Original Article

Accuracy of planned tooth movement with lingual straight wire technique

Paolo Albertini[a]; Enrico Albertini[b]; Federica Pellitteri[a]; Luis Huanca Ghislanzoni[c]; Luca Lombardo[d]

ABSTRACT

Objectives: To analyze the accuracy of planned tooth movements of torque, tip, rotations, and transverse width values with lingual straight-wire technique.

Materials and Methods: 40 Caucasian subjects with mean age of 23.9 years, consecutively treated in private practice with a lingual straight-wire appliance (STb, Ormco, Glendora, Calif) were evaluated. Maxillary and mandibular dental casts were taken before treatment (T0), in the setup (T1), and at the end of treatment (T2) and scanned with an intraoral 3D scanner Carestream CS 3600 (Carestream Dental, Atlanta, GA). Virtual models at the three time points were superimposed on T1 using 3D software, and the coordinates were exported as a set of x, y, and z values. Angular and linear measurements were analyzed to measure torque, tip, rotation movements, and transverse intra-arch widths. Changes among the three time points were analyzed with Friedman's nonparametric test.

Results: A general increase in torque was recorded in the setup and in the final result, except for the maxillary molars. Torque, tip, and rotation movement mean accuracy was ≥84% for incisors, canines, and premolars. A general increase in transverse width was measured in the setup and in the final models, except for the upper second molars, which showed reduced transverse width during treatment.

Conclusions: The movements planned in the setup to obtain the ideal torque, tip, and rotations actually occurred, except for second molars, which showed less accuracy. Planned expansion of the arches occurred only partially. (*Angle Orthod.* 0000;00:000–000.)

KEY WORDS: Lingual orthodontics; Accuracy; 3D superimposition; Digital planning

INTRODUCTION

Lingual orthodontic treatment has become increasingly popular in recent years due to patient esthetic desire in a changing, appearance-driven society. However, due to anatomic variability of the lingual surfaces among patients, the lingual system requires a precise setup. Indeed, invisibility of the appliance is not the only relevant feature; the real clinical objective is to achieve good facial harmony and perfect occlusion combined with smile esthetics and patient satisfaction. Lingual orthodontics achieves high biomechanical efficiency through three-dimensional tooth control. Additionally, some cases require a fixed appliance, since inferior results would be obtained with aligners and, in some cases, the lingual system is even more biomechanically advantageous than the traditional buccal technique.[1,2] However, Ata-Ali et al.[3] found no difference in the posttreatment peer assessment rating scores between patients treated using lingual and labial appliances.

Knowledge of the appliance limitations allows calibration to apply overcorrections during the setup procedure to achieve the best results for patients. Previous authors evaluated accuracy of different customized lingual systems with bent archwires, focusing on the differences between setup and final results, showing high accuracy, and less than 5° for the angular values.[4,5] Those studies, however, did not measure the ratio between achieved and planned movement for the lingual appliance.

[a] Assistant Researcher, Department of Orthodontics, University of Ferrara, Ferrara, Italy.
[b] Adjunct Professor, Department of Orthodontics, University of Ferrara, Ferrara, Italy.
[c] Assistant Researcher, Department of Orthodontics, University of Geneva, Geneva, Switzerland.
[d] Professor and Chair, Department of Orthodontics, University of Ferrara, Ferrara, Italy.
Corresponding author: Dr Paolo Albertini, Via Livatino 9, Reggio Emilia 42124, Italy
(e-mail: dr.paoloalbertini@gmail.com)

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The wide range of anatomic variability of the lingual surfaces among teeth requires indirect bonding to achieve high-quality treatment with lingual appliances. Therefore, the setup accuracy has assumed a fundamental role. For these reasons, the aim of this study was to analyze the accuracy of planned tooth movements of torque, tip, rotations, and transverse width changes with the lingual straight wire technique. Comparison between the setup and actual final result, as well as measuring the initial models, allows analysis of the discrepancy between planned and achieved movements in relation to the initial tooth positions.

MATERIALS AND METHODS

The study design was reviewed and approved by the Ethics Committee of the Postgraduate School of Orthodontics, Ferrara University (approval number:11/2019). Sample size was calculated in the validation study of the measurement method used. To detect an effect size of 0.6 for the average tip and torque angles, with an alpha of 0.05 and a desired power of 0.80, at least 24 dental casts were required in the sample.[6] In the present study, 40 patients were analyzed. They were consecutively treated in a private practice using a lingual straight-wire appliance with a horizontal wire insertion slot (STb, Ormco, Glendora, Calif), by the same operator (EA) over a 4-year period.

