Changes in maxillary incisor inclination and position after traction of unilateral vs bilateral maxillary impacted canines in nonextraction treatment: A cone-beam computed tomography study

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Introduction: The aim of this study was to compare the inclination and position changes of maxillary incisors after traction of unilateral vs bilateral maxillary impacted canines in nonextraction orthodontic treatment. **Methods:** This longitudinal and retrospective study evaluated 24 patients with impacted maxillary canines; 12 with unilateral impaction and 12 with bilateral impaction. All subjects had Angle Class I malocclusion and were orthodontically treated with a standardized traction protocol that did not include premolar extractions. Cone-beam computed tomographies were obtained before and after canine traction and the inclination and position of both maxillary central incisors were measured. Furthermore, dental arch, skeletal, and canine impaction characteristics were evaluated. Paired and independent *t* tests were used for intra and inter group comparisons, respectively. Multiple linear regressions were also used. **Results:** After canine traction, a significant incisor labial inclination was observed in the bilateral group (10.41° right side, $P = 0.008$ and 12.79° left side, $P = 0.001$), while in the unilateral group, this was observed only on the nonaffected side (6.67°, $P = 0.008$). Furthermore, a significant protrusion of incisors was observed in the bilateral group (2.66 mm right side, $P = 0.006$, and 3.15 mm left side, $P = 0.001$) and in the nonaffected side of the unilateral group (1.74 mm, $P = 0.022$). Intergroup comparisons showed greater values of incisor labial inclination for the bilateral group when compared with the unilateral group, independently of the sides. **Conclusions:** Traction of maxillary impacted canines, in nonextraction treatment, produces greater labial inclination of maxillary incisors in bilateral cases and similar protrusion in both unilateral and bilateral cases. Unilateral impaction cases showed significant incisor inclination and protrusion in the nonaffected side. These treatment effects should be considered by clinicians. (Am J Orthod Dentofacial Orthop 2019;156:767-78)

An undesired effect of maxillary canine impaction is the alteration of the dental occlusion, which prevents the obtaining of an ideal functional occlusion.[1] Frequently, the absence of the impacted canine produces mesial migration of the adjacent premolars, altering the dental intercuspidation and favoring the presence of malocclusion.[2,3] In some cases of maxillary canine impaction, distoangulation of the lateral incisor crowns is commonly observed and sometimes leads to the presence of interdental incisor spaces.[4,5] This

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change of angulation could also modify the ideal torque of these teeth because of the direct relationship that exists between these 2 variables (angulation/torque).[6]

The presence of maxillary impacted canines in Class I or II malocclusion patients with biprotrusion could lead to the extraction of first premolars as a treatment alternative,[7,8] which allows traction and distalization of the impacted canine until its position in a canine Class I relationship. However, in Class I malocclusion cases without biprotrusion or in Class III cases with maxillary deficiency, the labial crown inclination and protrusion of maxillary incisors is a plausible alternative to obtaining space for the impacted canine.[9] This can be achieved using activated open nickel-titanium coil springs that simultaneously proincline the incisors and distalize the premolars until good intercuspation and adequate space for the canine are attained, without the need of extractions or affecting the soft tissue profile.[10]

Some studies have reported a positive direct correlation between canine angulation and the inclination of maxillary incisors indicating that, greater mesial angulation of the erupted maxillary canines produces a greater labial crown inclination of the maxillary incisors. It could be thought that the absence of the maxillary canine may produce changes in the labial inclination of maxillary incisors.[11,12] However, in cases of canine impaction, this relationship has not been studied or quantified. The scientific literature has reported that in cases of canine impaction, the maxillary incisors before their traction have smaller inclination compared with patients without impaction.[13] Likewise, some predictive models of canine impaction found a significant influence on the lateral incisor angulation.[14] Although it is expected that in canine traction treatments with nonextraction approach, the maxillary incisors would be proinclined as a result of obtaining space for the eruption of this tooth, no study has quantified this variation.

The biological limits of orthodontic treatment allow a maxillary incisor proinclination up to 3 mm, when necessary.[15,16] Greater amounts could cause dehiscence or fenestration that may produce periodontal and esthetic problems.[17,18] Obtaining the space to adequately position an impacted canine could produce greater labial crown inclination of the maxillary incisors in cases with bilateral impaction than in the unilateral ones. It could occur because spaces have to be obtained on both sides of the dental arch. Some orthodontic procedures include the use of open nickel-titanium coil springs, which will push the anterior teeth forward and are expected to generate incisor labial crown inclination. However, this effect has not been quantified in the scientific literature. Therefore, the purpose of this study was to compare the changes in the inclination and position of maxillary incisors after traction of unilateral vs bilateral impacted canines in nonextraction orthodontic treatment. The null hypothesis was that there are no differences in the changes of inclination and position of maxillary incisors between both groups of impaction.

