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Clinical effects of different prescriptions on the inclination of maxillary and mandibular incisors by using passive self-ligating brackets

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Objective: Controlling the incisal inclination is fundamental in orthodontics. However, the relationship between the inclination prescription and its clinical outcome is not obvious, and the incisal inclination changes generated by different bracket prescriptions were investigated. **Methods:** Twenty-eight non-extraction dental Class II patients (15 females, 13 males; mean age = 12.9) were retrospectively analyzed. Patients were treated using passive self-ligating fixed appliances with three inclination prescriptions for maxillary incisors (*high*, *standard*, *low*), and two for mandibular incisors (*standard, low*). Clinical outcomes were compared among different prescriptions, and regression analysis was used to explain the effects of bracket prescriptions and to understand the prescription selection criteria ($\alpha = 0.05$). **Results:** For maxillary central incisors, *low* and *high* prescriptions were related to linguoversion ($p = 0.046$) and labioversion ($p = 0.005$), respectively, while *standard* prescription maintained the initial dental inclination. Maxillary lateral incisors did not show significant changes. For mandibular incisors, *low* prescription led to linguoversion ($p = 0.005$ for central incisors, $p = 0.010$ for lateral incisors), while *standard* prescription led to labioversion ($p = 0.045$ for central incisors, $p = 0.005$ for lateral incisors). The factors affecting inclination changes were the imposed change and selected prescription, while prescription selection was influenced by the initial dental inclination and initial intercanine distance. **Conclusions:** The direction of correction of incisal inclination can be controlled by choosing a certain prescription, but the final inclination may show limited consistency with it. The amount of imposed inclination change was the most relevant predictor of the clinical outcome.

Key words: Digital models, Tooth movement, Incisor, Orthodontic brackets

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INTRODUCTION

Proper planning of the incisal position is important to achieve optimal esthetics and function[1] and clinicians should plan the incisal position based on the individual characteristics of patients, including their periodontal biotype[2] and malocclusion.[3,4] The importance of considering the incisal inclination from the treatment planning was first described by Tweed,[5] and ideal incisal inclinations were proposed by Andrews[6] for the straight-wire appliance with preadjusted brackets.[7] Subsequently, various inclination prescriptions have been suggested for incisors by Roth,[8] Alexander,[9] McLaughlin - Bennet - Trevisi (MBT),[10] Ricketts,[11] and others. Nevertheless, a single prescription may not fulfill the esthetic requirements of different patients[7] and specific treatment biomechanics may influence the choice of the inclination prescription. For this reason, Damon brackets include multiple standardized inclination prescriptions for maxillary (*high*, *standard*, *low*) and mandibular incisors (*standard*, *low*).[12,13] Despite the importance of choosing an appropriate bracket prescription in straight-wire appliance system,[14] the clinically achieved incisal inclination is often inconsistent with such prescriptions.[15] Force application far from the center of resistance,[14] wire-play,[16] and the mechanical properties of materials[17] may also influence the final dental inclination. Some studies investigated the clinical outcomes of the bracket prescription by measuring the root inclination with respect to the occlusal plane on cone-beam computed tomography (CBCT).[18] Others measured the inclination of the long axis of the tooth with respect to facial planes on cephalometric radiographs.[19] However, the method used to measure the angular information of the slot and the incisal inclination should be consistent to achieve a meaningful comparison.[20] In particular, incisal inclination ("torque") should be measured on dental models as the angle formed by the line perpendicular to the occlusal plane and the line that is tangent to the bracket site.[6] Furthermore, to the best of our knowledge, the clinical outcomes related to the use of passive self-ligating brackets with different prescriptions have not been previously reported in the published literature.

Objectives

The changes in incisal inclination generated by the use of a certain bracket may significantly differ from the angular information of the bracket slot and the primary aim of the present study was to assess the effects of different inclination prescriptions for central and lateral incisors on the final dental inclination of these elements.

