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Influence of impacted maxillary canine orthodontic traction complexity on root resorption of incisors: A retrospective longitudinal study

Luis Ernesto Arriola-Guillén,[a] Gustavo Armando Ruíz-Mora,[b] Yalil Augusto Rodríguez-Cárdenas,[c] Aron Aliaga-Del Castillo,[d] Mariana Boessio-Vizzotto,[e] and Heraldo Luis Dias-Da Silveira[e]
Lima, Perú, Bogotá, Colombia, Bauru, São Paulo, and Porto Alegre, Rio Grande do Sul, Brazil

Introduction: The orthodontic traction of impacted canines is a procedure of variable complexity. The objective of this study was to determine the influence of this complexity on the root resorption (RR) of adjacent incisors, using cone-beam computed tomography. **Methods:** This longitudinal retrospective study included 45 patients (19 female, 11 male; ages, 18.16 ± 7.3 years) with maxillary impacted canines, classified into 2 groups according to the level of orthodontic traction complexity: low complexity group (n = 20) and high complexity group (n = 25). The amounts of RR of 45 maxillary central and 45 lateral incisors were evaluated before and after treatment. Complexity was defined considering impaction sector, eruption inclination angle, and canine position (palatal, buccal, or bicortical). Three orthodontists measured RR in each maxillary incisor. Independent *t* tests or Mann-Whitney U tests were used to compare resorption between groups depending on the normality of the data. A multiple linear regression was calculated to evaluate the influence of all variables on RR ($\alpha = 0.05$). **Results:** RR of maxillary incisors in the sagittal, coronal, and axial sections showed no significant differences between groups ($P > 0.05$). Independently of the groups, RR ranged approximately from 1 to 1.5 mm and from 3 to 4 mm^2. RR was less than 2 mm^2 in the axial sections. Multiple linear regression indicated no significant influence of orthodontic treatment complexity on RR. Male patients had more RR, specifically in the maxillary central incisors than female patients ($P < 0.05$). **Conclusions:** The complexity of orthodontic traction of impacted maxillary canines is not a risk factor for greater RR of maxillary incisors close to the impaction area. (Am J Orthod Dentofacial Orthop 2019;155:28-39)

One undesired side effect after orthodontic treatment is root resorption (RR), mainly of the maxillary incisors.[1-3] RR has been reported in approximately 60% of treated patients but usually is less than 1 mm.[4] However, in some patients, RR may be severe (more than 4 mm) and could be related to various factors, including root shape and length, long orthodontic treatment, or heavy orthodontic forces.[5] Lateral incisors are usually the most exposed.[1,2] The orthodontic treatment of impacted canines requires special biomechanics,[6] which include forces with different traction vectors supported on the neighboring teeth using large-caliber arches to prevent side effects.[7-10] This situation could increase the risk of RR compared with a conventional orthodontic treatment approach.[11]

The reported prevalences of impacted maxillary canines range from 0.92% to 6.04%[12-14]; this is considered a clinical challenge for orthodontists. The treatment should try to maintain the unerupted teeth to allow the development of the canine eminence, which is important for facial esthetics, and to establish a canine guide that leads to a functional

[a]Divisions of Orthodontics and Oral and Maxillofacial Radiology, School of Dentistry, Universidad Científica del Sur, Lima, Perú.
[b]Division of Oral and Maxillofacial Radiology, School of Dentistry, Universidad Científica del Sur, Lima, Perú; Division of Orthodontics, Faculty of Dentistry, Universidad Nacional de Colombia, Bogotá, Colombia; Division of Oral and Maxillofacial Radiology, Faculty of Dentistry, Universidad Nacional de Colombia, Bogotá, Colombia.
[c]Division of Oral and Maxillofacial Radiology, School of Dentistry, Universidad Científica del Sur, Lima, Perú.
[d]Department of Orthodontics, Bauru Dental School, University of São Paulo, Bauru, São Paulo, Brazil.
[e]Division of Oral Radiology, Faculty of Dentistry, Federal University of Rio Grande do Sul, Porto Alegre, Rio Grande do Sul, Brazil.
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Address correspondence to: Luis Ernesto Arriola-Guillén, Calle Los Girasoles #194, Dpto. #302, Urb. Residencial Los Ingenieros de Valle Hermoso, Santiago de Surco, Lima, Perú; e-mail, luchoarriola@gmail.com.
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occlusion.[15,16] The place of impaction is considered a risk factor for RR, mainly the maxillary incisors. Bicortically impacted canines in the middle of the 2 cortical bones could generate greater RR of the incisors as a result of their eruption.[17,18] Likewise, this condition could be a greater risk for resorption after traction.

