Estimation and comparative evaluation of teeth prominence values of Saudis for bracket prescription

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Abstract  Background: The racial and ethnic disparities in tooth morphology and alignment indicate the need for different orthodontic prescriptions.

Purpose: This study aimed at utilizing the 3D digital models to measure the teeth prominence of Saudi adults and compare the results to previously published data.

Materials and methods: The sample included 60 sets of 3D digital dental models of subjects who presented with non-orthodontic normal occlusion and balanced profile. Rhinoceros™ 3D modeling software was used to mark the midpoint of the clinical crown (LA) and the embrasure line and then to measure the prominence of the teeth. The collected data was analyzed using SPSS (IBM SPSS Inc., version 20, Chicago, IL, USA). The mean and SD scores were obtained for each measurement. Independent t-test, paired t-test, and student t-test were used for the comparison at a significant level of P ≤ 0.05.

Result: Comparison between the right and the left sides, and between the male and female showed no significant differences, and hence the result data were combined. However, further comparison with the published data of the North American whites, Japanese, Indian, African and Italian showed significant differences in most of the teeth.

Conclusion: Racial differences influence the teeth prominence values that should be considered in presenting orthodontic bracket prescriptions. More research in this field is needed.

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1. Introduction

Orthodontist brackets are manufactured with pre-adjusted prescription values including tip, torque, and prominence to guide the mal-aligned teeth into the new correct position. In the previous article, the tip and torque for the Saudi adults
were determined and, in this part, the bracket prominence will be presented (Bukhary et al., 2021).

Tip and torque are angular measurements whereas, prominence is a linear measurement requiring different methods and instruments for measurements (Andrews, 1989). The term bracket prominence was introduced by Andrews in 1989 to represent the thickness of the bracket base and the method of measurements was well documented (Andrews, 1989). In the dental model, the occlusal part of the teeth was trimmed at the level of the midpoints of the clinical crown (LA). Then, the embrasure line was drawn between the most buccal mesial and distal contact points. The perpendicular line was drawn from the LA point to the embrasure line and measured in millimeter by Boley gauge with sharpened points. Andrews used these measurements inversely to calculate the bracket thickness for the bracket prescription of the American whites (Andrews, 1989). Few researchers, outside the United States, up to our knowledge replicated the well-acknowledged and laborious manual work of Andrews (1989) (Currim and Wadkar, 2004; Lombardo et al., 2015; Watanabe and Koga, 2001). Nevertheless, no such study was conducted in Saudi Arabia till today.

However, the advancement in technology and computer software allows the use of computerized digital dental models for measurements instead of the manual method (Lombardo et al., 2015; Luu et al., 2012). Multiple Studies confirmed the reliability and accuracy of using digital models for linear and angular measurements (Fleming et al., 2011; Gracco et al., 2007; Luu et al., 2012). The digital models are created either from scanning the plaster dental model or directly from the patient mouth. Lombardo et al. in well documented articles explained the use of digital images of the models to measure the bracket prescriptions (Lombardo et al., 2015, 2014). On the 3D digital models, the LA points were located, and the embrasure line was drawn to measure the bracket prominence. Lombardo et al. (2015) applied the method to measure teeth prominence for Italian and African.

The current study aims to use the 3D digital models to measure the teeth prominence of Saudis adults and compare it to the previously published data. The data of this study will be compared to North American white data of Andrews (1989), the Japanese data of Watanabe and Koga (2001), the Indian data of Currim and Wadkar (2004) and the Italian and African data of Lombardo et al. (2015). The teeth prominence will be added to the previously measured tip and torque in order to build a Saudi orthodontic bracket prescription (Bukhary et al., 2021).