MATERIALS AND METHODS

Participants and treatment

The sample size was based on the minimum requirement of 25 patients for performing a linear regression analysis.[21] Given the retrospective nature of the study, 28 adolescents (15 females and 13 males; mean age, 12.9 ± 1.3 years) consecutively treated at the Dental School of the University of Brescia (Brescia, Italy) were included. Patients with facial asymmetries, syndromes, a history of orthognathic or orthodontic treatment, and impacted or missing teeth were excluded. Only non-extraction cases, with dental Class II, skeletal Class II tendency (mean ANB angle = 3.8° ± 1.3°; range, 2.1°–6.6°), and mild crowding were included. All patients were treated by the same orthodontist (G.M., with ten years of experience in performing the adopted technique[22]). A fixed multi-bracket appliance with passive self-ligating (Damon©Q; Ormco, Glendora, CA, USA) preadjusted (0.022" × 0.028" slot) brackets was used. Incisal inclination prescriptions were *high* (+22°, n = 7, mean crowding = 1 mm), *standard* (+15°, n = 17, mean crowding = 0 mm), and *low* (+2°, n = 4, mean crowding = 2 mm) for maxillary central incisors; *high* (+13°, n = 4, mean crowding = 0 mm), *standard* (+6°, n = 16, mean crowding = 0 mm), and *low* (−5°, n = 8, mean crowding = 1 mm) for maxillary lateral incisors; *standard* (−3°, n = 14, mean crowding = 0 mm) and *low* (−11°, n = 14, mean crowding = 0 mm) for mandibular central incisors; and *standard* (−3°, n = 15, mean crowding = 1 mm) and *low* (−11°, n = 13, mean crowding = 1 mm) for mandibular lateral incisors. Archwires (Damon©; Ormco) were sequentially used: 0.014" copper-nickel-titanium (CuNiTi) during initial alignment (about 6 to 8 months, with light Class II elastics); 0.014" × 0.025" CuNiTi and 0.018" × 0.025" CuNiTi during final alignment and dental arch development (about 6 to 8 months, with medium Class II elastics); 0.019" × 0.025" titanium molybdenum alloy (TMA), 0.016" × 0.025" stainless steel (SS), and 0.016" SS or 0.018" SS during final refinement and occlusal settling (about 4 to 6 months, with heavy Class II elastics); and finishing, which included esthetic bends mainly in the upper anterior segment, with 0.019" × 0.025" SS or 0.019" × 0.025" TMA (about 4 to 6 months). The mean treatment duration was 23.9 ± 3.9 months. The study was approved by the Ethics Committee of the University of Brescia (registration number: NP3899 of clinical study ISW01).

Data acquisition

Pre- and post-treatment maxillary and mandibular digital casts were analyzed with VAM (Vectra Analysis Module) software (Vectra©; Canfield Scientific, Parsippany, NJ, USA) according to the method described by

Huanca Ghislanzoni et al.[20] (Figure 1). Teeth from incisors to second molars were included, and five points were recorded for each tooth. The most mesial and most distal points of the occlusal surface were identified. The facial axis of the crown (FACC) was determined,[6] and the gingival limit of the buccal FACC, the occlusal limit of the buccal FACC, and the gingival limit of the lingual FACC were identified. Points were digitalized using space coordinates (x, y, z), and a reference plane was established as the best-fit plane among all lingual points. The coordinates were converted to the new reference system, and linear distances and angles were calculated by using custom-made trigonometric macros (Microsoft Excel©; Microsoft, Redmond, WA, USA). A 90° angle with respect to the occlusal plane was used as the null value (0°), considering labial inclinations positive and lingual inclinations negative. The dental crowding, intercanine distance, and intermolar distance between first molars were calculated at the beginning and end of treatment. The same evaluator repeated the entire process (from the identification of points to all measurements) on 10 models after a wash-out period of approximately one month.

Statistical analysis

The intra-assessor agreement was calculated with the intraclass correlation coefficient,[23] which was excellent (> 0.8) for all measurements. The controlled variable was the selected inclination prescription (*Tsel*), while the outcome variables were the initial dental inclination (*Tin*), the final dental inclination (*Tfin*), the obtained inclination change (ΔT), the differential inclination applied (*Tsel-Tin*), and the differential inclination obtained (*Tsel-Tfin*). The Shapiro–Wilk test showed that data were not normally distributed. Paired-sample Wilcoxon test was used to assess changes between pre- and post-treatment. Mann–Whitney *U* test was used to compare *low* and *standard* inclination prescription of the mandibular incisors. Kruskal–Wallis one-way analysis of variance (with the Mann–Whitney *U* test as the *post-hoc* test and adjusted significance α = 0.05/3 = 0.017) was used to compare *low*, *standard*, and *high* inclination prescription of the maxillary incisors.

A multiple linear regression model was developed with ΔT as the outcome variable (investigating the factors contributing to the final inclination change), and another one was developed with *Tsel* as the outcome variable (investigating the factors affecting the prescription choice). Predictors for the first model included *Tsel*, *Tsel-Tin*, intercanine distance change, and intermolar distance change. Predictors for the second model were *Tin*, initial dental crowding, initial intercanine distance, and initial intermolar distance. Data analysis was carried out with statistical software (SPSS© ver. 22; IBM, Armonk, NY, USA) at significance level α = 0.05, and the threshold for clinical relevance was > 1 mm or > 1º.

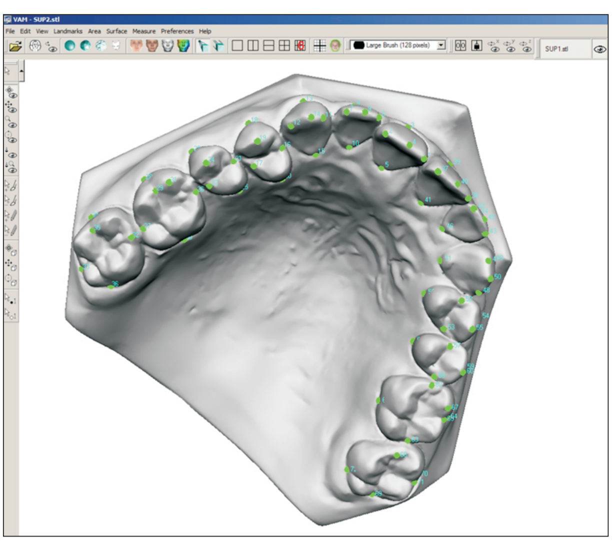

Figure 1. Example of maxillary digital cast analysis, where incisors to second molars were included, and five points were recorded for each tooth (points are highlighted in green).

