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ORIGINAL ARTICLE

Digital Assessment of Dental Parameters in Italian and Mozambican Subjects with Ideal Occlusion and Permanent Dentition

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ABSTRACT

Objective: To obtain reference values for tip, torque and in-out from digital models of Italian and Mozambican subjects in ideal occlusion using a repeatable and validated method and to compare these measurements with previously reported values. **Material and Methods:** Dental parameters were acquired from digital models of each subject, categorized to one of two groups: Italians (23 males, 27 females; mean age 28.3 years, ±5.7 years) and Mozambicans (14 males, 15 females; mean age, 23.4 years, ±5.9), using VAM software. All subjects had ideal occlusion, permanent dentition and no previous orthodontic treatment, fillings or prostheses. After normality of data was assumed ($p<0.05$), a paired t-test was performed to detect any statistical differences between the two groups ($p<0.05$). Then, classical inference (t-test and power analysis) was used to compare our data to those reported by other authors. **Results:** Mozambicans' incisors were more proclined, while their upper molars appeared to be more prominent regarding Italians'. Italians shown greater tip values, especially at the upper first premolars and lower first molars. In-out values were comparable between the two groups, except for the upper molars (more prominent in Mozambicans) and lower first molar (more prominent in Italians). Unlike other reports, upper second molars displayed negative tip in our samples. **Conclusion:** Pre-adjusted appliances with standard prescription should not be expected to guarantee optimal outcomes. Prescriptions specific for ethnicities are recommended and reference values should be reconsidered.

Keywords: Torque; Orthodontic Appliances; Orthodontics; Dental Occlusion.

Introduction

According to the results of the JCO's sixth nationwide Study of Orthodontic Diagnosis and Treatment Procedures, 96% of respondents rely on preadjusted prescription appliances [1-6]. However, after more than 50 years of using the straight-wire technique, it is evident that achieving good outcomes without archwire bending or rebracketing is almost impossible [7,8]. Indeed, there are several factors that can compromise results [9], namely archwire-slot play [10] inaccurate bracket positioning during bonding procedures [11], and intra and inter-individual variability in tooth morphology [12-14]. Furthermore, almost all straight-wire appliance (SWA) prescriptions are based on one famous study by Andrews [15], who measured dental parameters on 120 casts of solely white persons of Italian ancestry, without previous orthodontic treatment, although some authors have proposed orthodontic prescriptions based on both dental cephalometric values and the direction and entity of biomechanics applied [16].

Despite this, the use of the SWA has spread across the world without regard for any racial distinctions. Another issue that challenges the wisdom of basing treatment exclusively on Andrews' data is that his method of measurement was purely manual, and the accuracy of his data may have suffered as a result [17].

In particular, the adjustable reading arm protractor used routinely by Andrews [15] for tip and torque calculation is not a precise and reproducible measurement tool and suffers from operator handling issues. In particular, it is affected by a tilting problem during its positioning on the occlusal reference plane, and it is therefore difficult to reproduce the tangent he measured to the midpoint (FA) on the facial axis clinical crown (FACC line).

Moreover, Andrews [15] provided no information regarding repeatability, and therefore, despite his great efforts, his measurements were limited by the technologies and techniques available at that time, as well as by sample criteria selection and assessment issues.

Regarding method of measurements, nowadays digital measurement techniques provide precise and repeatable measurements, both linear and angular, and they are widely available in Orthodontics [18-20]. Despite the lack of these technologies in the past, several authors have still attempted to replicate Andrews' work [15] using different methods of measurement and including subjects of different ethnicities. Sebata [21], for example, analysed 41 untreated ideal casts belonging to Japanese subjects using an x-y plotter and a computer. Watanabe et al. [22] used a method similar to Andrews' [15] to measure 80 casts of Japanese subjects after manual set-up including different malocclusion and treatment options.

Currim and Wadkar [23] also used a very similar method to Andrews's [15], but in this case, they made linear measurements using a digital caliper. They measured 68 casts belonging to Indian subjects, providing measurement error data for 10% of the total sample. These were the first authors to take into account ethnicity as a key factor that may influence tooth values, selecting a heterogeneous group composed of both North and South Indians [23]. Similarly, Doodamani et al. [24] used a customized protractor device and Andrews' method [15] to measure 100 South Indian subjects. Kannabirian et al. [25] also measured the dental parameters of 40 South Indian subjects, albeit using a custom-made tip-torque device similar to that described by Mestriner et al. [26].

Lombardo et al. [27] were the first to replicate Andrews' study [15] using digital software (Rhinoceros®, Robert McNeel & Associates, Seattle, USA). They measured the dental parameters of two samples, Italian and Mozambican, with ideal occlusion. In line with previous studies, they found that torque, tip and in-out values are greatly affected by ethnicity [27]. However, despite their use of digital measurements and inclusion of subjects of different ethnicities, the method used by authors is fairly difficult to replicate, requiring advanced rendering and computing skills and involving a complicated system of reference planes and lines.