2. Material and methods

The study sample include 60 sets of standardized orthodontic dental models of Saudi adults with normal occlusion. The same sets of dental models were used in our previous tip and torque prescription research (Bukhary et al., 2021). The ethics and consent forms for this study were approved by the Institutional Review Board (IRB) of King Saud University Medical City, (E-18-3072). The Ceramill Map 400 scanner (Amanngir-bach, Pforzheim, Germany) used to scan the dental models to make the Stereolithography (STL) of the models. Then, the STL files were used to create 3D models and the Rhinoceros TM 4.0 software (Robert McNeel & Associates, Seattle, USA) for measurements.

Initially, prepare the dental models not to distract the scanning process. The standardized trimmed models should be dry, without any voids, or pencil marks. Subsequently, scan the upper and lower models. For measurement, the model was fixed in the scanning base of the Ceramill Map 400 scanner. Strips of laser light visibly outline and scan the 2D surface of the model in the slicing and mapping process until the whole surface of the dental model was scanned. This creates a series of stackable 2D outlines of the scanned model stored in the computer as a virtual 3D digital map of the model. Further, we constructed physical 3D models from the stored virtual 3D digital map using stereolithography technology. The constructed 3D model was viewed on the computer screen and saved in stereolithography (STL) format. A total of 120 files in STL format for upper and lower dental models were saved on the computer. Consequently, measure the tooth prominence using the Rhinoceros TM 4.0 software. Start with opening the STL file to view the 3D dental model for measurements (Fig. 1A). Then, locate the LA point in the 3D dental model utilizing the rendered view option of the program (Fig. 1A). Next, insert a small sphere (1 mm) at the LA point for all teeth. After that, construct the embrasure line for each tooth by connecting the most mesial and distal buccal contact points (Fig. 1B). Connecting the embrasure lines of one tooth to the next form a curve called the embrasure line. Finally, measure the perpendicular distance from the LA point to the embrasure line in millimeters for all teeth (Fig. 1B). The measurements will be stored directly in the computer for analysis. These procedures were repeated for the 120 STL files of the upper and lower 3D models.

2.1. Statistical analysis of the data

SPSS software (IBM SPSS Inc., version 20, Chicago, IL, USA) was used for the statistical analysis for this study, the power analysis was set at 90% with $\alpha = 0.05$ with an estimated standard deviation of SD = 0.82, the maximum difference of 0.5. A total of 60 subjects were required for this study.

The intra-examiner reliability was tested by selecting randomly 20 sets of dental models and measures the teeth’ prominence twice in 2 weeks intervals between the measurements. Pearson correlation and paired t-test were used.

The mean and the standard deviation of the mean were obtained for each measurement. The normality of the measurements was checked with the Kolmogorov-Smirnov test. For the comparison at a significant level of (P ≤ 0.05), a paired t-test was used. An independent t-test was used for the male and female comparison. Also, to compare the calculated data with the published data student t-test was used.

3. Results

Table 1 shows the mean, SD, p-value, and correlation coefficient ($r$) for the crown prominence values for the inter-examiner reliability. 20 sets of models were subjected to repeated measurements at 2 weeks intervals. The comparisons between the first and second measurements for the teeth prominence showed no statistically significant difference (P ≤ 0.05). Also, the correlation coefficient between the two readings for the prominence values ranged from 0.962 to 0.999 which was found to be very high.
Table 2 shows the mean, SD, \( t \)-test, and p-values of the paired \( t \)-test for the comparison of the crown prominence values between the right and left side data for the maxillary and mandibular teeth. Also, Table 3 shows the mean, SD, \( t \)-test, and p-values of the independent \( t \)-test comparing the teeth prominence values between the 30 male dental models and 30 female dental models. The results of the comparison between the male and female and the right and left showed no statistical differences (\( P \leq 0.05 \)) for all teeth which favored the idea of combining the data.
Table 4 shows the combined Saudi data. The total teeth for the Saudi teeth prominence data were 120 teeth.