The inclusion criteria for this case series study were: patients with a full permanent dentition (except for third molars), Class I or mild Class II Angle classification, nonextraction cases. The exclusion criteria were: patients with prosthetic rehabilitation, sucking habits, craniofacial syndromes, cysts, cleft lip or palate, multiple or advanced carious lesions, patients who needed corrective jaw surgery, and patients with incomplete or imperfect records.

A panoramic radiograph, lateral cephalograms, photographs, and dental casts were obtained for all subjects. All subjects were treated in both arches with a lingual straight-wire technique with STb brackets and a manual setup with single jigs, using the Komori KommonBase system.[7]

Treatment followed the same standard archwire sequence: an initial upper and lower 0.013-inch Copper Ni-Ti followed by a 0.018- × 0.018-inch Copper Ni-Ti and a 0.0175- × 0.0175-in. TMA (Ormco) for the finishing phase. No extractions were needed and no auxiliaries were used during the finishing phase, except for Class II elastics in the last treatment phase.

Before treatment (T0), setup (T1), and after treatment (T2) maxillary and mandibular dental casts were taken for each patient. A total of 240 dental casts were acquired, and each was assigned a number to protect patient identity and to obscure the casts from the operator who digitized them. An intraoral 3D scanner (Carestream CS 3600, Carestream Dental, Rochester, NY) was used to scan all study casts to perform the three-dimensional (3D) dental analysis. All of the models were saved as STL files.

On each virtual model, the same operator (PA) digitized a total of 74 points (total: 17,760 points), using VAM software (Vectra; Canfield Scientific, Fairfield, NJ, USA), following the methodology established by Ghislanzoni et al.[6] VAM software is currently widely used for attaining accurate model analysis.[6,8–13] A second expert operator double-checked the exact sequencing and placement of points (EA). The virtual models at the three time points were superimposed using a best-fit process on the digitized points, and the coordinates were exported as a collection of x, y, and z coordinates.

To calculate angular measurements, the models at T1 were utilized as a reference to build a common "Andrews-like" reference plane.[14] The flat occlusal plane at T1 was created in the setup as the optimal result, since the occlusal plane at T0 could eventually affect some torque measurements. The results of linear and angular measurements were examined. The angular values (tip, torque, and rotation values) were analyzed using the reference plane, while the cast superimpositions were generated using the best-fit alignment among the corresponding points on the digital casts (T0-T1-T2).

As reported by Andrews, torque was measured as the labiolingual inclination of the clinical crown's facial axis with respect to the reference plane (Figure 1a,b), and tip was quantified as the mesiodistal inclination of the clinical crown's facial axis with respect to the reference plane (Figure 1c).[14] The sign of the angular measurement corresponded to the traditional bracket prescriptions: positive values indicated buccal crown inclination, whereas negative values indicated lingual crown inclination.

The angular variation of the mesiodistal line (segment of the mesio and distal point) with respect to the reference plane was used to quantify rotations as described by Andrews (Figure 1d).[14]

Transverse arch widths at the canines, first and second premolars, and first and second molars were measured using the transverse intercusp distance (Figure 2).

The average differences between time points were calculated for each tooth and type of planned movement. The following formula was used to quantify the accuracy of each movement for each tooth with respect to the setup (accuracy is the % of movement achieved compared to the movement planned):