RESULTS

Changes in maxillary incisor inclination

For central incisors, when *low* prescription was used (+2°, intended to incline them lingually), the correction was followed by the teeth (p = 0.046). When *standard* prescription was used (+15°, intended to incline them labially), the initial dental inclination was maintained. When *high* prescription was used (+22°, intended to incline them labially), the correction was followed by the teeth (p = 0.005).

For lateral incisors, when both *low* prescription (–5°, intended to incline them lingually) and *standard* (+6°) or *high* (+13°) prescription (intended to incline them labially) were used, the initial inclination was maintained (Figures 2 and 3, Table 1).

Changes in mandibular incisor inclination

For central incisors, when the *low* prescription was used (–11°, intended to incline them lingually), the correction was followed by the teeth (p = 0.005). When the *standard* prescription was used (–3°, intended to incline the teeth lingually), incisors inclined labially instead (p = 0.045).

For lateral incisors, when the *low* prescription was used (–11°, intended to incline them lingually), the correction was followed by the teeth (p = 0.010). When the *standard* prescription was used (–3°, intended to incline

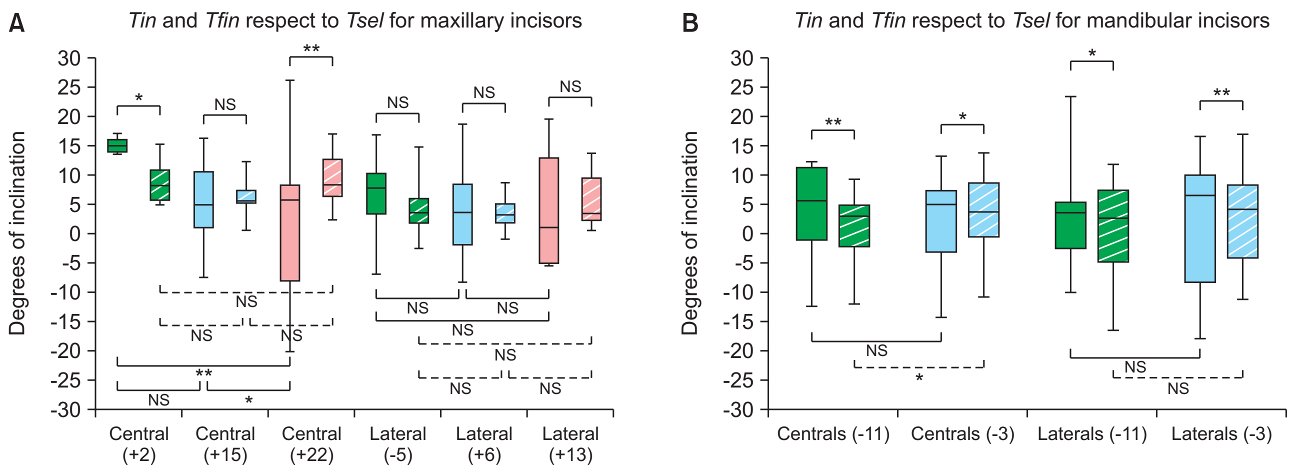

Figure 2. Comparison between initial inclination (*Tin*, full box) and final inclination (*Tfin*, striped box) of maxillary (**A**) and mandibular (**B**) incisors in relation to the inclination prescription.
Tsel, selected inclination prescription; NS, not significant.
$^{*}p < 0.05$; $^{**}p < 0.01$.