MATERIAL AND METHODS

This retrospective longitudinal study was approved by the ethics committee of the Faculty of Dentistry of the Universidad Científica del Sur, Lima, Republic of Peru (approval number 00008). The sample consisted of 24 patients diagnosed with impacted maxillary canines: 12 with unilateral impaction and 12 with bilateral impaction. Subjects were treated at a private clinic in Bogotá, Colombia by an orthodontist (G.A.R.M.) with more than 20 years of experience treating this type of cases. All patients were diagnosed with Angle Class I malocclusion, with $\leq$2 mm anterior dental crowding (measured between the central and lateral incisors) and were orthodontically treated with a standardized impacted canine traction protocol that did not include premolar extractions, only the deciduous canines were removed. Subjects with previous orthodontic treatment, cleft lip or palate, craniofacial anomalies, tumors, tooth loss (except third molar) or dental agenesis were excluded.

Sample size was calculated considering a mean difference of 4.99° in the incisor inclination between both groups, using a standard deviation of 5° (obtained from a previous pilot study) with a 2-sided significance level of 0.05 and a test power of 80%. Therefore, the minimum sample size required was 12 subjects per group.

Lateral headfilms and panoramic radiographs were used to evaluate the craniofacial and canine impaction characteristics, respectively. Treatment time was defined as the duration of the orthodontic traction of the impacted canine. Cone-beam computed tomographies (CBCTs) were obtained before (T0) and after (T1) canine traction until the occlusal plane. The PaX-uni 3D equipment (Vatech Co, Ltd, Hwaseong, Korea) configured at 4.7 mA, 89 KVp, voxel size 0.125, exposure time of 15 seconds, and field of view of 8 $\times$ 8 cm^2. The DICOM files were imported into Dolphin-3D software (version 11.7 Dolphin Imaging & Management Solutions, Chatsworth, Calif) where multiplanar and 3D reconstructions were evaluated.

Sagittal individual's skeletal characteristics (SNA, SNB, ANB,[19] APDI,[20] maxillary length PNS-ANS) were measured in lateral headfilms. Tooth dimension

Table I. Definition of craniofacial and impacted canine characteristics

Measurements	*Definition*
SNA angle	Angle formed by Sella, Nasion, and Subspinale points.[19]
SNB angle	Angle formed by Sella, Nasion, and supramental points.[19]
ANB angle	Angle formed by Subspinale, Nasion, and Submental points.[19]
APDI angle	The Antero Posterior Dysplasia Indicator is the arithmetic sum of 3 angles: Frankfort Horizontal plane to Facial plane, A-B plane to the Facial plane, and Frankfort plane.[20]
PNS-ANS distance	Distance in mm between posterior nasal spine to anterior nasal spine, (Palatal Plane).
Arch depth	Perpendicular distance in mm from a horizontal line passing through the mesial surfaces of the upper first molars to the incisal edge of the more protruded upper central incisor. This distance was measured in the axial section of the CBCTs.[21]
Inter first premolar distance	Distance in mm from the buccal cusp of the upper first right premolar to the buccal cusp of the first left premolar. This distance was measured in the axial section of the CBCTs.[21]
Inter first molar distance	Distance in mm from the mesio buccal cusp of the upper first right molar to the mesio buccal cusp of the first left molar. This distance was measured in the axial section of the CBCTs.[21]
Space requirement for the impacted canine	Difference in mm between the available space for the eruption of the impacted canine and the required space for this tooth. The available space was measured in the axial section, from the distal surface of lateral incisor to the mesial surface of the first premolar. The required space was measured in the coronal section, as the maximum width of the impacted canine crown.[22]
Previous incisor root resorption	Defined as presence or absence of root resorption of the central or the lateral upper incisor near to the impacted canine. This was evaluated only in the affected side through CBCT exploration in volume rendering and in the 3 sections (axial, sagittal, and coronal).
Initial root length	Root length was measured in mm on the longitudinal tooth axis from a perpendicular projection to the vestibular enamel-cement junction in the sagittal section up to the vertex of the radicular apex of each central incisor.
Location	The impacted canine location was evaluated as palatally, buccally or bicortically (located at the level of the occlusion line, or exactly centered in the alveolar bone, in the middle of the 2 cortical bones).[24,26]
Impaction sector	The evaluation of impaction sector was performed according to Ericson and Kurol classification, that is, sector 1, 2, 3, 4, or 5.[25,26]
α angle	Angle formed between the interincisor midline and the long axis of the impacted canine.[25,26]
β angle	Angle formed between the long axis of canine and the long axis of lateral incisor.[25,26]
Canine impaction height	The canine vertical height was evaluated measuring the distance "d" as the perpendicular distance from the cusp tip of the impacted canine to the occlusal plane formed by a tangent to the incisal edge of maxillary central incisor and the occlusal surface of the maxillary first molar.[25,26]

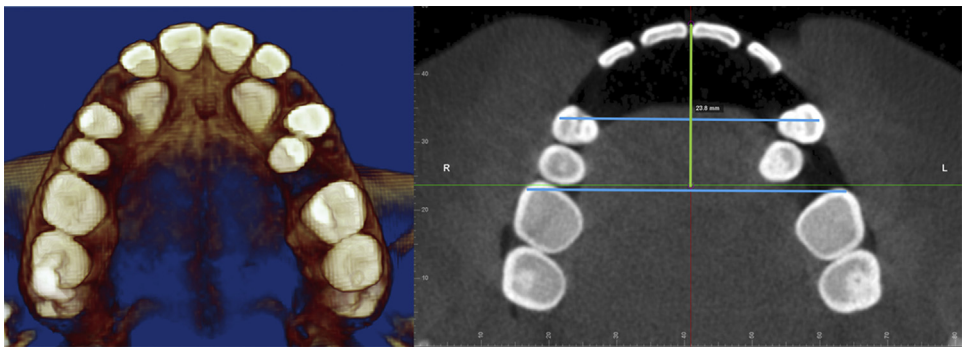

Fig 1. Measurements of the arch depth (green), interpremolar distance and intermolar distance (light blue) in the axial cut of the CBCT.