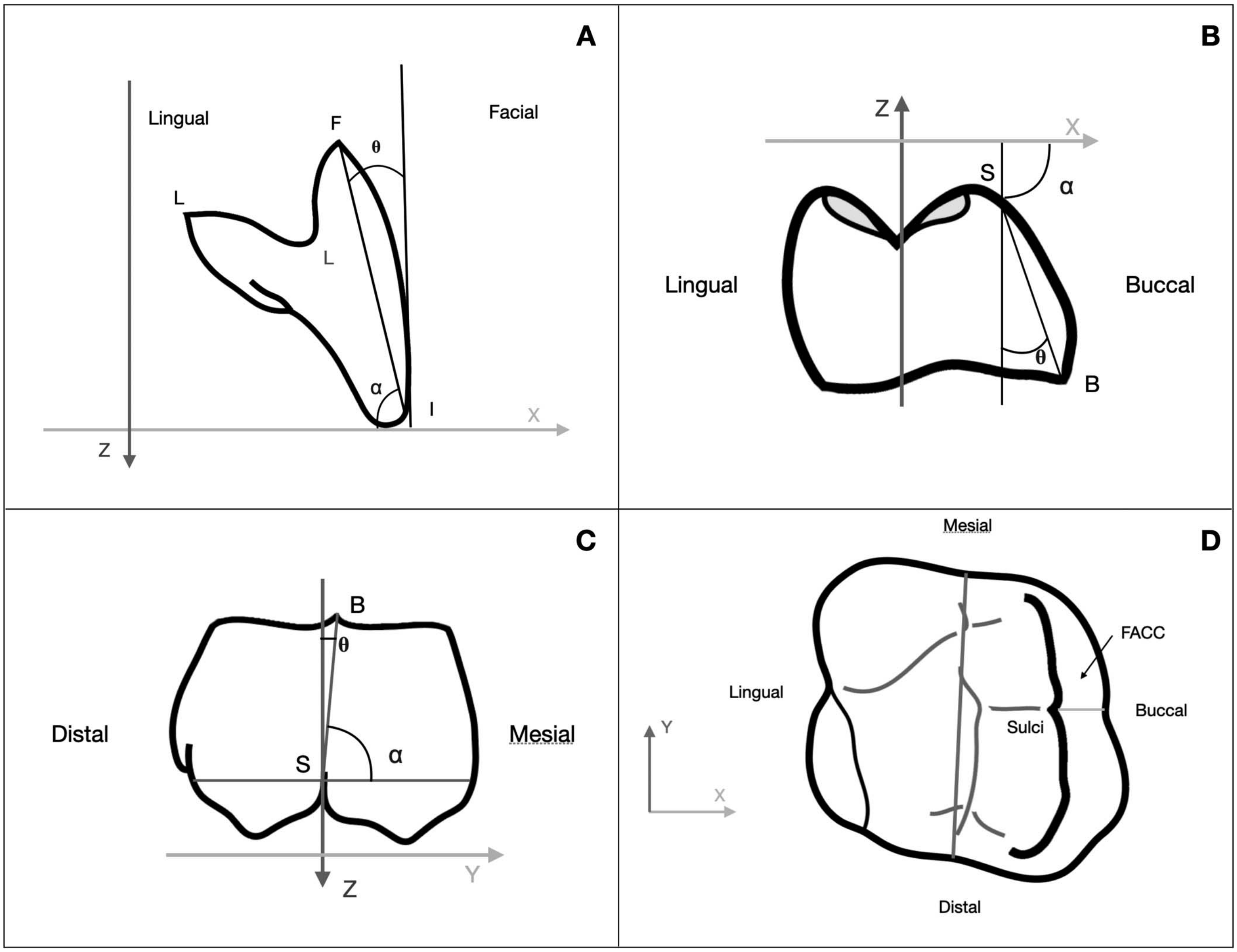

Figure 1. (a) Illustration showing the angle of crown torque of a lower incisor: X represents the occlusal plane, FI represents the facial axis of the clinical crown (FACC), θ represents the inclination of crown as the angle between FI and a line perpendicular to the occlusal plane. (b) Illustration showing the angle of crown torque of the posterior elements: S indicates the occlusal limit of the FACC, B indicates the gingival limit of the FACC and represents the horizontal projection point S on the X axis. θ is the angle representing the torque, obtained by subtracting α of 90°. (c) Illustration showing the angle of crown tip: X represents the occlusal plane, FI represents the FACC, θ represents the inclination of the crown as the angle between FI and a line perpendicular to the occlusal plane. (d) The illustration shows the rotation of the reference plane. The XY plane was rotated so that the Y axis was parallel to the mesiodistal line of each tooth.

$$movement\ accuracy = \frac{movement\ achieved(T2 - T0)}{movement\ planned(T1 - T0)}$$

Thus, an index of the accuracy of each movement was obtained. The closer that each value was to 1, the more precise the dental movement that was achieved (100% of the planned movement in the setup). The accuracy values presented represent the average for each individual accuracy value obtained with the formula (ratio between real [T2–T0] and programmed [T1–T0] movement) and not the average of the averages between real mean movement (average [T2–T0]) and programmed (T1–T0) movement.

Statistical Analysis

The Kolmogorov-Smirnov test was used to verify the normal distribution of the sample. The hypothesis that the data were distributed normally could not be rejected for any variable. Descriptive analyses were evaluated before the treatment (T0), in the setup (T1), and at the end of treatment (T2).

Friedman's nonparametric test was applied to verify the significant differences among the three time points. The Friedman test was used because the groups did not meet the minimum number required for parametric testing. In case of test significance, pairwise comparisons were used to determine which pairs of time points had a significant difference. Finally, a single-

