Assessment of crown angulations, crown inclinations, and tooth size discrepancies in a South Indian population

GEETA MARUTI DODDAMANI, ANMOL S KHALA, MALA MANGHAR, UMASHANKAR

Abstract

Aim and Objective: The aim of this study was to assess crown angulations, crown inclinations, and tooth size discrepancy in a sample population from Davangere, South India. Materials and Methods: One hundred adults (50 male and 50 female) of age 18–30 years, with Angle's class I ideal occlusion and balanced profiles, were selected for the study. Study models were prepared and crown angulations and crown inclinations were measured using a customized protractor device. Bolton's analysis was used to measure the tooth size discrepancies. Results: Maxillary and mandibular teeth had less crown angulations. Maxillary and mandibular incisors and maxillary molars showed increased crown inclinations, whereas mandibular molars and premolars had less crown inclinations than the original Andrews sample. The mean maxillary and mandibular tooth size ratios, overall and anterior, were similar to Bolton's ratios. Conclusions: The finding of this study indicates that there are possible racial and ethnic factors contributing to variations in crown angulations and crown inclinations.

Keywords: Crown angulations, crown inclinations, tooth size discrepancies

Introduction

Orthodontists treat various malocclusions of the jaws and aim at establishing an aesthetic, functional, and harmonious occlusion.[1] The emphasis at present is on treating the face as a whole and not just the occlusion; however, the importance of achieving an ideal occlusion that is in harmony with the face has not diminished since the time of Angle. Ideal occlusion, as we know it today, was described by John Hunter as early as the 18th century.[2] The most comprehensive and exhaustive study to understand the relationship of teeth was undertaken by Andrews in 1964. He made extensive measurements on 120 nonorthodontic normal casts of White North American origin to develop his 'six keys to normal occlusion.'[3] The six keys of Andrews help the orthodontist to establish the occlusion and serve as a yardstick for critical analysis of treatment results. These six keys show that despite the voluminous information available on occlusion, it can be simply explained and quantified. The presence of disproportionately sized teeth in either the maxillary or the mandibular arch can make it difficult to obtain an occlusion with good alignment, ideal overjet, ideal overbite, and a class I molar relationship. In order to fit the maxillary teeth well with the mandibular teeth, a definite proportionality of tooth sizes should exist. Therefore, the ability to analyze the proportionality of the maxillary and mandibular teeth is an important tool at the initial stages of treatment.[4]

The findings of Andrews’ study on 120 nonorthodontic models served as the foundation for the development of the straight-wire appliance.[5] This started the era of preadjusted edgewise appliances. Since the introduction of the preadjusted edgewise appliance, it has been extensively used all over the world, including in India. In pre-vedic times, India was inhabited by a short-statured, brown-skinned people, descendants of the Iberian race of Caucasians called the Dravidians. About 300 AD, Aryans, descendants of the Nordic group of Caucasians, invaded the Northern part of India, displacing the Dravidians to South. Today, North Indians are generally tall fair-skinned people, descendants of the Iberian race of Caucasians called the Dravidians. About 300 AD, Aryans, descendants of the Nordic group of Caucasians, invaded the Northern part of India, displacing the Dravidians to South. Today, North Indians are generally tall fair-skinned people, descendants of the Iberian race of Caucasians called the Dravidians. About 300 AD, Aryans, descendants of the Nordic group of Caucasians, invaded the Northern part of India, displacing the Dravidians to South. Today, North Indians are generally tall fair-skinned people, descendants of the Iberian race of Caucasians called the Dravidians. About 300 AD, Aryans, descendants of the Nordic group of Caucasians, invaded the Northern part of India, displacing the Dravidians to South. Today, North Indians are generally tall fair-skinned people, descendants of the Iberian race of Caucasians called the Dravidians. About 300 AD, Aryans, descendants of the Nordic group of Caucasians, invaded the Northern part of India, displacing the Dravidians to South. Today, North Indians are generally tall fair-skinned people, descendants of the Iberian race of Caucasians called the Dravidians. About 300 AD, Aryans, descendants of the Nordic group of Caucasians, invaded the Northern part of India, displacing the Dravidians to South. Today, North Indians are generally tall fair-skinned people, descendants of the Iberian race of Caucasians called the Dravidians.