characteristics including the arch depth, inter first premolar and first molar distances, space requirement for the impacted canine, and the presence of previous resorption and initial root length of the central incisor were measured in CBCT. These evaluations were defined in Table I[21,22] (Figs 1and 2). Likewise, the canine impaction characteristics were evaluated on panoramic radiographs generated from CBCT including the impacted canine location (buccally, palatally, or bicortically), impaction sector (1-5), alpha angle (°), beta angle (°)

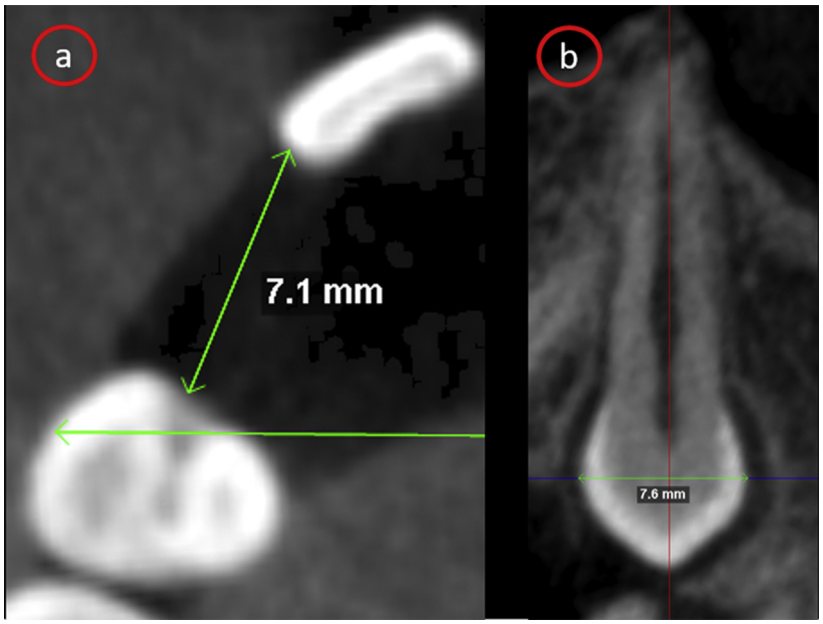

Fig 2. Evaluation of the space requirement for the eruption of maxillary impacted canine. a. Available space. b. Space required.

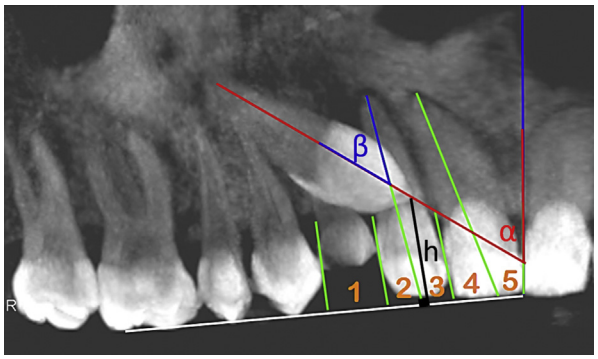

Fig 3. Characteristics of the maxillary impacted canines including the impaction sector (1-5), α angle, β angle and canine height (mm).

and canine height (mm).[23-26] (Fig 3). Furthermore, other characteristics such as sex and age were collected.

The entire sample was treated under a strict orthodontic and surgical protocol. A segmental alignment and leveling phase was performed with 0.016 × 0.022-in copper nickel-titanium (Ormco, Glendora, Calif) wires on 0.022 × 0.028-in metal slot brackets (Standard edgewise prescription, Synergy Rocky Mountain Orthodontics, Denver, Colo) in incisors and in the premolar and molar regions. Then, the space was prepared with 0.012 × 0.045-in open coil springs (RockyMountain Orthodontics, Denver, Colo) between lateral incisor and first premolar on 0.017 × 0.025-in nickel-titanium archwires until obtaining the space for the impacted canine in approximately 2-3 months (in cases of bilateral impaction the spaces for the canines were obtained on both sides). Then 0.017 × 0.025-in stainless steel archwires distally cinched, were placed in the previous aligned and leveled teeth before traction beginning. A closed surgical technique in each impacted tooth was performed. A rigorous process of isolation and trans-surgical adhesion of the button was considered. Nickel-titanium closed coil springs were placed from the vestibular surface of each impacted canine to the buccal hooks of the anchorage appliance (Fig 4). Activations from 4-5 mm every 4-8 weeks. In all patients, a heavy palatal anchorage appliance was installed. This anchorage was made of 1.1-mm or 1.2-mm stainless steel wires and was welded to adapted bands on the permanent first molars. The wire had extensions toward the anterior part of the incisors, ensuring a reinforced anchorage in the maxillary arch. Wire hooks of 0.7 mm stainless steel, extended buccally, were used to prevent the immersion of the closed nickel-titanium spring in the gingival tissue. First, the canine was distanced from the roots of the incisors with the help of the spring that was anchored to the hooks to avoid side effects on the neighboring teeth (Fig 4).[27] Canines were tractioned until they reached the occlusion plane. At this time, a control CBCT was requested (T1). Then, the appliance was removed, and finishing phase was started.