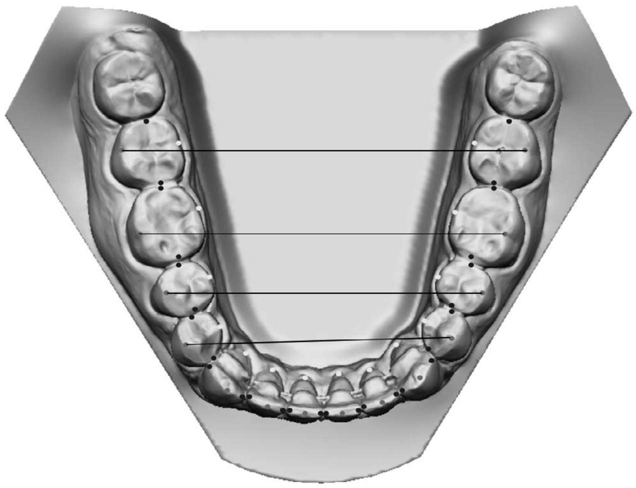

Figure 2. Transverse arch width measured at the cusp levels for every tooth.

sample *t*-test was carried out to verify whether the accuracy was significantly different from 0.

The method error was determined with Dahlberg's test. The same investigator digitized 10 randomly selected study casts at a 14-day interval.

A paired-sample *t*-test was applied to compare the left and right crown torque values for corresponding teeth in the maxilla and the mandible at T0. No statistically significant differences were found in the mean measurements between the teeth on the left and on the right sides at any time point and, therefore, the angular measurements were grouped for analogous teeth.

The level of significance was set at $P \leq .05$ for all statistical analyses. Statistical analyses were performed using R statistical software (R Core Team 2020) and SPSS Statistics software (IBM, version 28).

Table 2. Statistical Significance for Torque Value Differences

Tooth	Chi-square	*P*	*P* (T1–T0)	*P* (T2–T0)	*P* (T2–T1)
U1	25	<.001	<.001	<.001	.166
U2	23.154	<.001	<.001	<.001	.782
U3	33.429	<.001	<.001	<.001	.109
U4	4.933	.085	-	-	-
U5	2.533	.282	-	-	-
U6	24.947	<.001	<.001	.002	.433
U7	18	<.001	<.001	.34	.34
L1	25.613	<.001	<.001	<.001	.899
L2	20.583	<.001	<.001	<.001	.564
L3	30.333	<.001	<.001	<.001	.733
L4	15.077	<.001	<.001	.002	.579
L5	9	.011	.009	.009	1
L6	8.957	.011	.055	.003	.302
L7	21.478	<.001	<.001	.010	.314

RESULTS

The study sample consisted of 40 Caucasian subjects (28 female and 12 male) with a mean age of 23.9 years (SD: 9.3) and an average treatment time of 23.3 months (SD: 5.8). The method error, calculated from repeated measurements of digitized casts, was 0.6° and 0.2 mm for the angular and linear measurements, respectively.

Torque

A general increase of torque values was recorded in the setup (T1) and in the final result (T2), except for the maxillary molars (Tables 1 and 2). The mean accuracy for torque actually obtained (vs planned) was between 85% and 92% for incisors, canines, and premolars, whereas the accuracy for molars was between 52% (maxillary second molars) and 81% (mandibular first molars).

Table 1. Average Differences in Torque Values Between Initial Models (T0), Setup (T1), and Final Models (T2) and Accuracy (Torque Change Obtained/Torque Change Planned) Values

Tooth	T1–T0	SD	T2–T0	SD	T2–T1	SD	Accuracy	SD
U1	10.45**	8.47	8.64**	7.51	−1.81	4.01	0.87**	0.39
U2	7.62**	7.68	6.61*	6.94	−1.00	4.09	0.85**	0.43
U3	8.23**	9.55	8.15**	8.46	−0.08	4.15	0.91**	0.43
U4	3.52	8.29	3.54	6.92	0.13	3.33	0.85**	0.44
U5	1.15	8.26	2.20	5.82	1.12	4.46	0.87**	0.63
U6	−8.34**	6.30	−4.13*	4.88	3.96	4.79	0.60**	0.42
U7	−13.63**	10.52	−6.37	8.78	7.17	6.69	0.52**	0.43
L1	9.49**	13.09	8.70**	12.20	−0.79	4.59	0.90**	0.40
L2	7.90**	6.98	6.62*	6.49	−1.28	3.86	0.89**	0.36
L3	8.40**	6.58	7.83**	5.43	−0.57	2.95	0.91**	0.29
L4	6.11*	10.99	5.06*	10.05	−1.05	3.45	0.86**	0.37
L5	5.66*	9.20	5.37*	7.25	−0.29	4.01	0.92**	0.39
L6	6.57	10.22	5.12*	8.94	−1.45	4.08	0.81**	0.40
L7	13.44**	11.17	9.77*	9.66	−3.68	5.79	0.75**	0.36

* $P \leq .05$.
** $P \leq .01$.