The present study was carried out to assess crown angulations and crown inclinations in subjects from Davangere, South India, and to compare the obtained data with that of the
original values of Andrews. Also, we wished to evaluate the tooth size discrepancies in this population.

Materials and Methods

Five hundred subjects, native to Davangere, South India, were screened by a panel of judges that comprised two orthodontists, a lay person, and one oral surgeon. One hundred subjects (50 male and 50 female) who fulfilled the selection criteria were selected from the total sample of 500. The selection criteria were comparable with those used by Andrews[3] [Table 1].

Alginate impressions of these 100 subjects (50 males, 50 female) were made for both maxillary and mandibular arches and study models were prepared. Bolton analysis was used to determine disproportion in size between maxillary and mandibular teeth in all these 100 subjects. The determination of tooth size discrepancy was made according to the method described by Bolton.[6] The mean (with standard deviation), median, and range were calculated for both overall ‘12’ ratio and anterior ‘6’ ratio.

The facial axis of the clinical crown (FACC) and its mid-point, the facial axis point (FA point), were marked on each crown of each dental cast. The FACC represents the most prominent portion of the central lobe on the facial surface of each crown; for molars, it represents the buccal groove that separates the two large facial cusps. The FA point was marked as the midpoint of FACC. The FACC served as the reference line from which crown angulation and inclination were measured. On the duplicated casts, the occlusal half of each crown was trimmed out.

The method of measurement of crown angulation and crown inclination was adapted from Andrews.[7] Crown angulations and crown inclinations were measured by using a customized protractor device, which had an adjustable readout arm as described by Andrews.[7] For measuring the crown angulation, the base of the protractor was placed on the occlusion plane parallel to a line that would connect the contact points of the crown being measured. The protractor readout arm was adjusted parallel to the crown’s FACC. The angulation of the crown was read from where the center line of the readout arm fell on the protractor’s scale. For measuring the crown inclination, the protractor was positioned at right angles to the line that would connect the contact points of the crown being measured. The protractor was adjusted to be parallel and tangential to the FACC at the FA point, and the inclination of the crown was read on the protractor’s scale.[7]

The mean, standard deviation, and standard error were calculated for crown angulations and inclination using the software EpiStat® (EpiStat, Round Rock, TX). To rule out inter-operator errors of measurement, 10% of the total sample was randomly selected and measurements were made by two independent workers. Measurements were presented as mean±SD and range. The 95% confidence limits were calculated for each tooth separately and are presented along with the mean and standard deviation.

Results

Positive maxillary angulation values were obtained for all teeth; however, incisors, canines, and premolars were less angulated in our study subjects than in Andrews’s sample, while molars had similar angulation as in Andrews’ sample. Mandibular incisors and canines were less angulated, whereas premolars and molars had the same angulation as in Andrews’ sample. Among maxillary teeth, the mean crown angulation was highest in the lateral incisors and canines, while both

| Table 1: Selection criteria[3] |
|-------------------------------|
| **Inclusion criteria**         |
| 1. Subjects in the age group of 18–30 years |
| 2. No history of past orthodontic treatment |
| 3. Subjects in good health and exhibiting normal growth |
| 4. Well-related vertical, transverse, and anteroposterior relationships |
| 5. Subjects having reasonably well-balanced profiles |
| 6. Arches well aligned, with no supernumerary teeth |
| 7. Normal appearing teeth |
| 8. Low decayed, missing, and filled tooth index numerical value |
| 9. No large restorations or fixed replacements |
| 10. Subjects with Angle class I molar and canine relationships, and overjet and overbite within normal limits |
| **Exclusion criteria**         |
| 1. Presence of large overjet and overbite |
| 2. Class II and III molar relation |
| 3. Subjects with dental anomalies |
premolars had the lowest value. In the mandibular teeth, incisors had least crown angulation and the canines showed the highest crown angulation [Table 2].