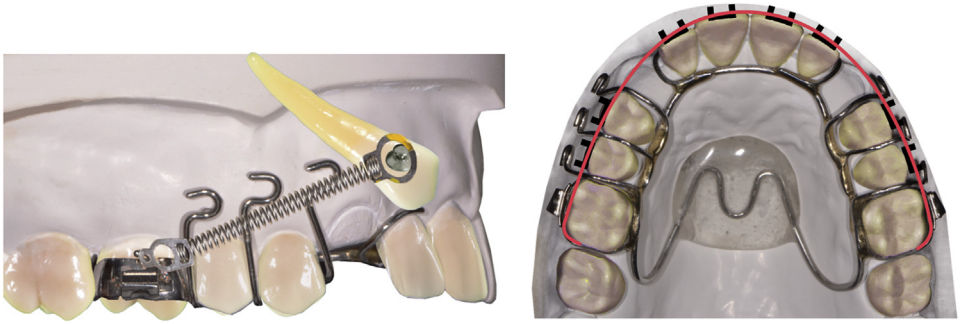

Fig 4. Reinforced anchorage for maxillary impacted canine traction. Occlusal view and lateral view.

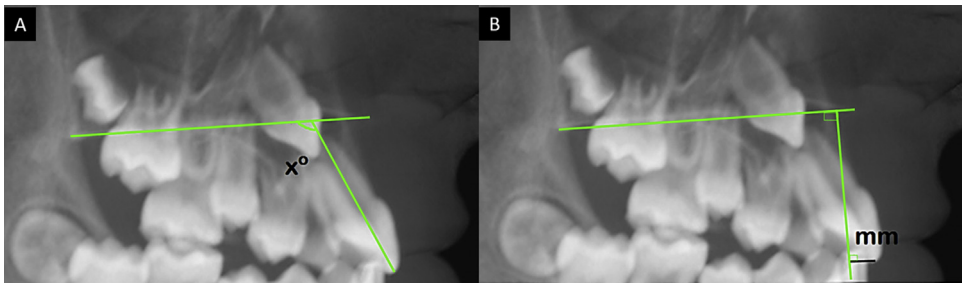

Fig 5. **A**. Maxillary incisor inclination measurement. Angle formed by the palatal plane and incisor longitudinal axis in the axial cut of CBCT. **B**. Maxillary incisor position measurement. Distance in mm from incisal edge to a perpendicular line through A point to the palatal plane in the axial cut of CBCT.

The inclinations of both maxillary central incisors (before and after traction) were evaluated. For this, in the axial section, the maxilla was segmented at the level of the sagittal midline into right and left sides, and cuts were obtained, avoiding tooth overlap. Then, in the sagittal sections, the inclination of the central incisors was measured by the angle formed between the longitudinal axis of each maxillary central incisor and the palatal plane (Fig 5, *A*). The positions of both central incisors were also measured as the distance from the incisal edge of each maxillary central incisor to a line perpendicular to the palatal plane tangent to A point (Subspinal) (Fig 5, *B*).

The inclination and position of the maxillary incisors were measured by the same examiner (C.CH.A.) twice, with a one-month interval between the measurements. The intraobserver agreement was evaluated using the Intraclass correlation coefficient. The Interclass correlation coefficients were greater than 0.7 for all variables (95% confidence interval 0.77-0.99).

Statistical analysis

Statistical analyses were performed using SPSS software (version 24; IBM, Armonk, NY). Sex, previous incisor root resorption, impacted canine location, and impaction sector distribution were compared between groups using Fisher exact and chi-square tests. Data normal distribution was tested and confirmed with Shapiro-Wilk test. First, paired t test was employed in the unilateral impacted canines group to compare the inclination and position changes between the affected vs nonaffected side. Then, paired t tests and independent t test were used to compare the before/after traction inclination and position changes in each group and to compare the changes between both groups (unilateral vs bilateral), respectively. Finally, multiple linear regressions were performed to know if there was a significant influence of any of the predictor variables on the outcome variables (inclination and position) for each incisor using the overfit method. This method performs an initial multiple linear regression analysis with all variables followed by a second regression with only variables showing P values smaller than 0.25.[28] The level of significance adopted for all tests was $P < 0.05$.

RESULTS

Sex distribution, presence/absence of root resorption before treatment, impacted canine location and impacted canine sector were similar between groups (Table II).

Table II. Sample initial characteristics according to the type of maxillary canine impaction

		Impaction type			
Variable	*Categories*	*Unilateral*	*Bilateral*	*Total*	P *value*
Sex	Male	4	5	9	0.630*
	Female	8	7	15	
	Total	12	12	24	
Previous incisor root resorption	Absent	10	8	18	0.221*
	Present	2	4	6	
	Total	12	12	24	
Impacted canine location	Palatally	6	11	17	0.081†
	Buccally	6	6	12	
	Bicortically	0	7	7	
Impaction Canine Sector	Sector 1	3	4	7	0.540†
	Sector 2	2	5	7	
	Sector 3	5	5	10	
	Sector 4	1	5	6	
	Sector 5	1	5	6	

*Fisher exact test; †Chi square test.