Therefore, we set out to use a simple, predictable and validated digital assessment method to determine the dental parameters in two groups of Italian and Mozambican subjects, with a view to obtaining new informations or confirming previous findings on tooth position values and compared these with those reported by Andrews [15] and other authors [21-25]. The null hypothesis is that there are some differences on dental parameters, such as torque, tip and in-out values, between two groups due to different ethnicity and that findings reported by Andrews [15] could be confirmed in the Italian group.

Material and Methods

Sample Selection

Measurements were obtained from a total of 79 digital models (STL files) taken from the University of Postgraduate School of Orthodontics Clinic's electronic database. Digital acquisition of models was performed via direct and indirect scanning using either a 3Shape R700™ scanner (Great Lakes Orthodontics, Tonawanda, New York, USA) or an Orthodontic 3D Scanner™ (3Shape D700/710, Copenhagen, Denmark). The total sample was divided into two groups according to ethnicity: one composed of Italian subjects (23 males, 27 females; mean age 28.4 years, ±5.7), and one of Mozambican subjects (14 males, 15 females; mean age 25.4 years, ±5.9). Italian subjects were recruited from the University of Ferrara, Department of Orthodontics Clinic, whereas Mozambican subjects were recruited from amongst the students of Eduardo Mondlane University, Inhambane, Mozambique. Ethnicity was verified to three previous generations.

The design of this study had been approved by the Ethical Committee of the post-graduate school in Orthodontics of the University of Ferrara.

Digital models were subjected to the following inclusion criteria: complete permanent dentition (except for the third molars), dental Class I molar and canine relationship, minimal crowding (<1.5 mm) [28], ideal overjet and overbite values, no history of past orthodontic treatment, no conservative or prosthetic treatment, no gingival recession and no dental wear. All digital models matched these inclusion criteria.

Measurement of Digital Models

Digital models pertaining to each single subject in each group were analysed by a single operator using VAM® software (Vectra, Canfield Scientific Inc., Fairfield, NJ, USA), adopting the method proposed by Huanca Ghislanzoni. In brief, 100 anatomical reference points per model were identified, including second molars, and their three-dimensional coordinates exported into specific .txt files (Microsoft Excel®, Microsoft, Redmond, WA, USA). This enabled extrapolation through a complex algorithm of the tip, torque and in-out values of each tooth with respect to an occlusal reference plane passing through the following points:

- The mesiovestibular cusp on the right first molar (Point A).
- The mesiovestibular cusp on the left first molar (Point B).
- The centroid of all the most occlusal points on the FACC line (the facial axial of the clinical crown) of the all teeth, excluding the cusp of the canines and the second molar (Figure 1).

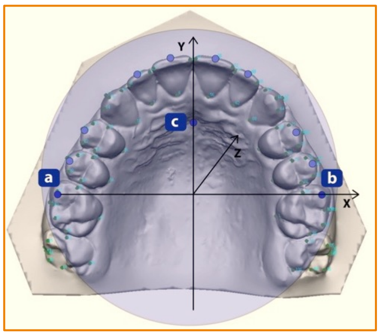

Figure 1. 3D view of occlusal plane used as a reference for all measurements.

Thus, six points were assigned to the incisors and canines, respectively, and eight points were assigned to each of the premolars and molars (Figure 2A and 2B).

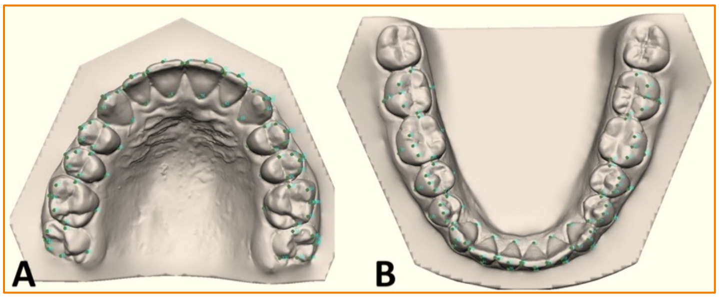

Figure 2. 100 anatomical reference points in maxilla (A) and in mandible (B), respectively.

To test intra-operator repeatability, 20% of all digital casts from both groups were randomly selected and measurements were repeated by the same operator after four weeks. The method error (ME) was calculated according to Dahlberg' formula, and Student's t-test was used to assess any systematic error (SE) between the two sets of measurements, with a p value <0.05 considered as significant.

The main systematic error value was 0.45, and no p value was under the established threshold of 0.05; the main method error was 0.25 mm, and statistical analysis confirmed the reliability and the repeatability of our measurements.