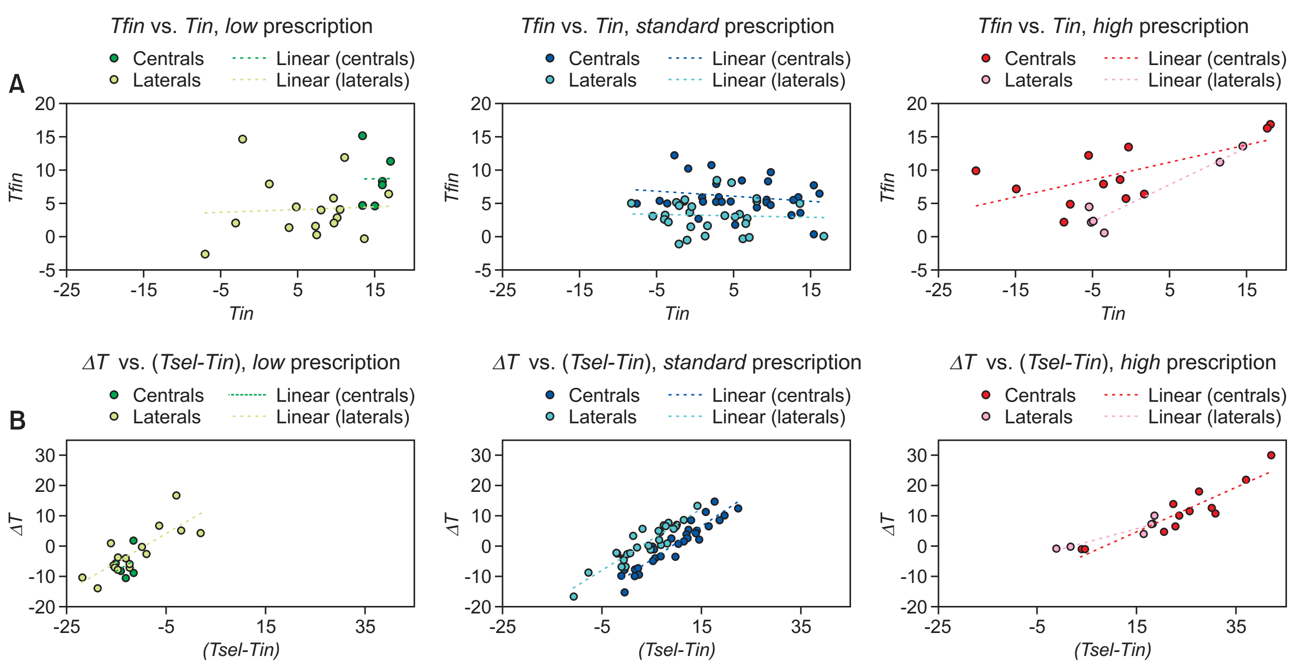

Figure 3. *Low* (green), *standard* (blue), and *high* (red) inclination prescriptions for maxillary incisors. Correlation between the final inclination (*Tfin*) and initial inclination (*Tin*) (**A**). Correlation between the change in inclination (Δ*T*) and differential inclination applied (*Tsel-Tin*) (**B**).
Tsel, selected inclination prescription.

them lingually), they inclined labially instead ($p = 0.005$) (Figures 2 and 4, Table 2).

Comparisons among different inclination prescriptions for maxillary incisors

For central incisors, the applied differential inclination was different between *low* and *standard* ($p < 0.001$), *low* and *high* ($p = 0.001$), and *standard* and *high* ($p < 0.001$) prescriptions. Similarly, the obtained differential inclination was different between the *low* and *standard* ($p < 0.001$), *low* and *high* ($p = 0.001$), and *standard* and *high* ($p = 0.011$) prescriptions. However, the final inclination was similar among different prescriptions.

For lateral incisors, the applied differential inclination

Table 1. Changes of maxillary incisors inclination relative to different prescriptions

Tsel (°)		*Tin* (°)	*Tfin* (°)	*ΔT* (°)	*p*-value‡	*Tsel-Tin* (°)	*Tsel-Tfin* (°)	*ΔT*/(*Tsel-Tin*) (%)
Maxillary central incisors								
Comparisons between pre- and post-treatment								
All	Mean	5.0	7.2	2.2	0.177	10.1	7.9	22
	SD	9.1	3.5	9.4		13.1	6.6	
	CI lower bound	2.5	6.2	–0.4		6.5	6.1	
	CI upper bound	7.5	8.2	4.8		13.8	9.8	
+2 (*low*), N = 4	Mean	15.1	8.8	–6.4	0.046*	–13.1	–6.8	49
	SD	1.4	4.0	4.3		1.4	4.0	
	CI lower bound	14.0	5.5	–9.8		–14.3	–10.0	
	CI upper bound	16.3	12.0	–3.0		–12.0	–3.5	
+15 (*standard*), N = 17	Mean	5.8	6.1	0.3	0.866	9.2	8.9	3
	SD	6.6	2.5	7.5		6.6	2.5	
	CI lower bound	3.5	5.2	–2.3		6.9	8.1	
	CI upper bound	8.1	6.9	2.9		11.5	9.8	
+22 (*high*), N = 7	Mean	–2.2	9.3	11.6	0.005**	24.2	12.7	48
	SD	11.2	4.6	9.0		11.2	4.6	
	CI lower bound	–8.6	6.7	6.5		17.9	10.1	
	CI upper bound	4.1	11.9	16.7		30.6	15.3	
Comparison among prescriptions								
+2 vs. +15	*p*-value§	0.002††	0.229	0.029		< 0.001†††	< 0.001†††	
+2 vs. +22	*p*-value§	0.025	0.639	0.001††		0.001††	0.001††	
+15 vs. +22	*p*-value§	0.009†	0.020	0.001††		< 0.001†††	0.011†	
Maxillary lateral incisors								
Comparisons between pre- and post-treatment								
All	Mean	3.4	3.8	0.4	0.612	–0.1	–0.5	–540
	SD	6.6	3.6	6.8		10.4	7.1	
	CI lower bound	1.6	2.8	–1.5		–3.0	–2.5	
	CI upper bound	5.2	4.8	2.3		2.8	1.5	
–5 (*low*), N = 8	Mean	6.4	4.2	–2.1	0.163	–11.4	–9.2	19
	SD	6.4	4.5	7.6		6.4	4.5	
	CI lower bound	3.2	2.1	–5.8		–14.5	–11.4	
	CI upper bound	9.5	6.4	1.6		–8.2	–7.1	