Age, initial inclination and position of both maxillary central incisors, the skeletal characteristics [SNA, SNB, ANB, APDI angles and maxillary length (PNS-ANS)], the initial root lengths, arch depth, inter first premolar and first molar distances, and the space requirement for impacted canine were similar between the groups. Traction time in months was greater in the bilateral group (2.39 months, $P = 0.049$) (Table III).

In the unilateral impacted canines group, the changes of inclination and position of central incisors did not show statistically significant differences between the affected and nonaffected sides ($P = 0.180$ and $P = 0.524$, respectively), Table IV. Although this lack of statistical significance, the nonaffected side inclination change was numerically greater than the affected side.

Before/after traction comparisons on each side showed that in the unilateral group, the nonaffected side demonstrated significant inclination and position changes (6.67°, $P = 0.008$ and 1.74 mm, $P = 0.022$, respectively), Table V. The bilateral impaction group showed significant incisor inclination and protrusion changes on the right side (10.41°, $P = 0.008$ and 2.66 mm, $P = 0.006$) and on the left side (12.79°, $P = 0.001$ and 3.15 mm, $P = 0.001$).

For intergroup comparisons (unilateral vs bilateral groups), each affected/nonaffected side of the unilateral group was compared with each right/left side of the bilateral group (Table VI). The bilateral group showed greater labial crown inclination of incisors when compared with the unilateral group, independently of the sides. Nevertheless, the only statistically significant difference was found for the maxillary left central incisor of the bilateral group vs the affected side incisor of the unilateral group (mean difference 9.08°, $P = 0.010$). Besides, protrusion changes were similar between unilateral (affected or nonaffected side) and bilateral (right or left side) groups.

Multivariate analysis considering the changes of incisors' inclination as outcome variables showed significant influence of the presence of previous root resorption that increased the labial crown inclination of the incisors between 7.46° and 11.58° (Table VII). Likewise, the initial inclination of the incisors also showed significant influence on the outcome variables. For each degree of increase in the incisors' initial inclination, the possibility of changing the incisors final inclination decreased between 0.33° and 0.42°. Traction time and impaction sector had an irregular behavior with influence on the right side ($P = 0.042$ and $P = 0.031$ respectively) and without any influence on the left side.

When the changes in the incisors' position were considered as outcome variables, the multivariate analysis showed only significant influence of the presence of previous root resorption predictor variable ($P = 0.019$ on both sides), indicating that the presence of previous resorption favors a final protrusion of incisors between 2.68 mm and 3.13 mm after canine traction (Table VIII).

DISCUSSION

The correlation between the mesiodistal angulation of maxillary canines and the inclination of the maxillary incisors has been described in the scientific literature.[29] In addition, it has been reported that the absence of the impacted canine in the dental arch produces some

Table III. Quantitative variables before canine traction according to the type of impaction

Variables	Canine impaction type	n	Mean	SD	P value	Mean difference	95% CI	
							Lower limit	Upper limit
Age	Unilateral	12	19.00	8.72	0.745	1.18	−6.33	8.69
	Bilateral	12	17.82	7.28				
Initial inclination–RUCI	Unilateral	12	116.81	10.35	0.227	6.71	−4.56	17.98
	Bilateral	12	110.10	13.07				
Initial inclination–LUCI	Unilateral	12	116.88	11.14	0.261	6.06	−4.9	17.02
	Bilateral	12	110.82	11.97				
Initial position–maxillary right central incisor	Unilateral	12	6.69	1.38	0.071	1.88	−0.18	3.94
	Bilateral	12	4.81	2.65				
Initial position–maxillary left central incisor	Unilateral	12	7.00	2.06	0.062	2.1	−0.12	4.32
	Bilateral	12	4.90	2.56				
Traction time in months	Unilateral	12	6.33	1.32	0.049*	−2.39	−4.79	0.01
	Bilateral	12	8.73	3.2				
SNA	Unilateral	12	85.95	4.47	0.778	0.68	−4.3	5.65
	Bilateral	12	85.27	5.83				
SNB	Unilateral	12	82.64	4.3	0.533	1.49	−3.42	6.39
	Bilateral	12	81.15	5.82				
ANB	Unilateral	12	3.31	1.95	0.295	−0.81	−2.39	0.77
	Bilateral	12	4.12	1.4				
APDI	Unilateral	12	82.42	4.95	0.63	1.19	−3.91	6.29
	Bilateral	12	81.23	5.73				
PNS-ANS	Unilateral	12	47.75	2.82	0.494	−1.27	−5.08	2.54
	Bilateral	12	49.01	4.79				
Initial root length–maxillary left central incisor	Unilateral	12	11.81	2.14	0.24	1.73	−1.26	4.72
	Bilateral	12	10.08	3.79				
Initial root length–maxillary right central incisor	Unilateral	12	10.68	3.54	0.612	0.85	−2.61	4.31
	Bilateral	12	9.83	3.76				
Unilateral	12	28.47	1.50	0.117	1.29	−0.35	2.94	
Arch depth	Bilateral	12	27.17	1.93				
Inter first premolar distance	Unilateral	12	44.88	1.81	0.384	1.32	−1.78	4.43
	Bilateral	12	43.55	4.11				
Inter first molar distance	Unilateral	12	55.26	4.11	0.966	−0.08	−4.44	4.26
	Bilateral	12	55.35	4.99				
Space requirement for impacted canine	Unilateral	12	−0.69	0.85	0.087	2.03	−0.32	4.40
	Bilateral	12	−2.73	3.28				