Table 3. Average Differences in Tip Values Between Initial Models (T0), Setup (T1), and Final Models (T2) and Accuracy (Tip Change Obtained/Tip Change Planned) Values

Tooth	T1–T0	SD	T2–T0	SD	T2–T1	SD	Accuracy	SD
U1	0.88*	13.66	0.12*	13.38	−0.76	2.24	0.88**	0.42
U2	−2.76*	7.88	−1.64	7.01	1.12	3.28	0.92**	0.51
U3	−2.14	10.15	−0.97	9.24	1.16	3.22	0.82**	0.45
U4	−3.95*	9.57	−3.14*	7.60	0.81	3.31	0.85**	0.40
U5	−4.80**	6.12	−2.77*	6.07	2.03	3.50	0.94**	0.60
U6	−0.64	7.45	0.18	6.17	0.81	4.37	0.92*	0.62
U7	7.87**	15.43	5.34*	13.52	−2.53	7.60	0.80 **	0.55
L1	0.88*	29.06	0.12*	23.38	−0.76	2.24	0.92**	0.36
L2	5.07**	6.93	3.59*	7.13	−1.48	2.89	0.90*	0.49
L3	5.28	8.07	3.52	6.43	−1.77	3.24	0.84*	0.41
L4	−1.35	6.06	−0.76	5.35	0.59	2.74	0.88**	0.54
L5	−5.10**	7.93	−4.11*	6.92	0.99	4.01	0.87**	0.55
L6	−5.55*	8.20	−4.93*	6.47	0.62	4.30	0.87*	0.57
L7	−10.73**	11.11	−8.68**	9.23	2.05	7.33	0.73**	0.57

* $P \leq .05$.
** $P \leq .01$.

Tip

The tip movement mean accuracy was between 84% and 94% for incisors, canines, premolars, and first molars, whereas the second molars showed slightly lower values (Tables 3 and 4).

Rotations

The rotational movement mean accuracy was between 85% and 93% for incisors, canines, and premolars, while the molars showed values between 57% and 87% (Tables 5 and 6).

Transverse widths

A general increase of transverse widths was measured in the setup (T1–T0; mean values between 1.4 mm and 2.5 mm) and in the final models (T2–T0; mean values between 0.4 mm and 1.4 mm), except for the second molars, which showed reduced intercusp transverse width during treatment. The transverse width mean accuracy was between 70% and 90% for canines, between 46% and 70% for premolars and first molars, and 20% for the mandibular second molars, whereas the maxillary second molars showed negative mean values of accuracy (Tables 7 and 8; Figure 3).

Table 4. Statistical Significance for Tip Value Differences

Tooth	Chi-square	P	P (T1–T0)	P (T2–T0)	P (T2–T1)
U1	12.250	.002	.001	.006	.617
U2	7.333	.026	.02	.176	.176
U3	3.467	.177	-	-	-
U4	6.381	.041	.014	.440	.90
U5	20.857	<.001	<.001	.008	.061
U6	0.261	.878	-	-	-
U7	22.462	<.001	<.001	.006	.052
L1	10.067	.007	.003	.014	.606
L2	14	<.001	<.001	.014	.221
L3	5.226	.073	-	-	-
L4	0.56	.756	-	-	-
L5	16.345	<.001	<.001	.006	.237
L6	13.714	.001	.001	.001	1
L7	34.357	<.001	<.001	<.001	.061

DISCUSSION

In lingual orthodontics, unlike the buccal technique, the setup is a mandatory step due to the anatomic variability of the lingual surfaces among patients. The setup is an important diagnostic and therapeutic tool. Knowledge of the limitations of the appliance used will allow clinicians to plan the treatment objectives to get closer to the ideal result. Previous literature documents that indirect bonding shows high positional accuracy in the mesiodistal, buccolingual, and occlusogingival dimensions; therefore, the movement planned in the setup is completely transferred to the teeth.[15]

The present study analyzed the limitations of the lingual technique, but also aimed to quantify the overcorrections in the setup required for the correction of torque, tip, rotation, and transverse width. The accuracy percentages (amount of movement achieved compared to movement planned) were the average of each accuracy value, expressed as the ratio between achieved (T2–T0) and planned (T1–T0) movement.