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Table 1. Continued

Tsel (°)		*Tin* (°)	*Tfin* (°)	*ΔT* (°)	*p*-value‡	*Tsel-Tin* (°)	*Tsel-Tfin* (°)	*ΔT*/(*Tsel-Tin*) (%)
+6 (*standard*), N = 16	Mean	2.2	3.2	1.0	0.316	3.8	2.8	26
	SD	5.8	2.5	6.4		5.8	2.5	
	CI lower bound	0.1	2.3	–1.4		1.7	1.9	
	CI upper bound	4.3	4.1	3.4		5.9	3.7	
+13 (*high*), N = 4	Mean	1.1	5.7	4.7	0.116	11.9	7.3	39
	SD	9.2	5.4	4.4		9.2	5.4	
	CI lower bound	–6.3	1.4	1.2		4.6	3.0	
	CI upper bound	8.4	10.0	8.1		19.3	11.6	
Comparison among prescriptions								
–5 vs. +6	*p*-value§	0.019	0.678	0.055		< 0.001††	< 0.001†††	
–5 vs. +13	*p*-value§	0.269	0.555	0.030		0.001††	< 0.001†††	
+6 vs. +13	*p*-value§	0.343	0.484	0.130		0.052	0.071	

Comparisons between pre- and post-treatment, and multiple comparisons among inclination prescriptions (*high*, *standard*, and *low*), relative to initial inclination (*Tin*), final inclination (*Tfin*), change in inclination (*ΔT*), differential inclination applied (*Tsel-Tin*), and differential inclination obtained (*Tsel-Tfin*).

Tsel, selected inclination prescription; N, number of patients; SD, standard deviation; CI, confidence interval.

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

†$p < 0.05/3$; ††$p < 0.01/3$; †††$p < 0.001/3$.

‡Wilcoxon signed-rank test.

§Kruskal–Wallis one-way ANOVA (*post hoc*: Mann–Whitney *U* test, adjusted significance at $\alpha = 0.017$).

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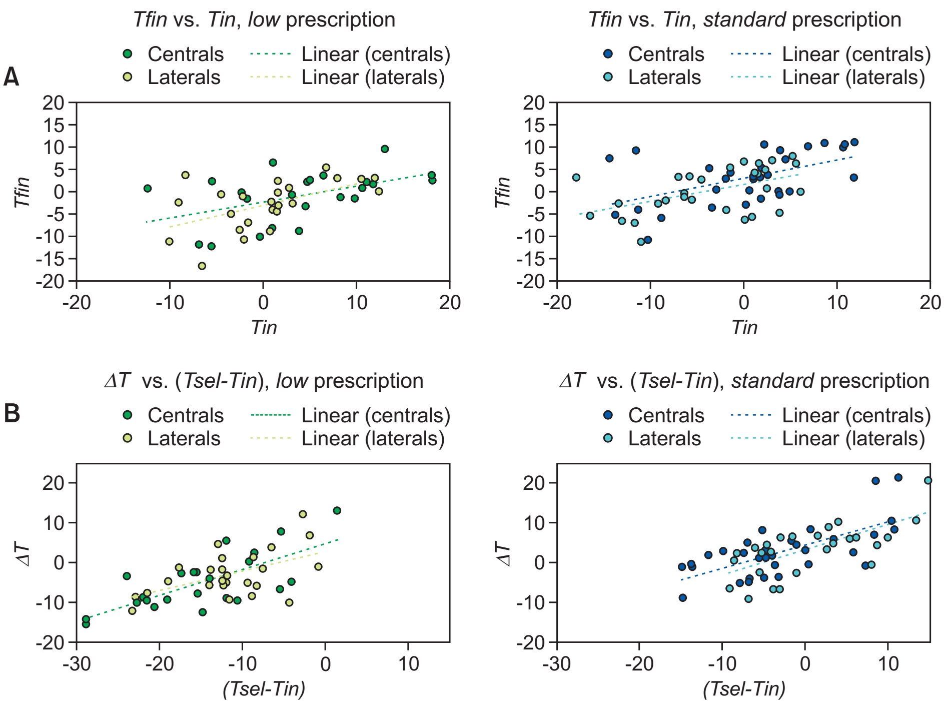

Figure 4. *Low* (green) and *standard* (blue) inclination prescriptions for mandibular incisors. Correlation between the final inclination (*Tfin*) and initial inclination (*Tin*) (**A**). Correlation between the change in inclination (*ΔT*) and differential inclination applied (*Tsel-Tin*) (**B**).
Tsel, selected inclination prescription.

was different only between the *low* and *standard* ($p < 0.001$) and *low* and *high* ($p = 0.001$) prescriptions. Similarly, the obtained differential inclination was different between the *low* and *standard* ($p < 0.001$) and *low* and *high* ($p < 0.001$) prescriptions. However, the final inclination was similar among different prescriptions (Figure 2, Table 1).