Independent *t* test.
RUCI, maxillary right central incisor; *LUCI*, maxillary left central incisor.
*Significant at $P < 0.05$.

palatal inclination of the maxillary incisors.[4,11-13] However, the quantification of the amount of inclination and position changes in the maxillary incisors after impacted canines traction in nonextraction treatment has not been reported. Therefore, the purpose of this study was to compare the changes in the inclination and position of the maxillary central incisors after traction of unilateral vs bilateral impacted canines in nonextraction treatments.

Quantitative information regarding the amount of protrusion and inclination occurred in the maxillary central incisors after generating space to position impacted maxillary canines is relevant for orthodontists because this positional change would have a direct impact on the soft profile and smile esthetics.[30,31] For this reason, these changes should be considered in treatment planning. It has been pointed out that for each millimeter of change in central incisors position, 0.5 mm change occurs in the upper lip.[30,32,33] In impaction cases, protrusion changes could be favorable in cases of retruded or even straight profiles that could tolerate mild protrusion without significant

Table IV. Maxillary central incisor inclination and position changes before and after canine traction in unilateral impacted canines

						95% CI	
Canine impaction type	*Measurement*	*Mean*	*SD*	P *value*	*Mean difference*	*Lower limit*	*Upper limit*
Unilateral group	Affected side inclination change	3.71	4.55	0.180	−2.96	−6.81	0.90
	Nonaffected side inclination change	6.67	5.72				
	Affected side position change	2.03	3.05	0.524	0.29	−0.71	1.29
	Nonaffected side position change	1.74	1.85				

Paired *t* test.

Table V. Maxillary central incisor inclination and position changes before and after canine traction in both groups

							95% CI	
Canine impaction type	*Measurements*		*Mean*	*SD*	P *value*	*Mean difference*	*Lower limit*	*Upper limit*
Unilateral group	Affected side inclination	Before traction	116.71	13.88	0.652	−3.71	−6.21	2.79
		After traction	120.42	9.83				
	Nonaffected side inclination	Before traction	113.56	2.20	0.008*	−6.67	−11.07	−2.27
		After traction	120.22	7.08				
	Affected side Position	Before traction	6.96	1.71	0.081	−2.03	−4.38	0.31
		After traction	8.99	2.27				
	Nonaffected side Position	Before traction	7.63	1.68	0.022*	−1.74	−3.17	−0.32
		After traction	9.38	1.89				
Bilateral group	Maxillary right central incisor inclination	Before traction	110.1	13.07	0.008*	−10.41	−17.48	−3.34
		After traction	120.51	12.82				
	Maxillary left central incisor inclination	Before traction	110.82	11.97	0.001*	−12.79	−18.65	−6.93
		After traction	123.61	10.61				
	Maxillary right central incisor position	Before traction	4.81	2.65	0.006*	−2.66	−4.39	−0.94
		After traction	7.47	3.19				
	Maxillary left central incisor position	Before traction	4.90	2.56	0.001*	−3.15	−4.76	−1.53
		After traction	8.05	2.62				

Paired *t* test.
RUCI, maxillary right central incisor; *LUCI*, maxillary left central incisor.
*Significant at $P < 0.05$.

effects on the facial profile esthetics. Nevertheless, it must be considered that modifications of the soft profile depend on several factors such as inclination of the incisors, thickness and height of the lips, and race, among others.[31,34]

All Class I malocclusion cases in this sample were treated without extractions by one experienced orthodontist; this controlled the influence of different treatment mechanics and clinician expertise on the results. The inclusion of other type of malocclusion was not considered because they could have different initial characteristics and could use different mechanics to obtain the spaces for canine traction.

Many studies have analyzed changes in the upper incisors' inclination and position after traction of maxillary impacted canines using radiographic examinations. However, the exact value, in degrees and millimeters, without magnification can be only obtained using CBCT because of its 1:1 ratio, and the anatomical overlap absence. In addition, it should be considered that central incisors do not always present the same inclination and position. For this reason, the change in both teeth was evaluated. Even with the limitations mentioned above, this study is the first in performing this type of comparisons.