Table 5 shows the mean, SD, and the p-value for the comparison between Saudi data and North American, Japanese, Indian, Italian, and African. Comparing the teeth prominence values between Saudi data and published data showed statistically significant differences between Saudi and Andrews North American values in all teeth, the L4 shows the greatest difference 0.93 mm. Furthermore, the Japanese study shows the highest values among all studies mainly in the posterior region, with a significant difference in all teeth compared to our study. The upper first molar shows great variation in our reading it

Table 2 Right and left comparison of teeth prominence.

| Tooth | N | Right | | Left | | t-test | | p-value |
|-------|---|-------|---|------|---|------|---|--------|
|       |   | M     | SD | M    | SD |      |   |        |
| U1    | 60| 1.66  | 0.35| 1.66 | 0.33| 0.43 | 0.66 |        |
| U2    | 60| 1.49  | 0.34| 1.49 | 0.33| 1.52 | 0.13 |        |
| U3    | 60| 2.03  | 0.27| 2.03 | 0.28| 0.01 | 0.98 |        |
| U4    | 60| 1.83  | 0.23| 1.82 | 0.21| 0.54 | 0.58 |        |
| U5    | 60| 1.67  | 0.27| 1.66 | 0.24| 0.86 | 0.39 |        |
| U6    | 60| 2.22  | 0.25| 2.23 | 0.27| 0.71 | 0.47 |        |
| U7    | 60| 2.31  | 0.35| 2.34 | 0.36| 2.28 | 0.06 |        |
| L1    | 60| 1.04  | 0.13| 1.05 | 0.13| 1.81 | 0.07 |        |
| L2    | 60| 1.05  | 0.19| 1.05 | 0.23| 0.36 | 0.71 |        |
| L3    | 60| 2.01  | 0.21| 2.02 | 0.21| 1.88 | 0.06 |        |
| L4    | 60| 1.79  | 0.22| 1.80 | 0.20| 1.01 | 0.31 |        |
| L5    | 60| 1.70  | 0.19| 1.69 | 0.18| 0.40 | 0.68 |        |
| L6    | 60| 2.30  | 0.24| 2.35 | 0.31| 1.68 | 0.09 |        |
| L7    | 60| 2.37  | 0.32| 2.38 | 0.32| 1.76 | 0.08 |        |

N: sample size; M: mean value; SD: standard deviation; U1: tooth abbreviation related to upper central incisor.

Table 3 Male and female comparison of teeth prominence.

| Tooth | N | Male | | Female | | t-test | | p-value |
|-------|---|------|---|-------|---|------|---|--------|
|       |   | Mean | SD | Mean  | SD |      |   |        |
| U1    | 60| 1.65 | 0.35| 1.67  | 0.32| 0.39 | 0.69 |        |
| U2    | 60| 1.48 | 0.34| 1.50  | 0.33| 0.24 | 0.80 |        |
| U3    | 60| 2.01 | 0.20| 2.06  | 0.34| 0.84 | 0.39 |        |
| U4    | 60| 1.82 | 0.23| 1.83  | 0.21| 0.16 | 0.86 |        |
| U5    | 60| 1.66 | 0.24| 1.67  | 0.27| 0.11 | 0.90 |        |
| U6    | 60| 2.21 | 0.23| 2.24  | 0.28| 0.59 | 0.55 |        |
| U7    | 60| 2.28 | 0.35| 2.36  | 0.35| 1.22 | 0.22 |        |
| L1    | 60| 1.04 | 0.13| 1.05  | 0.12| 0.50 | 0.61 |        |
| L2    | 60| 1.07 | 0.24| 1.03  | 0.17| 1.05 | 0.29 |        |
| L3    | 60| 2.01 | 0.21| 2.02  | 0.21| 0.18 | 0.85 |        |
| L4    | 60| 1.80 | 0.20| 1.78  | 0.21| 0.58 | 0.58 |        |
| L5    | 60| 1.71 | 0.20| 1.68  | 0.17| 0.99 | 0.32 |        |
| L6    | 60| 2.33 | 0.30| 2.32  | 0.26| 0.28 | 0.77 |        |
| L7    | 60| 2.34 | 0.30| 2.41  | 0.33| 1.23 | 0.22 |        |