Tip, Torque and in-out Measurement

Torque was measured as the labiolingual inclination of the FACCs (Figure 3A), and tip as the mesiodistal inclination of the FACCs relative to the occlusal reference plane (Figure 3B). An individual tooth coordinate system was necessary to determine such values. In–out was measured considering the distance between the FA point and the mesial and distal points of the buccal ridge of each tooth (Figure 3C).

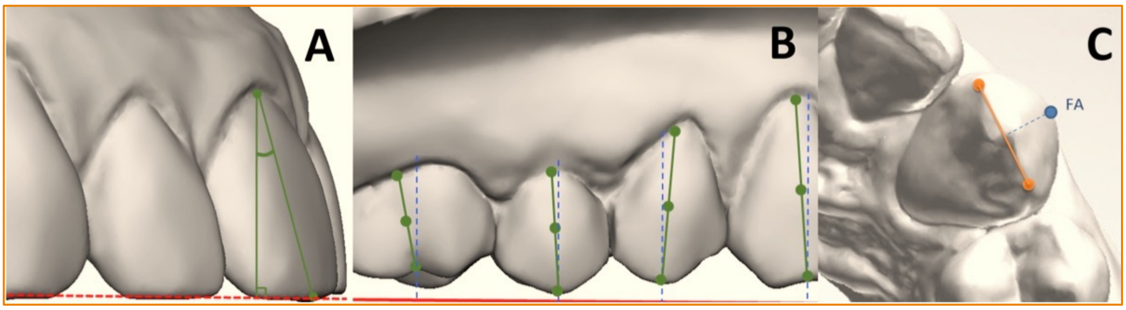

Figure 3. Graphical representation of torque (A), tip (B) and in-out (C) measurements.

Statistical Analysis

Means and standard deviations for each tooth were calculated using R software. The Shapiro-Wilk normality test was applied on the overall measures considered, and the assumption of normality is well supported by our data. Normality was rejected only on two measurements when a threshold of p value <0.01 was used, while it was rejected in 11 cases when a threshold p value of <0.05 was used. In order to detect any significant difference between the two groups investigated, a two-sample t-test was applied with a p value<0.05 considered as significant, and taking into account the samples' size by the effect size (Table 1). In particular, we compared the differences between study means on an effect-size basis. The resulting effect size was compared against the minimum effect size (MEFR) required to achieve a statistical power of 80% (1-β), given a level of confidence (1-α) of 95% and taking into account the actual sample size for the given measure. Confidence intervals and p-values were reported for all comparisons whose effect size were found to be larger than the MEFR.

We then used power analysis to compare our tip, torque and in–out values with those reported by other authors. In essence, power analysis enabled us to assess the minimum effect size that can be detected given an α level of confidence of 95%, as well as a β power (80%) and the actual sample size. As a rule of thumb, a d effect size of around 0.25 is deemed small, around 0.5 is deemed moderate, and over 0.8 is deemed large. We used a two-samples t-test to perform the pairwise analysis required to compare the estimates of pairs of studies, and therefore a power analysis of two independent samples. Accordingly, Table 1 and appendix on-line Table includes the column "empiricalD", which reports the empirical effect size of the comparison between each dataset. "MinD" shows the minimum effect size that our sample size could be used to assess. Finally, the 'difference' column indicates whether the differences between each pair of samples can be deemed statistically significant given the aforementioned assumptions for α and β.

Results

The results of our comparative analysis are reported in Table 1. The mean and standard deviation (SD) of each measurement are reported for each group investigated and comparison performed by a two-sample t-test, considering p<0.05 as significant, taking also into account also sample size by effect size.

Italian Sample

In the Italian sample the maxillary torque shows a typical pattern, with decreasing values moving from the anterior to posterior regions. The only exception was recorded for upper second molar, whose torque value was more positive with respect to the upper first molars (-7.8° *vs.* -10.2°). In the mandibular arch, we observed the typical progressive increase in lingual inclination from incisors to molars, registering the only positive value at the lower central incisors (2.3°). All Italian teeth displayed positive tip values, except for the upper second molars (-8.1°) and, to a lesser extent, the lower central and lateral incisors (-0.1° and -0.3°, respectively).

Mozambican Sample

In the Mozambican sample, both maxillary and mandibular torque values showed a decreasing pattern from the anterior to posterior. Mozambican tip values were all positive except for at the upper second molars (-6.8°) and, to a lesser extent, the lower central incisors (-0.9°).

Comparison of Italian and Mozambican Sample

As regards torque, Mozambican subjects displayed more proclined upper central and lower incisors than Italian subjects, to a statistically significant degree. All comparisons in the lower arch yielded statistically significant differences ($p<0.05$), except for the lower second molars, where the difference was less than 1°. The only tooth at which Mozambicans displayed lesser torque than Italians was the second upper molar ($p<0.05$). Despite the differences between the two groups, the general trend in torque was very similar, with both displaying a progressive decrease from the anterior to posterior sectors.