The CBCTs were requested for diagnostic purposes (T0) and to evaluate and control the effects of traction on the surrounding tissues when the canine reached the occlusal plane (T1). The as low as reasonably achievable principles accept these tomographic records at both times of treatment.[35] CBCTs after brackets removal were not obtained because the patients already had 2 previous

Table VI. Maxillary central incisor inclination and position changes after canine traction between both groups

Measurements	Canine impaction type	n	Mean	SD	P value	Mean difference	95% CI Lower limit	95% CI Upper limit
Inclination changes—after canine traction	Unilateral (AS)	12	3.71	4.55	0.072	−6.70	−14.34	0.94
	Bilateral (RS)	12	10.41	10.53				
	Unilateral (AS)	12	3.71	4.55	0.010*	−9.08	−16.73	−3.66
	Bilateral (LS)	12	12.79	8.72				
	Unilateral (NS)	12	6.67	5.72	0.637	−3.74	−12.79	8.30
	Bilateral (RS)	12	10.41	10.53				
	Unilateral (NS)	12	6.67	5.72	0.147	−6.12	−13.99	2.50
	Bilateral (LS)	12	12.79	8.72				
Position changes—after canine traction	Unilateral (AS)	12	2.03	3.05	0.807	−0.30	−3.04	2.44
	Bilateral (RS)	12	2.66	2.56				
	Unilateral (AS)	12	2.03	3.05	0.269	−1.12	−3.65	1.17
	Bilateral (LS)	12	3.15	2.41				
	Unilateral (NS)	12	1.74	1.85	0.565	−0.92	−2.85	1.67
	Bilateral (RS)	12	2.66	2.56				
	Unilateral (NS)	12	1.74	1.85	0.126	−1.41	−3.6	−0.53
	Bilateral (LS)	12	3.15	2.41				

Independent *t* test.
AS, affected side; *RS*, right side; *LS*, left side; *NS*, nonaffected side.
*Significant at $P < 0.05$.

Table VII. Multiple linear regression to evaluate the maxillary central incisor inclination changes before canine traction

Predictor variables	B	P value	B	P value
	Maxillary right central incisor		Maxillary left central incisor	
Constant	32.587	0.011*	48.405	0.011*
Impaction Type Unilateral	–	–	–	–
Bilateral	−3.052	0.250	4.525	0.142
Previous root resorption Absent	–	–	–	–
Present	11.582	<0.001*	7.466	<0.037*
Initial inclination—maxillary central incisor	−0.336	0.002*	−0.426	0.002*
Traction time in months	0.951	0.042*	0.429	0.447
Impaction sector	1.787	0.031*	0.210	0.815
	$R^2 = 0.835$		$R^2 = 0.748$	

*Significant at $P < 0.05$.

Table VIII. Multiple linear regression to evaluate the maxillary central incisor position changes before canine traction

Predictor variables	B	P value	B	P value
	Maxillary right central incisor		Maxillary left central incisor	
Constant	4.446	0.023*	4.342	0.009*
Impaction Type Unilateral	–	–	–	–
Bilateral	−0.962	0.417	−0.386	0.701
Previous root resorption Absent	–	–	–	–
Present	3.136	0.019*	2.680	0.019*
Initial position—upper central incisor	−0.408	0.111	−0.364	0.076
	$R^2 = 0.355$		$R^2 = 0.385$	

*Significant at $P < 0.05$.

exposures and because final CBCTs are not indicated as routine. This could be a limitation of the study since some final variations could occur in the position and inclination of the incisors during finishing phases. However, this should not be clinically relevant because of the short time that could be expected between these 2 phases in nonextraction Class I malocclusion treatment.

This study focused mainly on quantifying the sagittal position change of the incisors since it could have influence on the soft profile and smile esthetics. Nevertheless, it was not plausible to evaluate the changes in the soft profile because of the presence of brackets in the CBCTs at T1. The transverse and vertical sections obtained in the CBCTs were used to make the exact diagnosis of canine impaction. Although this sagittal evaluation could be performed using cephalometrics, it had limitations of image superimpositions. In the case of impacted canines near the roots of the incisors, accurate assessments are needed.

Incisor change comparisons between the affected and nonaffected side, in the unilateral group, showed

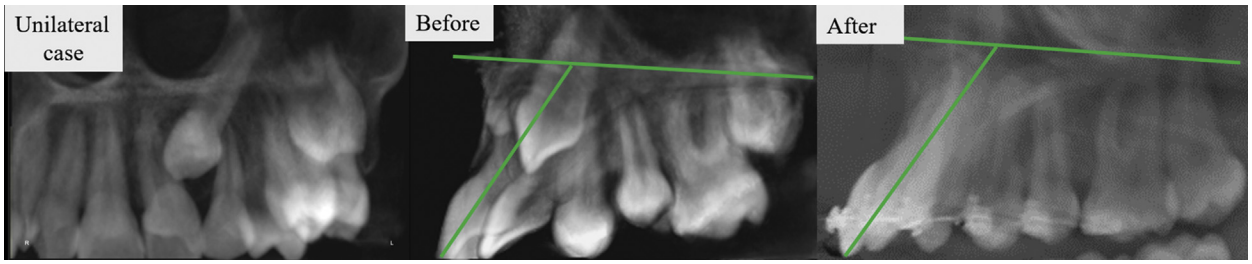

Fig 6. Maxillary incisor inclination changes, before and after traction of a unilateral maxillary impacted canine.