Comparison between different inclination prescriptions for mandibular incisors

For central incisors, the differences were present between *low* and *standard* prescriptions for each parameter except for the initial incisal inclination.

For lateral incisors, differences were present between *low* and *standard* prescription for each parameter except for the initial and the final incisal inclinations (Figure 2, Table 2).

Model showing the factors related to the clinical inclination change (Δ*T*)

For maxillary incisors, the model for central incisors showed that an increase in the applied differential inclination ($\beta = 1.255$, $p < 0.001$) was related to increased ΔT, while an increase in the selected inclination prescription ($\beta = -0.476$, $p < 0.001$) or intermolar distance ($\beta = -0.203$, $p < 0.001$) was related to reduced ΔT. The model for lateral incisors showed similar results, in addition to the fact that the change in the intercanine distance was relevant ($\beta = -0.180$, $p = 0.022$), rather than the intermolar distance.

For mandibular incisors, the model showed that an increase in the applied differential inclination was related to increased ΔT for both central ($\beta = 0.767$, $p < 0.001$) and lateral ($\beta = 0.735$, $p < 0.001$) incisors (Table 3).

Model showing the factors related to the selection of the inclination prescription (*Tsel*)

For maxillary incisors, the model for central incisors showed that the higher the initial inclination ($\beta = -0.484$, $p < 0.001$) and the greater the initial intercanine distance ($\beta = -0.247$, $p = 0.047$), the lower was the *Tsel*. The model for lateral incisors showed similar findings for the relevance of the initial intercanine distance ($\beta = -0.409$, $p = 0.028$), but the initial inclination was not significant.

For mandibular incisors, the model for central incisors showed that only the initial inclination was relevant ($\beta = -0.292$, $p = 0.036$). The model for lateral incisors showed that both the initial inclination ($\beta = -0.361$, $p = 0.007$) and the intercanine distance ($\beta = 0.290$, $p = 0.028$) influenced the *Tsel* (Table 3).

DISCUSSION

The choice of inclination prescription is based either on the intention to change the initial incisal inclination or to counteract its undesirable change.[19] If the initial labio-lingual incisal position is appropriate, but the inclination is not, a force couple to selectively change the inclination is required. Conversely, if the initial inclination is correct, but the labio-lingual position is not, a force couple is required to counteract undesirable in-

Table 2. Changes in mandibular incisor inclination relative to different prescriptions

Tsel (°)		*Tin* (°)	*Tfin* (°)	*ΔT* (°)	*p*-value[†]	*Tsel-Tin* (°)	*Tsel-Tfin* (°)	*ΔT*/(*Tsel-Tin*) (%)
Mandibular central incisors								
Comparisons between pre- and post-treatment								
All	Mean	2.0	1.4	–0.6	0.335	–8.4	–7.8	7
	SD	7.7	6.0	7.7		9.5	6.0	
	CI lower bound	–0.1	–0.2	–2.7		–10.9	–9.4	
	CI upper bound	4.1	3.0	1.5		–5.9	–6.2	
–3 (*standard*), N = 14	Mean	0.4	3.0	2.6	0.045*	–3.4	–6.0	–77
	SD	7.3	5.7	6.5		7.3	5.7	
	CI lower bound	–2.2	1.0	0.4		–6.0	–8.1	
	CI upper bound	3.0	5.1	4.9		–0.8	–4.0	
–11 (*low*), N = 14	Mean	4.1	–0.8	–5.0	0.005**	–15.1	–10.2	33
	SD	7.9	5.7	7.2		7.9	5.7	
	CI lower bound	0.9	–3.2	–7.9		–18.3	–12.5	
	CI upper bound	7.3	1.5	–2.0		–11.9	–7.8	
Comparison among prescriptions								
–3 vs. –11	*p*-value[‡]	0.115	0.018*	< 0.001***		< 0.001***	0.018*	
Mandibular lateral incisors								
Comparisons between pre- and post-treatment								
All	Mean	–1.7	–1.0	0.6	0.611	–5.1	–5.7	–12
	SD	6.8	5.5	6.8		8.9	6.0	
	CI lower bound	–3.5	–2.5	–1.2		–7.4	–7.3	
	CI upper bound	0.2	0.4	2.4		–2.7	–4.1	
–3 (*standard*), N =15	Mean	–3.6	0.1	3.7	0.005**	0.6	–3.1	602
	SD	6.9	5.1	6.2		6.9	5.1	
	CI lower bound	–6.1	–1.8	1.4		–1.9	–5.0	
	CI upper bound	–1.1	2.0	6.0		3.1	–1.2	
–11 (*low*), N = 13	Mean	0.6	–2.3	–2.9	0.010*	–11.6	–8.7	25
	SD	6.0	5.7	5.7		6.0	5.7	
	CI lower bound	–1.8	–4.5	–5.2		–14.0	–10.9	
	CI upper bound	3.0	–0.1	–0.7		–9.2	–6.5	
Comparison among prescriptions								
–3 vs. –11	*p*-value[‡]	0.068	0.136	< 0.001***		< 0.001***	0.001**	