As regards tip values, Italians showed a more positive tip trend with respect to Mozambicans, with the exception of the upper incisors and lower lateral incisors. That being said, statistically significant differences were only detected at the maxillary first premolar and mandibular first molar ($p<0.05$). As regards in-out values, we found that Mozambican subjects exhibited greater prominence of the upper molars, but less prominent mandibular first molars. Both differences were statistically significant ($p<0.05$). In general, Mozambicans displayed higher in-out values in the maxillary arch, whereas Italians showed greater crown prominence in the mandibular arch.

Comparison of Mozambican and Italian Groups with Andrews's Study

We used power analysis to compare the data pertaining to our two samples with that reported by Andrews, and results are reported in Table 1. In order to better illustrate these comparisons, trends regarding torque, tip and in-out values are displayed in Figure 4.

Taking our sample as a whole, torque values we recorded for the upper canines and upper first premolars in Italian subjects were less negative than those reported by Andrews, i.e., the medial sector appeared to be more upright transversely. However, with respect to Andrews' sample our Mozambican subjects displayed greater positive torque on the upper central incisor, upper canines and upper first premolars and more negative torque on the second molar and all these differences were statistically significant. As for mandibular torque, Andrews's values were comparable to those in our Italian sample, except for at the central incisors, canines and second molars, where statistically significant differences were found. In contrast, our Mozambican sample displayed greater torque values with respect to Andrews' for all mandibular teeth, except for the second molars, which presented less torque than Andrews' sample. All these differences were found to be statistically significant.

In terms of mesiodistal angulation, in the maxillary arch statistical differences between our Italian and Andrews's sample were found in the posterior sector, from the first premolar to second molar. In this sector, a more positive tip trend was exhibited by our Italian group with respect to Andrews's sample. However, our Mozambican sample only displayed statistically significant differences from Andrews' at the upper canine (more uprighted mesiodistally) and the molars (the first and second molars were tipped more mesially and distally, respectively). In the lower arch, on the other hand, our Italian group displayed more positive mesiodistal angulation on the canines, premolars and molars with respect to the tip reported by Andrews; in each case the difference was statistically significant ($p<0.05$). Our Mozambican group also showed significant differences with respect to Andrews' sample, exhibiting more negative tip on the central lower incisors, and more positive tip on the premolars and second molars ($p<0.05$).

All our in-out values were significantly lower than those reported by Andrews ($p<0.05$). Despite this, in the maxillary arch the trend in in–out was similar up to the second premolar. Indeed, in Andrews' subjects, the most prominent maxillary teeth were the first and second molars, while in both our Italian and Mozambican groups they were the canine, followed by the first premolar. As regards the mandibular in-out, our Italian sample displayed the same pattern as Andrews', whereas our Mozambican sample did not. On the whole, the most prominent teeth in our sample were the second molars, whilst in Andrews's sample the most prominent tooth was the mandibular first molars.

Table 1. Mean values and standard deviation for in-out (mm) and tip and torque (°) values in both Italian and Mozambican group investigated.

Measure	Italians (Mean/SD)	Mozambicans (Mean/SD)	EmpiricalD	MinD	p-value	Group	Authors	EmpiricalD	MinD	Uci	lci	p-value
U1 TORQUE	5.99 (± 5.6)	11.01 (± 7.1)	0.03	0.47	<0.05	Italians	Andrews	0.03	0.47			ns
						Mozambicans	Andrews	1.04	0.58	6.83	2.97	<0.05
U2 TORQUE	4.44 (± 5.6)	6.54 (± 6.9)	1.55	0.51	ns	Italians	Andrews	0.0	0.47			ns
						Mozambicans	Andrews	0.43	0.58			ns
U3 TORQUE	-2.9 (± 5.6)	-2.79 (± 6.5)	0.65	0.6	ns	Italians	Andrews	0.93	0.47	5.90	2.80	<0.05
						Mozambicans	Andrews	0.94	0.58	6.39	2.53	<0.05
U4 TORQUE	-6.23 (± 5.0)	-5.13 (± 7.5)	0.04	0.53	ns	Italians	Andrews	0.51	0.47	3.70	0.77	<0.05
						Mozambicans	Andrews	0.68	0.58	5.37	1.32	<0.05
U5 TORQUE	-7.34 (± 5.0)	-6.75 (± 6.6)	3.28	0.49	ns	Italians	Andrews	0.33	0.47			ns
						Mozambicans	Andrews	0.43	0.58			ns
U6 TORQUE	-10.2 (± 5.7)	-11.13 (± 7.5)	0.5	0.6	ns	Italians	Andrews	0.3	0.47			ns
						Mozambicans	Andrews	0.08	0.58			ns
U7 TORQUE	-7.8 (± 8.3)	-14.46 (± 8.3)	0.24	0.66	<0.05	Italians	Andrews	0.03	0.47			ns
						Mozambicans	Andrews	1.04	0.58	-3.90	-9.00	<0.05
L1 TORQUE	2.28 (± 5.9)	9.93 (± 7.7)	0.93	0.66	<0.05	Italians	Andrews	0.7	0.47	5.90	2.08	<0.05
						Mozambicans	Andrews	1.9	0.58	14.14	9.14	<0.05
L2 TORQUE	-0.91 (± 5.9)	6.51 (± 7.1)	1.04	0.58	<0.05	Italians	Andrews	0.42	0.47			ns
						Mozambicans	Andrews	1.7	0.58	12.10	7.41	<0.05
L3 TORQUE	-9.64 (± 5.4)	-3.01 (± 7.1)	0.39	0.61	<0.05	Italians	Andrews	0.63	0.47	4.72	1.47	<0.05
						Mozambicans	Andrews	1.86	0.58	11.86	7.59	<0.05
L4 TORQUE	-16.73 (± 5.9)	-12.19 (± 7.4)	0.27	0.69	<0.05	Italians	Andrews	0.42	0.47			ns
						Mozambicans	Andrews	1.23	0.58	9.01	4.50	<0.05
L5 TORQUE	-22.41 (± 5.4)	-17.3 (± 8.1)	1.09	0.63	<0.05	Italians	Andrews	0.22	0.47			ns