The location of impacted canines (palatal, buccal, or bicortical) and the distance to the roots of the maxillary incisors increase the risk of RR by direct contact with them during traction.[17,19] To quantify the severity of canine impaction, several classifications have been made, allowing the orthodontist to estimate how complex the treatment of a specific canine impaction could be.[20-23]

Any orthodontic treatment including canine disimpactation is considered complex.[24,25] However, this complexity varies depending on location, sector, and angle of impaction. Impacted canines closer to the midline have greater complications during treatment. If an impacted canine crosses the midline toward the opposite side, the difficulty of the treatment will be high.[26] The sectors of impaction 4 and 5 (close to the midline) according to the classification proposed by Ericson and Kurol[23] are the most complex to treat because they require special biomechanics for orthodontic traction. Likewise, the impacting angle clearly compromises the prognosis of the treatment; horizontally impacted canines are more challenging for orthodontists than vertically impacted canines, which have the best prognosis.

It has been reported that there are no significant differences in RR after orthodontic traction in patients with unilateral vs bilateral impacted canines.[27] However, bilateral impaction does not necessarily demand a complex treatment because it could involve 2 vertically impacted canines or could be located between a lateral incisor and a first premolar, with a good prognosis. Otherwise, a unilateral impaction is not always simplified treatment. If it is close to the midline or horizontal, the treatment may be more complex. This is why it was considered important to demonstrate whether a complex canine impaction treatment has a greater risk for RR of the incisors adjacent to the canine impaction. The purpose of this study was to determine the influence of orthodontic traction complexity of impacted maxillary canines on the RR of adjacent incisors.

The null hypothesis was that there is no significant difference in the amount and area of RR of the maxillary incisors after orthodontic traction of impacted canines with different levels of complexity.

MATERIAL AND METHODS

This retrospective longitudinal study was approved by the ethics and research committee of the Universidad Científica del Sur in Lima, Peru (number 00008). The sample included 45 patients (11 male; 19 female; age, 18.2 ± 7.3 years) with maxillary impacted canines treated in a private orthodontic clinic (G.A.R.M.). Two groups were established according to the level of orthodontic traction treatment complexity: low complexity group (n = 20) and high complexity group (n = 25). In both groups, the RR of the 45 maxillary central and 45 maxillary lateral incisors adjacent to the impacted canines were evaluated before and after traction (90 incisors) using cone-beam computed tomography (CBCT) images. The minimum sample size required was 20 impacted canines per group, determined by a formula to compare 2 means, with a 95% confidence level and 80% test power, when the average difference of RR between groups was 0.5 mm (data from a previous pilot test), and with a standard deviation of 0.64 mm.

The sectors of impaction according to the classification of Ericson and Kurol[23,28] are presented in Table I. The inclusion criteria were male or female patient with at least 1 impacted canine, with complete records including clinical histories, study models, extraoral and intraoral photographs, panoramic and lateral head films, and CBCT images before treatment and after canine traction.

Patients with periapical lesions circumscribed to the maxillary incisors before orthodontic treatment, with brackets or maxillary surgeries before the study, and with agenesis of a maxillary tooth were excluded.

The demographic and occlusal characteristics of the sample are described in Table II.

The low complexity group included patients with impacted maxillary canines in impaction sectors 1, 2, or 3 according to the classification of Ericson and Kurol[23,28] (Table I, Fig 1). In the case of sector 3, the α angle (angle between the interincisor midline and the long axis of the impacted canine) was 40° or less. Buccally or palatally maxillary impacted canines were included.[23] RR before orthodontic treatment was measured (Tables III and IV).