N: sample size; SD: standard deviation; U1: tooth abbreviation related to upper central incisor.
was the smallest 2.23 mm, compared to North American value of 2.88 mm and the highest value is in the Japanese reading 5.02 mm. The Indian values, on the other hand, show significant differences in teeth, however in higher values than our study. Also, The Italian value show statistically significant differences between all teeth except the upper second premolar (U5) which is 1.66 mm, and this study is 1.67 mm. In addition the African teeth prominence values that show no statically significant differences at U4, U6, U7, and L2, the remaining teeth show a statistically significant difference.

Table 5 shows the Saudi adult orthodontic prescription values, including the tip, torque, and prominence of teeth.

4. Discussion

New inventions are the wheels of advancement in civilization. The invention of a new orthodontic bracket by the authors requires the determination of bracket prescription (Bukhary et al., 2018). In the previous study, the tip and torque for Saudi adults with normal occlusion were presented (Bukhary et al., 2021). This study is a continuation to determine the prominence or in-out for bracket prescription.

The result of method errors indicated an accurate measurement with small and acceptable random error (Bland and Altman, 1996). This result was in agreement with Lombardo et al. (2015) who found very small measurement errors.

The present study as a continuation of the previous study combined the measurements from the right and left sides and the male and female. Combining the data was in agreement with (Currim and Wadkar, 2004; Lombardo et al., 2015; Watanabe and Koga, 2001) who combined the right and left sides, the male and female data to be presented as an upper and lower quadrant.

Comparison of the combined Saudi data for the prominence to the published data in Table 5 (Fig. 2), showed generally significant differences in all the measurements except for U5 between Saudi and Italian and U4, U6, U7, and L2 between Saudi and African. This was in agreement with several authors including (Currim and Wadkar, 2004; Lombardo et al., 2015; Watanabe and Koga, 2001) who found significant differences between their samples and the compared sample from other ethnic backgrounds. They pointed out the importance of considering the racial variations in applying the bracket prescriptions (Currim and Wadkar, 2004; Haskell and Segal, 2014; Lombardo et al., 2015; Watanabe and Koga, 2001). However, an indepth analysis at the comparisons the prominence values for the Saudi sample were generally smaller than North American, Japanese, and Indians respectively (Table 5) and showed significant differences in all the measurements for the prominence.

However, it should be mentioned that the method of measurement was different. In this study computerized digital measurement was applied whereas, for North American, Japanese, and Indians the manual direct measurements were used. The comparison between Saudi and Italian and African was more significant because the method of measurements was comput-

| Tooth | This study | N American | Japanese | Indian | Italian | African |
|-------|-----------|------------|----------|--------|---------|---------|
| N     | M | SD | M | P | M | P | M | P | M | P | M | P |
| U1    | 120 | 1.66 | 0.34 | 2.01 | S | 2.67 | S | 2.25 | S | 1.48 | S | 1.62 | S |
| U2    | 120 | 1.49 | 0.33 | 1.84 | S | 2.49 | S | 2.09 | S | 1.15 | S | 1.25 | S |
| U3    | 120 | 2.03 | 0.28 | 2.67 | S | 3.93 | S | 2.92 | S | 1.66 | S | 1.56 | S |
| U4    | 120 | 1.83 | 0.22 | 2.54 | S | 4.58 | S | 3.11 | S | 1.61 | S | 1.89 | NS |
| U5    | 120 | 1.67 | 0.26 | 2.48 | S | 4.50 | S | 3.03 | S | 1.66 | NS | 1.85 | S |
| U6    | 120 | 2.23 | 0.26 | 2.88 | S | 5.02 | S | 3.33 | S | 2.01 | S | 2.29 | NS |
| U7    | 120 | 2.32 | 0.35 | 3.00 | S | 4.92 | S | 3.44 | S | 2.75 | S | 2.47 | NS |
| L1    | 120 | 1.04 | 0.13 | 1.59 | S | 1.97 | S | 1.88 | S | 1.01 | S | 1.18 | S |
| L2    | 120 | 1.05 | 0.21 | 1.64 | S | 1.99 | S | 1.78 | S | 0.93 | S | 1.16 | NS |
| L3    | 120 | 2.02 | 0.21 | 2.37 | S | 3.38 | S | 2.41 | S | 1.38 | S | 1.36 | S |
| L4    | 120 | 1.79 | 0.21 | 2.72 | S | 4.11 | S | 2.91 | S | 1.93 | S | 2.01 | S |
| L5    | 120 | 1.69 | 0.18 | 2.60 | S | 4.34 | S | 2.93 | S | 1.91 | S | 2.06 | S |
| L6    | 120 | 2.33 | 0.28 | 3.02 | S | 5.18 | S | 3.14 | S | 2.66 | S | 2.53 | S |
| L7    | 120 | 2.37 | 0.31 | 2.79 | S | 5.04 | S | 3.30 | S | 2.83 | S | 2.22 | S |