						Mozambicans	Andrews	1.03	0.58	8.84	3.81	<0.05
L6 TORQUE	-31.97 (± 5.7)	-25.35 (± 8.4)	1.69	0.6	<0.05	Italians	Andrews	0.22	0.47			ns
						Mozambicans	Andrews	0.83	0.58	7.96	2.69	<0.05
L7 TORQUE	-39.55 (± 7.6)	-40.3 (± 9.4)	0.3	0.69	ns	Italians	Andrews	0.51	0.47	-1.23	-5.81	<0.05
						Mozambicans	Andrews	0.59	0.58	-1.33	-7.21	<0.05
U1 TIP	2.19 (± 2.8)	3.19 (± 3.4)	0.54	0.74	ns	Italians	Andrews	0.66	0.47	-0.70	-2.09	<0.05
						Mozambicans	Andrews	0.19	0.58			ns
U2 TIP	6.67 (± 4.1)	7.37 (± 3.6)	0.06	0.75	ns	Italians	Andrews	0.42	0.47			ns
						Mozambicans	Andrews	0.22	0.58			ns
U3 TIP	7.68 (± 4.2)	5.52 (± 3.7)	0	0.47	ns	Italians	Andrews	0.21	0.47			ns
						Mozambicans	Andrews	0.92	0.58	-1.60	-4.15	<0.05
U4 TIP	4.61 (± 3.9)	1.53 (± 4.3)	1.34	0.51	<0.05	Italians	Andrews	0.77	0.47	2.81	1.12	<0.05
						Mozambicans	Andrews	0.47	0.58			ns
U5 TIP	5.68 (± 4.4)	3.02 (± 4.2)	0.58	0.6	ns	Italians	Andrews	1.06	0.47	3.76	1.96	<0.05
						Mozambicans	Andrews	0.09	0.58			ns
U6 TIP	9.2 (± 4.6)	8.11 (± 4.8)	0	0.53	ns	Italians	Andrews	1.18	0.47	4.45	2.50	<0.05
						Mozambicans	Andrews	0.88	0.58	3.48	1.28	<0.05
U7 TIP	-8.11 (± 9.0)	-6.78 (± 7.6)	1.36	0.49	ns	Italians	Andrews	1.23	0.47	-6.13	-10.66	<0.05
						Mozambicans	Andrews	1.16	0.58	-4.57	-9.57	<0.05
L1 TIP	-0.08 (± 3.9)	-0.87 (± 3.1)	0.6	0.6	ns	Italians	Andrews	0.26	0.47			ns
						Mozambicans	Andrews	0.78	0,58	-0.67	-2.14	<0.05
L2 TIP	-0.35 (± 4.2)	0.46 (± 2.9)	0.3	0.66	ns	Italians	Andrews	0.28	0.47			ns
						Mozambicans	Andrews	0.04	0.58			ns
L3 TIP	4.97 (± 5.5)	4.24 (± 4.1)	0.45	0.66	ns	Italians	Andrews	0.61	0.47	3.84	1.14	<0.05
						Mozambicans	Andrews	0.51	0.58			ns
L4 TIP	4.93 (± 5.3)	2.79 (± 4.2)	0.43	0.58	ns	Italians	Andrews	1.12	0.47	4.74	2.57	<0.05
						Mozambicans	Andrews	0.6	0.58	2.53	0.48	<0.05
L5 TIP	5.83 (± 4.7)	3.86 (± 4.7)	0.83	0.61	ns	Italians	Andrews	1.54	0.47	5.22	3,36	<0.05
						Mozambicans	Andrews	0.97	0.58	3.29	1.34	<0.05
L6 TIP	7.32 (± 6.4)	2.66 (± 4.9)	0.16	0.69	<0.05	Italians	Andrews	1.48	0.47	6.48	4.10	<0.05
						Mozambicans	Andrews	0.27	0.58			ns
L7 TIP	12.62 (± 8.01)	9.65 (± 7.52)	0.41	0.63	ns	Italians	Andrews	2.08	0.47	11.23	8.13	<0.05
						Mozambicans	Andrews	1.78	0.58	8.25	5.17	<0.05