The high complexity group included patients with impacted maxillary canines in impaction sectors 3, 4, or 5 according to the classification of Ericson and Kurol.[23,28] In the case of sector 3, the angle α was greater than 40°. Buccally, palatally, and bicortically maxillary impacted canines (at the level of the occlusion line or exactly in the middle of the 2 cortical bones) were included (Tables III and IV).[17,18]

Table I. Classification of impacted canines of Ericson and Kurol[28]

Sector	*Definition*
1	The cusp tip of the canine is between the mesial aspect of the first premolar and the distal aspect of the lateral incisor
2	The cusp tip of the canine is between the distal aspect of the lateral incisor and the long axis of the lateral incisor
3	The cusp tip of the canine is between the long axis of the lateral incisor and the mesial aspect of the lateral incisor
4	The cusp tip of the canine is between the mesial aspect of the lateral incisor and the long axis of the central incisor
5	The cusp tip of the canine is between the long axis of the central incisor and the interincisor median line

Table II. Initial characteristics of the sample

Variable	*Condition*	*Total*
Sex	Male	11
	Female	19
Angle malocclusion	Class I	20
	Class II Division 1	0
	Class II Division 2	5
	Class III	5
	Mean	SD
Age (y)	18.16	7.32

The angle β, formed between the long axis of the canine and the long axis of the lateral incisor, was also measured. The canine vertical height was evaluated, measuring the distance as the perpendicular distance from the peak of the impacted canine to the occlusal plane formed by a tangent to the incisal edge of the maxillary central incisor and the occlusal surface of the maxillary first molar (Fig 2).[23,29]

Three trained orthodontists (L.E.A.G., G.A.R.M., and Y.A.R.C.) evaluated the impaction sector and position of the impacted canine in each CBCT image. Interobserver concordance was assessed with the kappa test, with perfect agreement (1.0). For continuous variables, 1 investigator (L.E.A.G.) performed all measurements twice, with a month interval. The intraobserver concordance was evaluated with the intraclass correlation coefficient. Values higher than 0.9 (95% CI, 0.80-0.97) were obtained. Additionally, random errors were calculated with Dahlberg's formula.[30] Dahlberg coefficients were smaller than 1 mm or 1 mm^2 for all variables.

CBCT scans of all patients were taken (PaX-Uni 3D; Vatech, Hwaseong, South Korea) set at 4.7 mA, 89 kV(p), voxel size of 0.125, and exposure time of 15 seconds. Each field of view mode was 8 × 8 cm.[2]

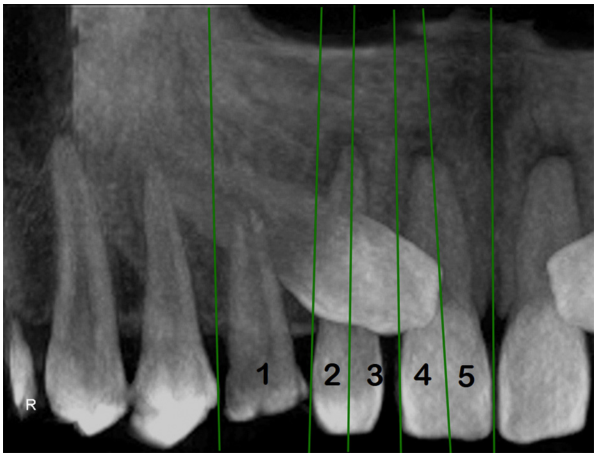

Fig 1. Sectors of canine impaction, based on the study of Ericson and Kurol.[28]

Table III. Characteristics of the impacted canines according to orthodontic traction complexity

Measurement	*Condition*	*Low complexity group*	*High complexity group*	*Total*	*P, chi square*
Localization of impaction	Palatal	10	10	20	0.034*
	Buccal	10	8	18	
	Bicortical	0	7	7	
Impaction sector	1	10	0	10	<0.001*
	2	9	0	9	
	3	1	10	11	
	4	0	9	9	
	5	0	6	6	
Initial RR	Present	3	15	18	0.002*
	Absent	17	10	27	

*Statistically significant at $P < 0.05$.