The results of this study confirmed the high accuracy rate of the setup and lingual systems, excluding, however, the second molars, which are more difficult to control. In particular, the final torque values approached the setup, for an average percentage greater than 85% of the programmed movements. However, the average accuracy for the molars was between 52% and 81%. These differences were attributable to the fact that the archwire is less rigid in

Table 5. Average Differences in Rotation Values Between Initial Models (T0), Setup (T1), and Final Models (T2) and Accuracy (Rotation Obtained/Rotation Planned) Values

Tooth	T1–T0	SD	T2–T0	SD	T2–T1	SD	Accuracy	SD
U1	−1.26	24.24	0.12	23.79	1.38	3.15	0.91**	0.50
U2	−6.03*	12.44	−3.53	10.82	2.50*	3.84	0.86**	0.36
U3	−4.04	15.03	−3.45	12.99	0.58	5.07	0.88**	0.45
U4	−2.78*	10.39	−2.16	9.18	0.62	3.30	0.90**	0.45
U5	4.26	15.82	5.05	15.13	0.80	3.49	0.89**	0.50
U6	2.88*	7.52	4.33*	5.72	1.45	4.51	0.73**	0.65
U7	−5.95*	8.27	−1.70	6.75	4.24	6.25	0.57**	0.71
L1	−2.42	29.11	−2.50	27.61	−0.08	3.19	0.93**	0.40
L2	3.41	12.20	2.71	10.71	−0.70	4.10	0.89**	0.38
L3	−3.97*	18.63	−1.08	13.71	2.88	15.10	0.92**	0.50
L4	2.51	18.81	4.65	12.16	2.14	13.74	0.91**	0.56
L5	9.95**	15.93	7.12*	10.70	−2.83	14.30	0.85**	0.42
L6	3.40*	6.54	4.14*	5.18	0.74	3.80	0.87**	0.49
L7	−1.47	8.43	−0.05	6.20	1.42	5.40	0.72**	0.67

* $P \leq .05$.
** $P \leq .01$.

the posterior areas. Also, the posterior teeth are subjected to chewing forces and their root structure allows less control.

On the other hand, tip and rotation values denoted the high precision of this system, achieving between 72% and 94%, and 85% and 93%, of planned movement up to the second premolars and between 57% and 87% in the molar region, the latter being influenced by the use of elastic chains during lingual treatment. Grauer and Proffit,[4] despite having analyzed another lingual system on another sample and using different software, obtained similar values to those of the current study, concluding that the discrepancies between setup and final models were minimal, less than 1 mm for linear discrepancies and 4° for rotational discrepancies, except for the second molars, which exhibited greater discrepancies. However, the limitation of Grauer and Proffit's study[4] was that only the discrepancies between the setup and final models were analyzed, while the present study also considered the initial positions of the teeth. In the current study, a percentage of the movement obtained was calculated between the starting situation and the ideal programmed one. Pauls et al. published two similar scientific articles in which the discrepancies between setup and final models were analyzed. In those two studies, two different lingual systems were considered,

Table 6. Statistical Significance for Rotation Value Differences

Tooth	Chi-square	P	P (T1–T0)	P (T2–T0)	P (T2–T1)
U1	1	.607	-	-	-
U2	10.343	.006	.002	.403	.023
U3	1.824	.402	-	-	-
U4	6.067	.048	.014	.156	.302
U5	5.226	.073	-	-	-
U6	9.789	.007	.015	.004	.626
U7	8.4	.015	.004	.343	.058
L1	5.856	.054	-	-	-
L2	0.065	.968	-	-	-
L3	8.909	.012	.003	.065	.268
L4	4.938	.085	-	-	-
L5	16.333	<.001	<.001	.001	.564
L6	7.6	.022	.011	.027	.752
L7	0	1	-	-	-

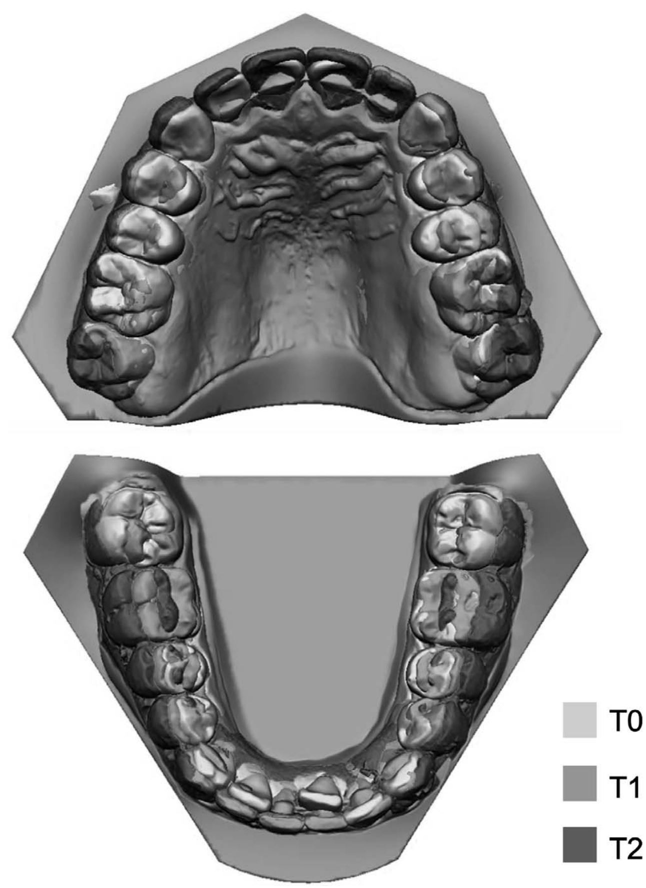

Figure 3. Digital models in a representative case superimposed at T0 (gray), at T1 (red), and at T2 (green).