U1 INOUT	1.3 (± 0.5)	1.27 (± 0.6)	0.73	0.6	ns	Italians	Andrews	1.86	0.47	-0.58	-0.84	<0.05
						Mozambicans	Andrews	1.91	0.58	-0.58	-0.89	<0.05
U2 INOUT	1.12 (± 0.5)	1.24 (± 0.5)	0.21	0.69	ns	Italians	Andrews	2.03	0.47	-0.60	-0.83	<0.05
						Mozambicans	Andrews	1.69	0.58	-0.46	-0.75	<0.05
U3 INOUT	1.98 (± 0.5)	2.27 (± 0.6)	0.05	0.74	ns	Italians	Andrews	1.57	0.47	-0.54	-0.83	<0.05
						Mozambicans	Andrews	0.91	0.58	-0.22	-0.58	<0.05
U4 INOUT	1.77 (± 0.4)	1.98 (± 0.4)	0.12	0.75	ns	Italians	Andrews	2.11	0.47	-0.65	-0.89	<0.05
						Mozambicans	Andrews	1.52	0.58	-0.41	-0.72	<0.05
U5 INOUT	1.63 (± 0.4)	1.83 (± 0.3)	0.93	0.47	ns	Italians	Andrews	2.34	0.47	-0.73	-0.97	<0.05
						Mozambicans	Andrews	1.84	0.58	-0.51	-0.80	<0.05
U6 INOUT	1.52 (± 0.4)	1.79 (± 0.4)	0.49	0.51	<0.05	Italians	Andrews	3.41	0.47	-1.23	-1.50	<0.05
						Mozambicans	Andrews	2.76	0.58	-0.93	-1.25	<0.05
U7 INOUT	1.26 (± 0.4)	1.75 (± 0.4)	0.7	0.6	<0.05	Italians	Andrews	3.61	0.47	-1.58	-1.90	<0.05
						Mozambicans	Andrews	2.53	0.58	-1.04	-1.45	<0.05
L1 INOUT	0.97 (± 0.3)	0.81 (± 0.4)	0.54	0.53	ns	Italians	Andrews	2.14	0.47	-0.53	-0.72	<0.05
						Mozambicans	Andrews	2.5	0.58	-0.65	-0.91	<0.05
L2 INOUT	1.13(± 0.4)	0.94 (± 0.4)	1.44	0.49	ns	Italians	Andrews	1.52	0.47	-0.40	-0.62	<0.05
						Mozambicans	Andrews	2.07	0.58	-0.56	-0.84	<0.05
L3 INOUT	2.1 (± 0.5)	2.01 (± 0.5)	0.45	0.6	ns	Italians	Andrews	0.62	0.47	-0.12	-0.41	<0.05
						Mozambicans	Andrews	0.87	0.58	-0.19	-0.54	<0.05
L4 INOUT	2.33 (± 0.4)	2.22 (± 0.4)	0.07	0.66	ns	Italians	Andrews	0.94	0.47	-0.25	-0.52	<0.05
						Mozambicans	Andrews	1.2	0.58	-0.33	-0.67	<0.05
L5 INOUT	2.25 (± 0.4)	2.21 (± 0.3)	0.13	0.66	ns	Italians	Andrews	1.02	0.47	-0.24	-0.47	<0.05
						Mozambicans	Andrews	1.16	0.58	-0.25	-0.53	<0.05
L6 INOUT	2.49 (± 0.4)	2 (± 0.4)	0.94	0.58	<0.05	Italians	Andrews	1.29	0.47	-0.40	-0.67	<0.05
						Mozambicans	Andrews	2.5	0.58	-0.86	-1.19	<0.05
L7 INOUT	2.49 (± 0.46)	2.39 (± 0.47)	0.5	0.61	ns	Italians	Andrews	0.64	0.47	-0.14	-0.45	<0.05
						Mozambicans	Andrews	0.85	0.58	-0.21	-0.59	<0.05

*Comparison between groups is performed using a two-sample t test (p<0.05) taking into account sample size by effect size. Further comparison between both groups investigated and Andrew's study performed by power analysis and the assessment of the minimum effects size; ns: not significant.