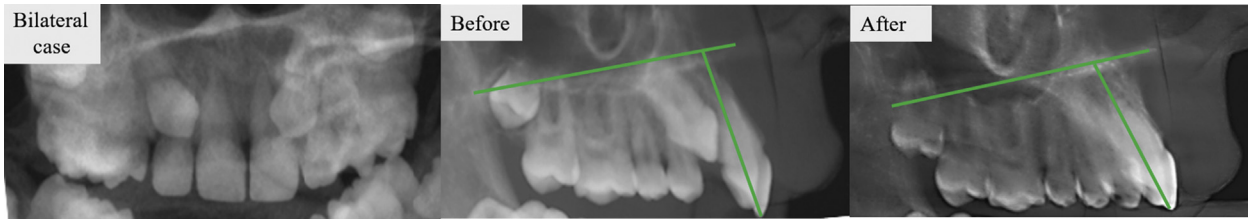

Fig 7. Maxillary incisor inclination changes, before and after traction of a bilateral maxillary impacted canine.

a greater but statistically insignificant labial inclination in the nonaffected side (Table IV). Furthermore, significant labial inclination before/after traction were observed on the nonaffected incisor, in the unilateral group (Table V). This could be expected because of the smaller value of incisor inclination that this side presented before traction. Then, greater labial inclination was needed. This could also explain the numerically greater incisor inclination observed in the nonaffected side when compared with the affected side, mentioned above. Therefore, this finding should be considered during treatment planning.

Significant labial inclination of central incisors was observed on both sides (right and left) in the bilateral group, and these values were greater than those observed for the nonaffected side on the unilateral group (Table V).

For unilateral vs bilateral comparisons, each affected/nonaffected side of the unilateral group was compared with each right/left side of the bilateral group (Table VI). This was performed to show specific side comparisons between groups. Although a statistically greater labial inclination was only found for the left side of bilateral cases when compared with the affected side of unilateral cases, inclination changes on the bilateral group were considerably greater (numerically), independently of the sides. This could have an important clinical impact because of the amount of inclination changes observed which may affect the patient's soft tissue profile (Figs 6 and 7). Likewise, orthodontists must be aware about these results when treating patients with bilateral canine impaction without extractions, especially in cases who already have a greater labial inclination of maxillary incisors before treatment. The possibility of increasing this labial inclination could have effects on the smile and facial profile esthetics. This treatment approach would probably be indicated for cases with palatal inclined incisors, typical on Class II division 2 malocclusions, or for incisors with an adequate inclination in which a slight labial inclination is proposed, that is, cases of Class I malocclusion without biprotrusion or in the compensatory treatment of Class III malocclusion.

The protrusion of central incisors was significant on the nonaffected side of the unilateral group. This could be expected because of the significant labial inclination produced in this side, mentioned above. The bilateral group showed significant protrusion on both; right and left sides, showing that canine disimpaction could promote a protrusion of the incisors in a range of approximately 2-3 mm (Table V), values that are within acceptable limits of orthodontic treatment.[15,36] These changes may have some clinical relevance in specific cases, that is, patients with initial biprotrusion, since they could promote a worsening of the soft tissue profile by increasing this initial condition. Thus, it is important to

evaluate the initial position of the incisors in the diagnosis phase in order to determine if the patient's profile accepts or not some dental protrusion. Furthermore, it could be argued that the results of this study could be expected because of the inherent characteristics of the patients and because of the nonextraction treatment approach. However, it is important to estimate the amount of changes that could be expected in the nonextraction treatment of impacted canines to know if these treatment changes would be beneficial or not for each patient, considering its impact on the soft tissue profile.

The multivariate analysis allowed to know the influence of some variables such as the presence of previous root resorption in the labial inclination and protrusion of the incisors. This could be explained because a shorter root length could present lower resistance to the forces applied during treatment, which increases the chances of inclination and position changes. It is very common to observe initial root resorption of incisors in cases of canine impaction, so this condition must be considered during the treatment planning. The initial inclination of the incisors also showed significant influence on the total amount of the inclination change; when an initial labial inclination of the incisors is present, the amount of significant changes in the inclination of incisors decreases. Although this finding, orthodontists should evaluate the impact of this change on the final results. The other evaluated variables did not show significant influence or did not have a similar influence on both incisors, hence impact on the outcome variables lacked clinical implications. However, they should be evaluated in future research with larger samples. Even though groups showed similar distribution of the impaction sectors, they showed canines impacted in various sectors. This could explain the different behavior of this variable when its influence in the incisors' inclination changes was evaluated. Based on this specific sample, any strong relationship between impaction sector and incisors inclination changes could be stated. Again, this should be further investigated in future studies.

The findings of this study should be considered during treatment planning of impacted canines with nonextraction approaches. This study rejects the null hypothesis that there are no differences in the inclination changes of maxillary central incisors between unilateral and bilateral impaction groups; and regarding the position changes of incisors, the null hypothesis was accepted. Finally, clinicians must have special care when nonextraction orthodontic treatment is planned for bilateral impaction patients and on the nonaffected side in unilateral patients.

CONCLUSIONS

Traction of maxillary impacted canines, in nonextraction treatment, produces greater labial inclination of maxillary incisors in bilateral cases and similar protrusion in both unilateral and bilateral cases. In the case of unilateral impaction, significant inclination and protrusion are expected on the nonaffected side. The impact of these changes on the soft tissue profile should be considered during treatment planning for each specific case.

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