Table 7. Average Differences in Transverse Width Values Between Initial Models (T0), Setup (T1), and Final Models (T2) and Accuracy (Width Change Obtained/Width Change Planned) Values

Tooth	T1–T0	SD	T2–T0	SD	T2–T1	SD	Accuracy	SD
U3-3	2.23**	2.09	1.26	2.06	−0.97*	0.78	0.70**	0.64
U4-4	2.46**	2.00	1.35*	1.98	−1.11*	1.09	0.70**	1.03
U5-5	2.44**	2.12	1.19*	1.94	−1.25*	1.41	0.46**	0.67
U6-6	2.10**	2.33	0.82	1.68	−1.28**	1.71	0.46**	0.90
U7-7	1.70*	2.96	−0.68	1.95	−2.38**	2.30	−0.12	1.41
L3-3	1.73**	2.24	1.08*	1.98	−0.65*	0.63	0.90**	0.59
L4-4	2.26**	1.90	1.26*	1.72	−1.00**	0.79	0.50**	0.95
L5-5	2.53**	2.46	1.32	1.94	−1.21*	1.30	0.52	0.58
L6-6	1.40*	2.58	0.36	1.64	−1.04*	1.69	0.51**	0.84
L7-7	1.53*	2.81	−0.25	1.72	−1.77**	2.66	0.21	0.90

* $P \leq .05$.
** $P \leq .01$.

both with robotically bent wires. In both studies, although through different methodologies to those reported in the current work, values of high accuracy were obtained, with less than 1 mm in linear discrepancies and 5° for rotations, and slightly greater differences for the second molars (the arch terminal elements).[5,16]

Using the same measurement methods as in the current study, Lombardo et al.[11] presented accuracy values for treatment with aligners. They reported accuracy for mesiodistal tip of 83%, buccal lingual tip of 73%, and rotations of 67%. Despite the differences in the sample, it is possible to highlight a greater accuracy in the movements obtained with a lingual appliance compared to that achieved with aligners. This trend is confirmed by previous literature[1] in which the scientific evidence does not support the use of aligners as a treatment alternative with the same effectiveness as fixed appliances.

As previously reported by Ata-Ali et al.,[3] it may be concluded that predictable results, comparable to those shown for the lingual appliance in the current study, can be obtained using a buccal fixed orthodontic appliance. However, due to the lack of scientific data and the limited use of setups in buccal therapy, comparative analyses cannot be performed using the percent accuracy formula used in this study.

Table 8. Statistical Significance for Transverse Width Differences

Teeth	Chi-square	*P*	*P* (T1–T0)	*P* (T2–T0)	*P* (T2–T1)
U3	32.882	<.001	<.001	.064	.002
U4	37.161	<.001	<.001	.007	.007
U5	31.688	<.001	<.001	.008	.026
U6	24.938	<.001	<.001	.401	.002
U7	15.217	<.001	.003	.461	<.001
L3	23.529	<.001	<.001	.046	.046
L4	45.588	<.001	<.001	.033	<.001
L5	29.556	<.001	<.001	.055	.007
L6	9.941	.007	.016	.903	.008
L7	17.312	<.001	.003	.532	<.001

Regarding transverse expansion with the lingual appliance, it was shown in the current study that a programmed increase in transverse width was only partially realized. The accuracy of transverse expansion decreased in the terminal elements. Negative mean accuracy values suggested that the maxillary second molars actually moved in the opposite direction compared to the programmed movement in the setup. This was probably due to several factors: negative torque prescription, transverse bowing effect increased by the use of elastic chains, and effect of chewing forces on the posterior elements. Grauer and Proffit's study[4] was in agreement with these results; they concluded that the planned expansion programmed in the setup did not fully occur. For transverse expansion in aligner therapy, there are no scientific studies describing the percentage of accuracy. However, it has been shown that transverse bodily expansion with aligners is not predictable and overestimated in the setup, often resulting in coronal tipping movement.[1,3,12] An analogous situation occurs with the use of the buccal appliance in which expansion of the interarch widths is obtained through the use of wide arches. With buccal appliances, there is also a component of buccal inclination of the posterior elements.[10,13] For all these reasons, in a case that requires transverse expansion of the arches, planning a preliminary expansion phase or overcorrection of the transverse dimension in the finishing archwires is recommended.