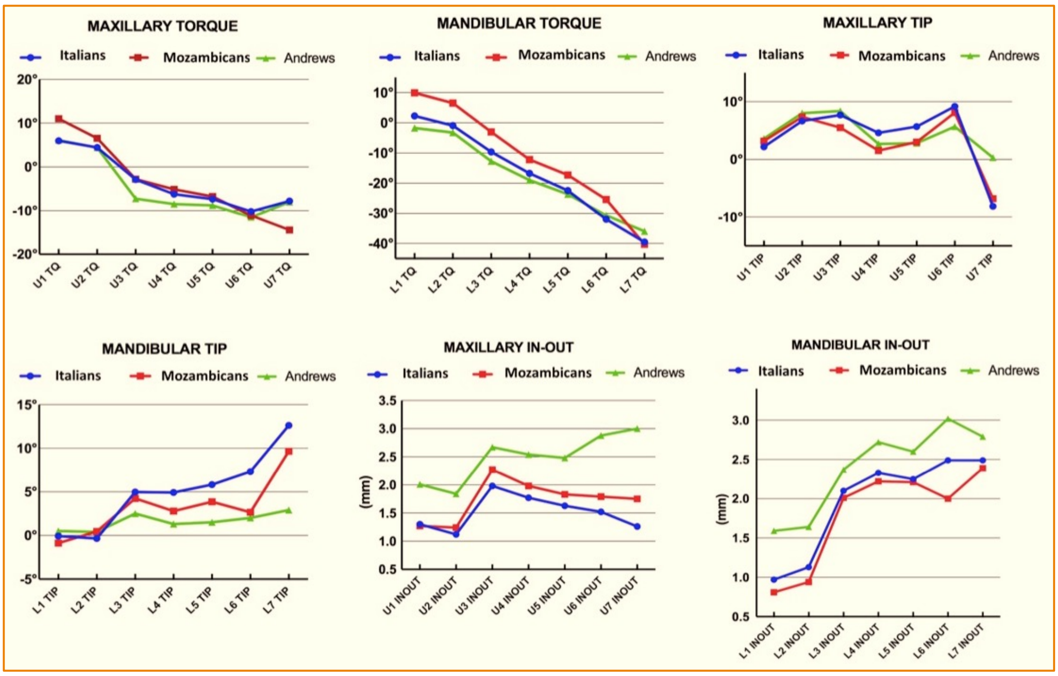

Figure 4. Graphical comparison of Italians, Mozambicans and Andrews' values for torque, tip and in-out in maxillary and mandibular arches.

Discussion

Nowadays, the majority of orthodontists use SWAs, whose prescriptions are largely based on Andrews' famous study [15] carried out on 120 models with ideal natural occlusion and no previous orthodontic treatment. Despite this research being innovative for its time and laying the foundation for the first SWA, as described above it was affected by several methodological issues, a lack of any repeatability testing, and no ethnic distinctions [29,30].

In this study, we aimed to overcame these limitations. Specifically, we set out to determine tip, torque and in–out in samples of Italian and Mozambican subjects with normal occlusion relying on a new, validated and accurate digital method of measuring dental parameters and to compare our measurements with Andrews and other author's findings.

Huanca Ghislanzoni et al. [31] reported a relative error ranging from 0.9% to 4.0% for angular measurements and 0.1% to 1.9% for linear measurements made according to this method, and overall, its repeatability is very good due to fact that a stable occlusal plane of reference for all subsequent measurements is well defined digitally. As a matter of fact, unlike the method proposed by Andrews [15], who defined the occlusal plane per each arch using a plastic template positioned on the occlusal surfaces of all teeth except for the canines, this digital method defines the reference occlusal plane passing through 3 points, without taking into account either canines or second molars. The fact that the occlusal plane is detected digitally ensures the repeatability and reproducibility of all tip and torque measurements without time-consuming and related-operator procedures during the positioning of a plastic template and the use of a manual protractor.

In line with the literature, our findings confirm that ethnicity affects both tooth dimension and dental parameters [32,33]. Regarding tooth dimensions, previous studies have pointed out that Italians, having smaller mesiodistal dimensions and generally an altered Bolton index, show good occlusion, while Mozambicans, having larger mesiodistal diameters with correct Bolton index, showing increased incisor crowding [34-36]. Arch form is also influenced by race: Chilean subjects have wider intercanine and intermolar distances with respect to Italians [17]; Japanese and Korean subjects have a more squared arch-form [37] whereas the Israeli arch form is more ovoid [38]. Furthermore, Bayome et al. [39] stated that Egyptians have narrower arches than Italian North Americans.

In our study, we found considerable variation in all dental parameters investigated. In particular, Mozambican subjects have more proclined upper and lower incisors with respect to Italians, likely due to the larger teeth characteristic of the former. This is important from a clinical perspective, as differences in first order values may necessitate in-out compensation adjustments to achieve perfect alignment in the posterior sectors of Mozambican subjects. Indeed, relying on Andrews' prescription brackets could cause lingual and vestibular displacement of the upper and lower first molars, respectively.