Increased maxillary positive crown inclination values were obtained for both central and lateral incisors, the central being twice as inclined as the lateral. The canines’ inclination values were similar to that reported by Andrews. Premolars and molars showed increased negative inclination. In the mandibular teeth, incisors showed increased negative inclination. Mandibular canines, premolars, and molars were less inclined than in Andrews’ sample. Among the maxillary teeth, the central and lateral incisors showed positive crown inclination of $16.68\pm 0.6^\circ$ and $8.93\pm 0.73^\circ$ respectively, while the first and second molars had more of negative inclination of $-14.78\pm 0.7^\circ$ and $-14.67\pm 0.7^\circ$ respectively. In the mandibular arch, all teeth showed negative crown inclination. Among them, the first molar showed relatively higher negative crown inclination of $-20.59\pm 0.5^\circ$ [Table 2].

The mean maxillary and mandibular tooth size ratios, overall and anterior, were similar to Bolton’s ratios. The mean anterior ratio for female subjects was $77.26\% (\pm 0.162)$ and the overall ratio was $91.3\% (\pm 0.140)$. The anterior ratio for male subjects was $77.3\% (\pm 0.120)$ and overall ratio was $91.34\% (\pm 0.134)$. Seven subjects showed an overall maxillary excess of 0.5 mm [Table 3].

The normal values of crown angulation and crown inclination for the Davangere population, South India, are presented in Table 4.

**Discussion**

Normal occlusion is dependent upon proper distal crown angulation, especially for the upper anterior teeth since they have the longest crowns. The degree of incisor angulation determines the amount of mesio-distal space they consume and, therefore, has a considerable effect on posterior occlusion and anterior esthetics.

Upper and lower crown inclinations are intricately complementary and significantly affect overbite and posterior occlusion. Properly inclined anterior crowns contribute to normal overbite and posterior occlusion. When they are too straight up or down they lose their functional harmony and overeruption results. When the upper anterior crowns are

| Tooth no. | Crown angulation | Crown inclination |
|-----------|------------------|-------------------|
|           | Study group      | Andrews’ group     | Currim and Wadkar group |
| Maxillary teeth |
| 1         | $5 \pm 0.5$      | $5.0$             | $3.30 \pm 2.63$          |
| 2         | $7 \pm 0.5$      | $9.0$             | $4.22 \pm 2.54$          |
| 3         | $7 \pm 0.6$      | $11.0$            | $2.66 \pm 4.60$          |
| 4         | $1 \pm 0.5$      | $2.0$             | $2.60 \pm 5.33$          |
| 5         | $1 \pm 0.5$      | $2.0$             | $5.07 \pm 4.3$           |
| 6         | $5.44 \pm 0.5$   | $5.0$             | $4.53 \pm 3.12$          |
| 7         | $5 \pm 0.5$      | $5.0$             | $3.00 \pm 4.6$           |
| Mandibular teeth |
| 1         | $1 \pm 0.5$      | $2.0$             | $0.23 \pm 1.91$          |
| 2         | $1 \pm 0.5$      | $2.0$             | $0.43 \pm 2.20$          |
| 3         | $3 \pm 0.6$      | $5.0$             | $1.17 \pm 4.04$          |
| 4         | $2 \pm 0.5$      | $2.0$             | $0.32 \pm 4.04$          |
| 5         | $2 \pm 0.5$      | $2.0$             | $1.54 \pm 3.47$          |
| 6         | $2 \pm 0.5$      | $2.0$             | $1.67 \pm 3.47$          |
| 7         | $2 \pm 0.5$      | $2.0$             | $2.12 \pm 4.51$          |