The DICOM files were imported into 3-dimensional software (version 11.7; Dolphin Imaging, Chatsworth, Calif) to obtain and evaluate multiplanar and 3-dimensional reconstructions.

Root lengths were measured in millimeters on the same longitudinal axis from a perpendicular projection to the vestibular cementoenamel junction in the sagittal section or mesial cementoenamel junction in the coronal section up to the vertex of the radicular apices of the central and lateral incisors adjacent to the impacted canine (Figs 3 and 4). Incisor root areas in square millimeters were measured as well. In the sagittal section, the area was measured from the buccal cementoenamel limit to the palatal cementoenamel limit (Fig 5). In the coronal section, the area included

Table IV. Measurements of the impacted canines according to orthodontic traction complexity

Measurement	*Complexity*	*n*	*Mean*	*SD*	P	*Mean difference*	*95% CI*	
							Lower	*Upper*
α angle (°)	Low	20	33.30	17.93	<0.001*	−21.49	−30.29	−12.69
	High	25	54.79	11.15				
β angle (°)	Low	20	38.88	19.46	0.165	−8.77	−21.27	3.74
	High	25	47.64	21.58				
Height (mm)	Low	20	11.02	5.00	0.606	−0.64	−3.13	1.85
	High	25	11.66	3.24				

*Statistically significant at $P < 0.05$. Independent t test.

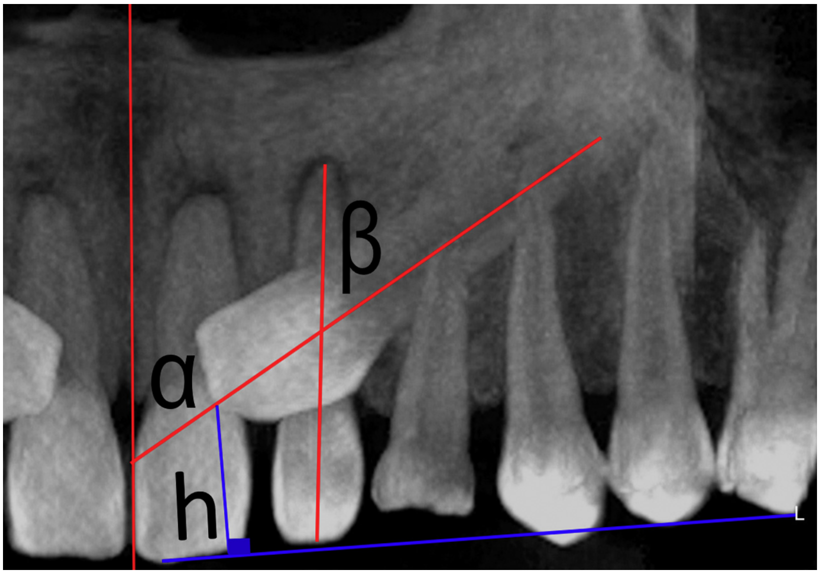

Fig 2. Measurement of angle α, angle β, and height h.

the path from the mesial to the distal cementoenamel limits (Fig 6). In the axial sections, the area of RR was measured at the level of 2 sectors. The root length on the sagittal section was divided into thirds, and the areas of the cervical and middle thirds in the axial sections were measured.

One rigid temporary anchorage device was installed. The appliance included a palatal acrylic button soldered on the bands in the permanent first molars and a modified palatal arch around the palatal surfaces of all maxillary teeth in 1.1-mm (0.043 in) or 1.2-mm (0.047 in) stainless steel wire (Dentaurum, Ispringen, Germany) with multiple palatal-occlusal-vestibular soldered hooks in 0.028-in wire between the first molar and second premolar, and the second and first premolars, mesial to the first premolar and distal to the lateral incisors (Figs 7 and 8). Vestibular hooks and device extensions allowed regulation of the buckles of closed helicoidal nickel-titanium coil springs, 0.010 × 0.036 in, 8 and 13 mm long, and 100 or 150 g of force (Dentos, Daegu, Korea), to perform intraosseous transalveolar traction. Activations of 4 to 5 mm were performed every 4 to 8 weeks (Fig 9). A passive 0.017 × 0.025-in stainless steel archwire placed on the previously aligned and leveled teeth was cinched distally of the last molar in the anchorage, before the traction. After traction, CBCT images were taken to control the treatment. Then, the final phase was started. All necessary procedures were performed to complete the orthodontic treatment.