A limitation of this study was the absence of a control group. In a previous study, a control group with similar characteristics showed no changes in transverse and torque measures. For this reason, it was assumed that the lack of a control group would not influence the interpretation of results.

CONCLUSIONS

This study measured the accuracy of the planned tooth movements of torque, tip, rotation, and transverse width values with a lingual straight wire system.

Comparison between the setup and final result allowed analysis of the differences between planned and achieved movements relative to the initial tooth positions:

- The movements planned to obtain ideal torque, tip, and rotations that actually occurred, demonstrating a high accuracy rate of the lingual system.
- The most posterior teeth (the second molars) showed less accuracy of achieved vs planned movements than the other dental elements.
- Expansion of the arches programmed in the setup occurred only partially as assessed in the final models, with greater accuracy for canines and premolars and less accuracy for the posterior elements. Therefore, when expansion is necessary, a separate expansion phase prior to lingual fixed therapy, or an overcorrection of the transverse dimensions of the archwires, is required.

REFERENCES

1. Papageorgiou SN, Koletsi D, Iliadi A, Peltomaki T, Eliades T. Treatment outcome with orthodontic aligners and fixed appliances: a systematic review with meta-analyses. *Eur J Orthod*. 2020;42(3):331–343.
2. Takemoto K, Scuzzo G. The straight-wire concept in lingual orthodontics. *J Clin Orthod*. 2001;35(1):46–52.
3. Ata-Ali F, Plasencia E, Lanuza-Garcia A, Ferrer-Molina M, Melo M, Ata-Ali J. Effectiveness of lingual versus labial fixed appliances in adults according to the Peer Assessment Rating index. *Am J Orthod Dentofacial Orthop*. 2019;155(6): 819–825.
4. Grauer D, Proffit WR. Accuracy in tooth positioning with a fully customized lingual orthodontic appliance. *Am J Orthod Dentofacial Orthop*. 2011;140(3):433–443.
5. Pauls A, Nienkemper M, Schwestka-Polly R, Wiechmann D. Therapeutic accuracy of the completely customized lingual appliance WIN: a retrospective cohort study. *J Orofac Orthop*. 2017;78(1):52–61.
6. Huanca Ghislanzoni LT, Lineberger M, Cevidanes LH, Mapelli A, Sforza C, McNamara JA Jr. Evaluation of tip and torque on virtual study models: a validation study. *Prog Orthod*. 2013;14:19.
7. Komori A, Fujisawa M, Iguchi S. KommonBase for precise direct bonding of lingual orthodontic brackets. *Int Orthod*. 2010;8(1):14–27.
8. Lombardo L, Arreghini A, Huanca Ghislanzoni LT, Siciliani G. Does low-frequency vibration have an effect on aligner treatment? A single-centre, randomized controlled trial [published correction appears in *Eur J Orthod*. 2019;41(4): 444]. *Eur J Orthod*. 2019;41(4):434–443.
9. Mucedero M, Rozzi M, Milazzo A, Cozza P. Morphometric analysis of the palatal shape and arch dimension in subjects with palatally displaced canine. *Eur J Orthod*. 2019;41(5): 460–467.
10. Lucchese A, Manuelli M, Albertini P, Ghislanzoni LH. Transverse and torque dental changes after passive self-ligating fixed therapy: a two-year follow-up study. *Am J Orthod Dentofacial Orthop*. 2019;156(1):94–103.
11. Lombardo L, Arreghini A, Ramina F, Huanca Ghislanzoni LT, Siciliani G. Predictability of orthodontic movement with orthodontic aligners: a retrospective study. *Prog Orthod*. 2017;18(1):35.
12. Houle JP, Piedade L, Todescan R Jr, Pinheiro FH. The predictability of transverse changes with Invisalign. *Angle Orthod*. 2017;87(1):19–24.
13. Lineberger MB, Franchi L, Cevidanes LH, Huanca Ghislanzoni LT, McNamara JA Jr. Three-dimensional digital cast analysis of the effects produced by a passive self-ligating system. *Eur J Orthod*. 2016;38(6):609–614.
14. Andrews LF. The six keys to normal occlusion. *Am J Orthod*. 1972;62(3):296–309.
15. Bachour PC, Klabunde R, Grünheid T. Transfer accuracy of 3D-printed trays for indirect bonding of orthodontic brackets. *Angle Orthod*. 2022;92(3):372–379.
16. Pauls AH. Therapeutic accuracy of individualized brackets in lingual orthodontics. *J Orofac Orthop*. 2010;71(5):348–361.