| Table 3: Comparison of tooth size discrepancy between study group and Bolton’s ratio |
|---------------------------------|-----------------|-----------------|
|                                | Male            | Female          |
|                                | Anterior ratio  | Overall         | Anterior ratio  | Overall         |
| Mean                           | 77.26           | 91.3            | 77.3            | 91.34           |
| SD                             | 0.162           | 0.140           | 0.120           | 0.134           |
In the present study, crown angulation of $1^\circ \pm 0.5^\circ$ for incisors, $3^\circ \pm 0.6^\circ$ for canines, and $2^\circ \pm 0.5^\circ$ for premolars and molars were found. The values obtained in the present study were lower than that of Andrews for incisors and canines, but the values for premolars and molars are similar. Currim and Wadkar[21] found negative angulations values for incisors ($-0.23^\circ$ and $-0.43^\circ$), canines ($-1.17^\circ$), and first premolar ($-0.32^\circ$), which are in contrast to our findings. However, they observed positive angulations for second premolars ($1.54^\circ$), first molars ($1.67^\circ$), and second molars ($2.12^\circ$), which were similar to our values.

### Crown inclination

In the maxillary arch, we observed positive crown inclinations for central and lateral incisors, whereas there were negative crown inclinations for canines, premolars, and molars. This findings is similar to the study of Currim and Wadkar[21] where there was positive crown inclination of $3.80^\circ \pm 3.44$ for central incisors and $4.44^\circ \pm 4.16^\circ$ for lateral incisors, and negative inclination of $-5.99^\circ \pm 5.82^\circ$ for canines, $-8.40^\circ \pm 5.24^\circ$ for first premolars, $-9.88^\circ \pm 6.1^\circ$ for second premolars, $-11.27^\circ \pm 7.17^\circ$ for first molars, and $-9.95^\circ \pm 6.87^\circ$ for second molars. Andrews'[3] original findings suggest an inclination of $7^\circ$ for central incisors, $3^\circ$ for lateral incisors, $-7^\circ$ for canines and first and second premolars, and $-9^\circ$ for first and second molars. In a study by Vardimon and Lambertz,[8] an inclination of $0.74^\circ \pm 4.45^\circ$ for central incisors and $-0.96^\circ \pm 1.16^\circ$ for lateral incisors, and negative inclination of $-8.39^\circ$ for canines, $-8.44^\circ$ for premolars, $-10.5^\circ$ for first molars, and $-9.28^\circ$ for second molar in the upper teeth were seen.

The result of present study found higher values of inclination for maxillary incisors than that found by Andrews,[3] Currim and Wadkar,[21] Vardimon and Lambertz,[8] and Morrow[20] ($3.76^\circ$ and $1.16^\circ$ for central and lateral incisors, respectively). The inclination values for canines in our study are similar to those of Andrews[3] but higher than that of Currim and Wadkar.[21] The crown inclination values obtained for premolars were similar to that of Andrews[3] however, Currim and Wadkar[21] found higher negative values than our study. The present study also found increased negative crown inclination values for molars compared to that found by Andrews[3] and Currim and Wadkar.[21] The study by Vardimon and Lambertz[8] showed lower values of crown inclination for central and lateral incisors when compared to the present study. Central incisors were upright and the lateral incisors showed negative crown inclination. Vardimon and Lambertz also obtained negative crown inclination from canines to second molars; however, the present study showed more negative crown inclination than their study. Morrow[20] found very low crown inclination values for maxillary central and lateral incisors ($3.76^\circ$ and $1.16^\circ$), respectively) than the present study. The values for the canines and premolars were found to be close to their values ($-6.53^\circ$ and $-6.83^\circ$, respectively). The values for first ($-6.86^\circ$) and second molars ($-2.22^\circ$) were less negative in their study than in the present study.

