlation between cephalometric axial inclination data (U1NA, L1NB, U1NL and L1ML, see Table 2) and sagittal-skeletal data, thus being in agreement with classical studies. As the correlation of sagittal-skeletal patterns (ANB) to upper incisor inclination data proved to be more distinct than to lower incisor findings (see Table 2), it can be stated that the natural dental compensation of sagittal-skeletal discrepancies in the ideal occlusion sample is less expressed via the lower than via the upper incisors. This conforms to the findings of Creekmore, who proposed that the determination of the amount and direction of axial incisor inclination correction should be based on the position of the upper incisors and not on the lower incisors as commonly recommended.

The present study realms of anteroposterior skeletal pattern and third-order assessments in a natural ideal occlusion group for the first time in Indian population. Thus, it represents a guideline to treat patients according to cephalometric data with enhanced accuracy. As a consequence, from the correlation between anteroposterior skeletal data and cephalometrically assessed inclination (U1NA and L1NB), it is observed from the present study that one can start incisor inclination adjustment by predefining upper and lower incisor position according to the regression equation U1NA = 28.96 – (1.86 × ANB) and L1NB = 27.046 + (1.37 × ANB). For facilitation, the regression equations might be integrated in diagnostic and treatment planning program. The gained values could then be used to constitute the required third-order angle using the regression equation U1TA = –10.05 + (0.83 × U1NA) and L1TA = –22.83 + (0.84 × L1NB).

The amount of third-order correction needed in an individual case is the discrepancy between the calculated third-order angle and the present U1TA, which is easily derived from dental cast measurements. The use of the presented regression equations helps to translate the cephalometric data into third-order data, which constitute the reference framework of straight wire appliances, whenever a straight wire appliance is chosen or some additional torque is created, it is identified as third-order angles and not cephalometric data. Thus, the presented method is instrumental in adapting third-order movements required by orthodontists to cephalometric diagnosis with enhanced precision.

Although, the radiographically assessed axial inclination data and the third-order values were also strongly correlated (Table 5), there was no significant correlation between the third-order angle (U1TA and L1TA) and either the skeletal vertical (NSL-NL and NSL-ML, see Table 3) or the sagittal-sagittal findings (SNA, SNB, see Table 2), although there was reasonably significant correlation between third-order values and ANB (see Table 2).

This leads to the assumption that it is crown morphology that is responsible for the lack of correlation between the third-order and skeletal-sagittal data as it seems to differ inter-individually. According to morphological studies, the labial surface angle, as formed by the facial tangent and the long axis of the tooth, varies up to 24°. Existing relationships between torque angle values and axial inclination data might be explained by the fact that both the incisor tip-apex connecting line and the FACC tangent are related to different areas of the same tooth. It is the crown shape that shows interindividual difference. This seems to be sufficiently strong to result in a reduction of the relationship between the inclination of the FACC tangent and the skeletal findings.

The reliability of the incisor inclinometer has been proven in several studies and found to be an effective method for the measurement of axial incisor inclinations. Measurement of the incisor inclination is an important part of treatment planning, which also consists of providing good facial and soft-tissue esthetics in consideration of the anteroposterior position of the anterior teeth, alignment, stability, good occlusion and correct functionality. To all these orthodontic

Table 5: Karl Pearson’s correlation coefficients (R) between upper torque angle and U1NA, U1NL and lower torque angle and L1NB, L1ML (n = 120)

<table>
<thead>
<tr>
<th>Karl Pearson’s correlation coefficients (R)</th>
<th>U1NA</th>
<th>U1NL</th>
<th>L1NB</th>
<th>L1ML</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper torque angle</td>
<td>0.9174</td>
<td>0.7448</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Lower torque angle</td>
<td>—</td>
<td>—</td>
<td>0.9330</td>
<td>0.7405</td>
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</table>
challenges, straight wire appliances cannot be the universal answer. However, the findings of the present study can be a guideline to adjust incisor inclination in harmony with skeletal structures and in coincidence with individual requirements in the Indian population. Further research can be attempted for testing of the presented linear regression formulas on a new sample.

CONCLUSION

According to this ideal occlusion sample, incisor inclination is strongly correlated with skeletal-sagittal data, but little with skeletal-vertical findings. The normal dental compensation of sagittal-skeletal discrepancies is less executed in the lower than the upper incisors. This study allies the realm of cephalometric assessment of incisor inclination and anteroposterior skeletal patterns with the field of contemporary orthodontic incisor inclination correction, thus providing an enhancement of the applicability of accepted cephalometric standards for axial incisor inclination in Indian population. As a consequence, third-order movements can be adapted to cephalometric diagnosis with higher precision. The use of third-order measurements in combination with the presented regression equations for defining targets in incisor inclination correction according to naturally found standards is recommended. Further research can be attempted for testing of the presented linear regression formulas on different samples with different sample sizes at various locations so as to standardize the above equations for Indian population.

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