As regards torque, both arches showed a very common trend, with a reduction of torque from the anterior to posterior sectors. Similarities with other authors were seen mostly in the premolar area. Sebata [21] reported more positive torque on the canine than Andrews, and our measurements were similar to Lombardo et al. 's [27], Watanabe et al.'s [22] and Kannabirian et al.'s [25] findings, in line with prescriptions that set maxillary canine torque at 0°.

Irrespective of the method of measurement, it is evident that the torque on the anterior teeth in the upper arch is affected by ethnic origin; values reported by Doodamani et al. [24] for South Indians and Japanese subjects [21,22] were greater than in Mozambican whereas Andrew's values were smaller than those of Currim and Wadkar [23] and our Italians. As for mandibular torque, Mozambican ethnicity seems to have a strong influence, as both our and Lombardo et al.'s [27] Mozambican samples displayed relatively greater labial inclination on all lower teeth, with the exception of the lower second molars. Doodamani et al.'s [24] values have the smallest variance from anterior to posterior, and indicate more uprighted second lower molars than premolars.

As regards second order values, in the maxillary arch the tip we recorded for the upper second molar is important to note; like Lombardo et al. [27], we found that this was negative in both samples. This contrasts with all previous studies, which reported positive or close to 0° values. Rather than ethnic features, this discrepancy may be linked to the digital assessment method used. In the lower arch, our Italian tip values were similar to those of other authors when incisor area is considered. However, it is impossible to detect a common trend towards the posterior regions, and our Italian sample showed more angulated teeth, similar to Sebata's data [21]. In our Mozambican group, on the other hand, the mandibular tip measured was perfectly comparable to those reported by Sebata [21], Kannabirian et al. [25] and Lombardo et al. [27] Mozambican group.

Concerning in-out, Andrews's values were larger than those found in our study for all teeth, albeit with a similar trend up to second premolars. Interestingly, Mozambican in-out values followed the same trend as Italians, except for at the first molars. The fact that the first molar in-out seems to be smaller in Mozambicans than Italian subjects cannot be explained by differences in measurement method or reference points, and may therefore be clinically relevant, as regards compensation for mandibular first molar in-out, in patients of Mozambican origin.

Despite these interesting findings, several factors should be considered before definitive conclusions can be drawn. First of all, we compared our values respect to these of other authors, without taking into account that different measurement methodologies were used, and without quantifying how measurements are affected by this. However, at this stage only Huanca Ghislanzoni et al. [31] method has been validated, whereas the methodologies used and described by other authors have not.

Furthermore, but in line with previous reports in the literature, our statistical analysis showed great standard deviation for all measured values [21,25,27]. This great amount of dispersion around the mean could be interpreted as a consequence of biological variation in the clinical crown profile even in subjects with ideal occlusion. In fact, it is well known that SWA needs some form of individualization through both archwire bends and bracket repositioning in the finishing phase, even if an accurate bonding procedure has been carried out. Both individual variation and ethnicity play a very important role in this, and therefore the use of individualized prescriptions and customized appliances on each patient should be emphasized [40], rather than the use of different kind of prescription for each ethnicity.

Moreover, although we performed analysis taking into account different ethnic groups, these cannot be considered representative of the global population, especially for the Mozambican group, in which only 29 subjects were assessed. Hence, further investigations including a larger sample and with different ethnicities should be performed, as ethnic differences are likely to occur even in the same continent.

Conclusions

1. The null hypothesis has been partially accepted.
2. Mozambican subjects have more proclined upper central incisors and lower teeth (except for lower second molars) than Italian subjects, whereas Italian subjects display slightly more tip on the upper first premolar and lower first molar than Mozambican subjects.
3. Mozambican subjects have more prominent upper first and second molars with respect to Italians, who, in contrast, have a more prominent mandibular first molar; these differences in in-out could affect final tooth positions in Mozambicans when relying on preadjusted bracket appliances.
4. As compared to Andrews' results, our upper canine and upper premolar displayed more positive torque, whereas the tip on the second upper molar of both Italian and Mozambican subjects was more negative than that reported by other authors (with the exception of Lombardo's study).
5. Due to the great standard deviation (biological individual variation) and differences in dental parameters between groups (ethnic variation), the use of fully customized appliances should be encouraged in order to achieve good results with minimal archwire bending and/or bracket repositioning.

Authors' Contributions

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FC	https://orcid.org/0000-0002-4641-2196	Methodology and Writing - Review and Editing.
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PA	https://orcid.org/0000-0002-4020-5065	Conceptualization, Methodology and Writing - Review and Editing.

All authors declare that they contributed to critical review of intellectual content and approval of the final version to be published.

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Conflict of Interest

The authors declare no conflicts of interest.

Data Availability

The data used to support the findings of this study can be made available upon request to the corresponding author.

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