### Crown angulation

In the current study, positive angulation values were obtained for all the maxillary teeth, similar to the values obtained by Andrews and in the study done by Currim and Wadkar[21] on an Indian population. The maxillary arch readings for crown angulations in the present study were $5^\circ \pm 0.5^\circ$ for the central incisors, $7^\circ \pm 0.5^\circ$ for lateral incisors, $7^\circ \pm 0.6^\circ$ for canines, $1^\circ \pm 0.5^\circ$ for first premolars and second premolars, $5.44^\circ \pm 0.5^\circ$ for first molars, and $5^\circ \pm 0.5^\circ$ for second molars. In comparison, Andrews’ original findings had confirmed the angulations of $5^\circ$ for central incisors, $9^\circ$ for lateral incisors, $11^\circ$ for canines, $2^\circ$ for first and second premolars, and $5^\circ$ for first and second molars. In the present study, the values of crown angulations of central incisors were same as that of Andrews,[3] Whereas angulations value for lateral incisors, canines, and premolars were found to be lower than those of Andrews, while the values for molars are almost similar. The study by Currim and Wadkar[2] showed lower angulation values for central incisors, lateral incisors, canines, and molars ($3.30^\circ$, $4.27^\circ$, $2.66^\circ$, $4.53^\circ$, and $3.0^\circ$, respectively) than our values. In contrast to the present study they observed higher values for premolars ($2.6^\circ$ and $5.07^\circ$ for first and second premolars, respectively).

Table 4: Normal value of crown angulations and crown inclinations established for this Davanagere population

| Tooth no. | Maxillary teeth | Mandibular teeth |
|-----------|-----------------|------------------|
| Angulation|                 |                  |
| 1         | $5 \pm 0.5$     | $1 \pm 0.5$      |
| 2         | $7 \pm 0.5$     | $1 \pm 0.3$      |
| 3         | $7 \pm 0.6$     | $3 \pm 0.6$      |
| 4         | $1 \pm 0.5$     | $2 \pm 0.5$      |
| 5         | $1 \pm 0.5$     | $2 \pm 0.5$      |
| 6         | $5.44 \pm 0.5$  | $2 \pm 0.5$      |
| 7         | $5 \pm 0.5$     | $2 \pm 0.5$      |

| Inclination|                 |                  |
|------------|-----------------|------------------|
| 1          | $16.68 \pm 0.6$ | $-6.65 \pm 0.6$ |
| 2          | $8.2 \pm 0.73$  | $-6.48 \pm 0.5$  |
| 3          | $-7.62 \pm 0.6$ | $-6.79 \pm 0.5$  |
| 4          | $-7.47 \pm 0.5$ | $-12.51 \pm 0.6$ |
| 5          | $-7.22 \pm 0.8$ | $-16.77 \pm 0.7$ |
| 6          | $-14.78 \pm 0.7$| $-20.59 \pm 0.5$ |
| 7          | $-14.67 \pm 0.7$| $-10.5 \pm 0.5$  |

Insufficiently inclined, the upper posterior crowns are forward of their normal position; when anterior crowns are properly inclined, the upper posterior teeth are encouraged into their normal position. The contact points move distally in concert with the increase in positive anterior crown inclination.[3]
In this study, the crown inclination of upper incisors was considerably higher than in all the other studies mentioned, with the difference between the crown inclination of the central and lateral incisors being almost double (16.68° vs 8.93°). These findings suggest that the crown inclination of maxillary incisors are more in this Davangere population.