Comparisons between pre- and post-treatment measurements, and between inclination prescriptions (*standard* and *low*) in relation to initial inclination (*Tin*), final inclination (*Tfin*), change in inclination (*ΔT*), differential inclination applied (*Tsel-Tin*), and differential inclination obtained (*Tsel-Tfin*).
Tsel, selected inclination prescription; N, number of patients; SD, standard deviation; CI, confidence interval.
**p* < 0.05; ***p* < 0.01; ****p* < 0.001.
[†]Wilcoxon signed-rank test.
[‡]Mann–Whitney *U* test.

Table 3. Regression models showing factors related to inclination changes and prescription selection

Outcome	Model statistics		Predictors							
	R^2	*p*-value	*Tsel-Tin*		*Tsel*		*Δ ICD*		*Δ IMD*	
			β	*p*-value	β	*p*-value	β	*p*-value	β	*p*-value
ΔT										
Maxillary central incisors	0.896	< 0.001***	1.255	< 0.001***	–0.476	< 0.001***	na	ns	–0.203	< 0.001***
Maxillary lateral incisors	0.746	< 0.001***	1.243	< 0.001***	–0.649	< 0.001***	–0.180	0.022*	na	ns
Mandibular central incisors	0.611	< 0.001***	0.767	< 0.001***	na	ns	na	ns	na	ns
Mandibular lateral incisors	0.531	< 0.001***	0.735	< 0.001***	na	ns	na	ns	na	ns
	Model statistics		**Predictors**							
	R^2	*p*-value	*Tin*		*ICDin*		*IMDin*		*DCin*	
			β	*p*-value	β	*p*-value	β	*p*-value	β	*p*-value
Tsel										
Maxillary central incisors	0.334	< 0.001***	–0.484	< 0.001***	–0.247	0.047*	na	ns	na	ns
Maxillary lateral incisors	0.135	0.021*	na	ns	–0.409	0.028*	na	ns	na	ns
Mandibular central incisors	0.111	0.050*	–0.292	0.036*	na	ns	na	ns	na	ns
Mandibular lateral incisors	0.181	0.006**	–0.361	0.007**	0.290	0.028*	na	ns	na	ns

The first model was used to investigate which variable was responsible for the change in inclination (*ΔT*), and the second model was used to understand which variable better explained the selection of inclination prescription (*Tsel*).
Δ, pre-post treatment difference; R^2, adjusted coefficient of determination; β, standardized coefficient beta; ICD, intercanine distance; IMD, intermolar distance between the first molars; in, initial; DC, dental crowding; na, not applicable; ns, not significant; *Tsel*, selected inclination prescription; *Tin*, initial dental inclination; *Tsel-Tin*, differential inclination applied.
$^*p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

clination changes during tooth translation. Lastly, both incisal inclination and labio-lingual position may require correction, which is a complex scenario involving multiple approaches based on the concordance/discordance between the direction of the angular and translational corrections. In addition, the prescription choice is also affected by the wire-play[16] that needs to be added/subtracted according to the direction of the planned movement.[14] Mechanical considerations related to variable forces exerted by different wires[17] and biological variables such as craniofacial type[7] add further complexity to the choice of the bracket prescription. Thus, prescription selection is a clinical decision based on a combined evaluation of these factors, and assessing its appropriateness was beyond the scope of this study.[11]

For discussion purposes, in the present work, the initial dental inclination was defined as "lingual" or "labial" based on a reference of +7° for central maxillary incisors, +4° for lateral maxillary incisors, and –6° for central and lateral mandibular incisors.[7] The present findings showed that inclination prescription was higher when the initial tooth inclination was low. In particular, for maxillary central incisors, the *low* prescription was chosen for the most labially inclined teeth (about +15°); the *standard* prescription for teeth with normal inclination (about +6°); and the *high* prescription for the most lingually inclined teeth (about –2°). Accordingly, the initial inclination was the most relevant parameter for the choice of the bracket inclination prescription for all teeth except for the maxillary lateral incisors. This may be justified by the fact that although clinical assessments can easily identify the initial inclination of central incisors, lateral incisors are more challenging since they are not clearly visible on lateral cephalograms.[16] The second most significant predictor for the selection of the inclination prescription was the initial intercanine distance, since the transverse dental arch development is arguably one of the most important parameters to be considered for proper incisal positioning.[24] In fact, if intercanine distance was small, *low* prescription was used for mandibular incisors (for reducing incisal proclination) while *high* prescription was applied for maxillary incisors (for achieving adequate interincisal relationship), since proclination of the lower incisors is a common consequence during tooth alignment even in cases with an increased intercanine distance.[25]