N: sample size; M: mean value; SD: standard deviation; U1: upper central incisor; P: t-test’s p-value; S: The mean difference is significant at the 0.05 level; NS: The mean difference is non-significant at the 0.05 level.

Table 5 Comparison of Saudi data with the published data.

Table 6 Orthodontic bracket Prescription for Saudi adult.

| Tip (°) | U1 | U2 | U3 | U4 | U5 | U6 | U7 | L1 | L2 | L3 | L4 | L5 | L6 | L7 |
|--------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 4.89   | 8.29 | 11.99 | 0.10 | 0.11 | 0.03 | 0.02 | 1.34 | 1.39 | 6.46 | 1.35 | 1.45 | 0.08 | –0.11 |
| 13.43  | 8.13 | –3.64 | –7.15 | –7.09 | –12.20 | –12.25 | –1.04 | –1.21 | –10.20 | –16.41 | –20.28 | –28.16 | –28.58 |
| 1.66   | 1.49 | 2.03 | 1.83 | 1.67 | 2.22 | 2.32 | 1.04 | 1.05 | 2.02 | 1.79 | 1.69 | 2.33 | 2.37 |
erized. Although, there were significant differences in most of the measurements except for U5 between Saudi and Italian and U4, U6, U7, and L2 between Saudi and African, the values of the measurements were small compared to the manual method. It should be said that the values of measurement for the Saudis were nearer to the Italian and Africans.

The differences between the Saudi teeth prominence values and the other published data were generally significant. This indicates that Saudi Arabia may have different racial backgrounds than the compared population. However, this study is the first of its type and suggests the need for more research in Saudi Arabia to look for more data for bracket prescriptions, either in Riyadh city or other provinces of Saudi Arabia.

However, needless to mention that establishing bracket prescription for the Saudi population as presented in Table 6 is very important to manufacture and use the patented orthodontic bracket. It should be remembered that gaining the patent gives us the right to manufacture and use the brackets.

Limitation: The manual method is one-step direct measurements from the models whereas the computerized digital measurements require several steps and we do not know what errors were hidden in between, the more steps the more errors involved (Fleming et al., 2011). Researchers pointed out that the main problem in scanning the dental model was the undercut areas (Fleming et al., 2011; Gabor et al., 2017, 2007; Rheude et al., 2005; Tomita et al., 2018). However, our measurement method was proved in accuracy and comparable to earlier published methods.

5. Conclusion

The prominence of the bracket prescription for Saudi adults was presented. Significant differences were found between the combined Saudi data and North American whites. In addition, significant differences were found also between the Saudi data and the Italian, African, Japanese, and Indians. Racial differences should be considered in presenting bracket prescriptions. More research in this field is needed. Finally, an orthodontic bracket prescription for Saudi is established and presented.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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