In the mandibular arch, the positive crown inclination obtained for the incisors was higher than that found by Andrews,[3] Negative crown inclination values from the canine to the second molar, which progressively increased, was observed in the current study as in the Andrews study.[3] Andrews found crown inclination values that were higher than our findings. In contrast to our study, Currim and Wadkar[2] found positive crown inclination for mandibular central and lateral incisors (1.36° and 0.88°, respectively). They observed a higher negative values for canines (−8.20°), first premolars (−14.6°), second premolars (−18.5°), first molars (−27.4°), and second molars (−33.6°). The results of the present study differ from the studies of Currim and Wadkar[2] and Andrews.[3] Similar to Currim and Wadker,[2] but in contrast to our findings, Vardimon and Lambertz[8] found positive crown inclination for the central incisors (2.24°). The inclination values from the lateral incisor to the second molar were negative in these two studies[2,8] as well as in our study. However, we found that crown inclination values were much lower from the canine to the second molar.

The crown inclination value of the second mandibular molar obtained in the present study differs from all the previous studies,[2,3,8,9] by being much lower and not also by following the progressively increasing negative inclination from the canine to the second molar. Also, the lower incisors had a higher negative crown inclination than in other studies,[2,3,8,9] which showed positive crown inclination for central incisors or mild negative crown inclination for both lower incisors. All these findings suggest that the lower incisors and second molars are more upright in this Davangere population.

**Tooth size discrepancy**

Even when the upper teeth are in proper occlusion with the lower posterior teeth, undesirable spaces will result somewhere between the anterior and posterior teeth, if the inclinations of anterior crowns is not sufficient. This space, in treated cases, is often incorrectly attributed to tooth size discrepancy.[3]

Specific dimensional relationships must exist between the maxillary and mandibular teeth to ensure proper interdigitation, overbite, and overjet. Achieving a good functional occlusion with proper overbite and overjet requires that maxillary and mandibular teeth be proportional in size. Interarch tooth-size discrepancy hinders achievement of ideal occlusion. Proper relationships of the total mesio-distal width of the maxillary dentition to the mesio-distal width of the mandibular dentition will favor an optimal post-treatment occlusion.[16] Due to this reason, the second objective of the present study was to find out the tooth size discrepancy in this population using Bolton’s analysis.

The present study showed values identical to that of Bolton’s study[6] for anterior and overall ratio. But a few of the subjects showed 0.5-mm overall maxillary excess. This was an expected finding as only normal occlusions were chosen for this study and this finding is in accordance with the view that good occlusions do not have tooth size discrepancies. It also confirms that the sample chosen had good occlusion.

Smith, Buschang, and Watanabe,[11] evaluated Bolton’s interarch ratios in three population (i.e., Black, Hispanic, and White) and also evaluated the variation between genders. They found significantly different relationships between the lower and upper teeth. Also, significant gender differences were observed for the overall and posterior ratios but not for the anterior ratio. The anterior ratio (77.26%) evaluated in our study is lower than that found by Smith, Bushang, and Watanabe for all the three populations, but the overall ratio (91.34%) is higher in our study. No gender differences in overall and anterior ratios were observed in the present study, in contrast to their study.

Similarly, Lavelle[12] showed that there was sexual dimorphism in tooth dimensions and in the ratio of upper and lower arch tooth sizes. He found that Blacks have larger overall and anterior ratios than Whites and Asians, although the actual differences were not tested and the arch segments responsible for the differences were not evaluated. He also showed that the overall and anterior ratios were consistently larger in males than in females, regardless of race, which finding differs from our study. The tooth size data reported by Moorrees et al.[13] imply gender differences in the overall ratio, which disagrees with our findings. Stifter[14] replicated Bolton study in class I dentitions and reported similar results, which matches our study results.

**Conclusions**

- All maxillary and mandibular teeth showed positive crown angulation.
- Maxillary lateral incisors, canines, and premolars were less angulated.
- Mandibular incisors and canines were also less angulated.
- Maxillary incisors and molars were more inclined.
- Mandibular incisors were more inclined, whereas canine, premolar, and molar were less inclined.
- This study sample did not show any significant difference in the anterior and overall Bolton ratio.
- No sexual dimorphism in the overall and anterior Bolton ratios was seen.

The results of the present study indicate that there are possible racial and ethnic factors contributing to the difference in crown angulations and crown inclinations.
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