Interestingly, the final inclination of the maxillary central incisors was similar among different inclination prescriptions. In fact, all upper central incisors converged toward an ideal inclination of +7° (ranging between +6° and +9°), despite the marked initial discrepancies (ranging between –2° and +15°). Notably, for maxillary

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central incisors, the *standard* prescription (+15°) was used despite an almost ideal initial inclination of +7°, so that the lingual inclination caused by Class II elastics could be counteracted. Maxillary lateral incisors also converged toward their respective optimal inclination of +4°, and eventually showed a similar inclination at the end of treatment (ranging between +3° and +5°). These findings show that in the context of passive self-ligating brackets with an estimated wire-play of approximately ±7° between a 0.019" × 0.025" finishing wire and a 0.022" slot,[26] patients with similar types of malocclusions may need specific inclination prescriptions based on the initial dental inclination, even when the final position to be achieved is the same. However, in both cases, *high* prescription led to overcorrection, providing reasons to limit its use only for teeth with severe lingual inclination.

Conversely, mandibular central incisors showed different final inclinations based on the inclination prescription adopted. In particular, the *low* prescription limited incisal proclination, but the *standard* prescription did not, as reported by previous authors.[18] In fact, the initially proclined mandibular incisors, which received the *low* prescription, showed partial correction of proclination. However, mandibular incisors that were not severely proclined at the beginning of treatment, which received *standard* prescription, were excessively proclined after treatment. Thus, *low* rather than *standard* prescription should be considered if proclination of the mandibular incisors should be limited.[18]

Although the inclination value of the slot is seldomly achieved by the incisors,[15] the prescription selection had a predictable influence on the direction of the correction (lingual vs. labial). In general, there was an agreement on the differential inclination imposed, which should reflect the rationale for selection of the bracket prescription,[19] and the inclination change achieved. On the other hand, a simple comparison of the difference between pre- and post-treatment inclinations may have limited clinical relevance,[19] since it overlooks the nature of the couple applied to the tooth. The present findings stress the importance of assessment of incisal inclination on dental models - rather than using lateral cephalometry or CBCT imaging[19] - since the discrepancy between the slot and tooth inclination (which determines the moment of the force) can be estimated only by using the same occlusal reference for both parameters. Moreover, it was not obvious that compared to *standard*, *low* prescription for mandibular incisors led to lower final inclinations. In fact, the minimum amount of differential inclination that should be applied to generate a clinically significant effect is debatable, since the difference between Roth and MBT incisal prescriptions was reported to be irrelevant.[27] Nevertheless, the consistency between the amount of imposed inclination and the amount of clinical change is a more complex topic. For example, for maxillary central incisors, the consistency was minimal for *standard* prescriptions aiming at a +9° inclination change, and it was good for *low* and *high* prescriptions aiming at −13° and +24° inclination changes, respectively. Such behavior was in contrast with the fact that a smaller inclination correction should be easier to achieve. However, the wire-play may have affected the accuracy of the system,[28] leading to small corrections being less controllable. In addition, mandibular central incisors with the *standard* prescription showed even negative consistency between the clinical results and the imposed angular change. In particular, for mandibular incisors, their labioversion may be explained by the use of Class II elastics, or by variations in dental crowding and curve of Spee,[29] highlighting the importance of considering all biomechanical variables in the choice of the inclination prescription.

Limitations

The method used in the present study was validated by a comparison with the prescription values declared by Andrews,[6] and showed overlapping results.[20] However, measurement of dental inclination changes did not allow discrimination between "tipping" and "torque" movements. In addition, even though central and lateral mandibular incisors had the same values of *low* and *standard* prescriptions (−11° and −3°, respectively), these teeth were analyzed separately for internal validation of the method, and they showed similar findings. Due to different ligation systems, self-ligating brackets may exert different engagement force on the archwire compared to conventional brackets,[30,31]. Nevertheless, conventional ligatures may not apply standardized forces and may act as a confounding factor.[27] Although prospective randomized trials would remove the allocation bias such trials may present ethical concerns since randomization may assign *high* inclination prescriptions to patients with already protruded incisors and *vice versa*, potentially worsening their malocclusion. Lastly, the observed clinical changes may have been influenced by growth and should not be attributed solely to the treatment.

CONCLUSIONS

- The chosen inclination prescription caused clinical change in dental inclination that was coherent with the direction of the correction (labial vs. lingual), and this was applicable to every teeth that was analyzed except mandibular central incisors.
- The imposed inclination change was the most relevant predictor of the clinically achieved change. How-

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ever, the final inclination had limited consistency with the value of the selected prescription.

● The initial incisal inclination was the leading factor determining the choice of the bracket prescription.

● A comprehensive consideration of all biomechanical variables affecting the force system is important in choosing the bracket prescription.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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