RR in each incisor was measured by subtracting the initial value from the final value of length in millimeters and area in square millimeters in the 3 sections evaluated.

Statistical analyses

All statistical analyses were performed using SPSS software for Windows (version 19.0; IBM, Armonk,

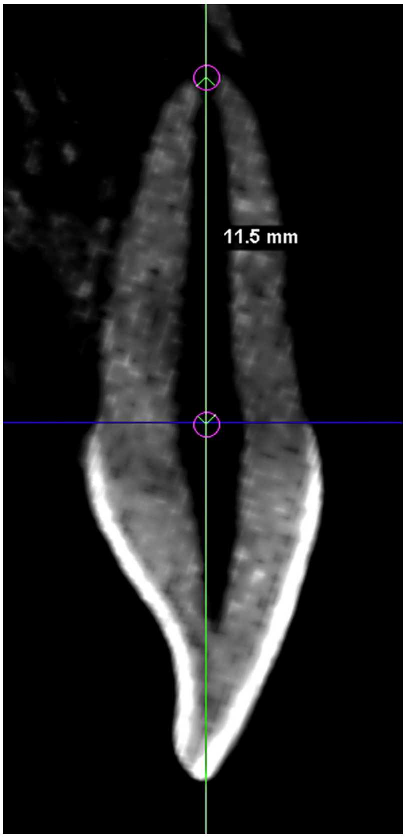

Fig 3. Assessment of the root length in the sagittal plane.

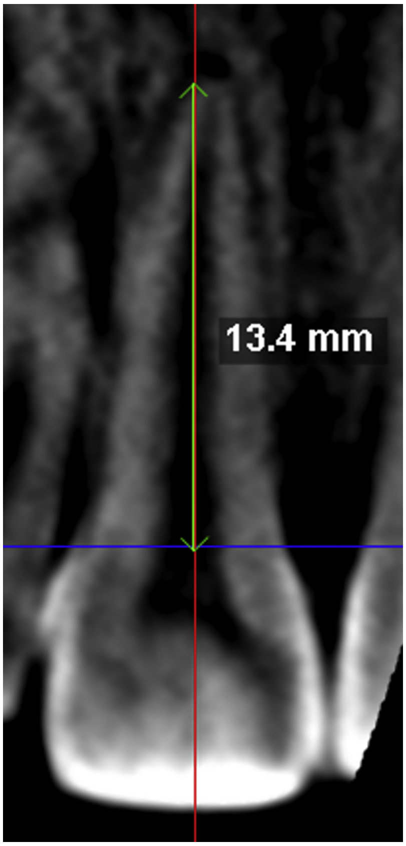

Fig 4. Assessment of the root length in the coronal plane.

NY). The data distribution was determined by Shapiro-Wilk tests. When the distribution was not normal, comparisons of RR between groups were evaluated with Mann-Whitney U tests; otherwise, we used *t* tests. Finally, a multiple linear regression model to determine the influence of each variable on RR was applied. The significance level was set at $P < 0.05$ for all tests.

RESULTS

The RR of maxillary incisors in the sagittal and coronal sections showed no significant differences between groups. Altogether, the root length range of RR was 1 to 1.5 mm, and the area range was 3 to 4 mm^2 in both groups (Tables V and VI). No significant differences were found in the axial sections between groups; likewise, the RR area was less than 2 mm^2 in both groups (Table VII).

Multivariate analysis using multiple linear regression with RR as the outcome variable did not show a significant influence on the complexity of orthodontic treatment ($P > 0.05$). However, the variable sex had an influence, specifically on the RR of the maxillary central incisors, and the location of the impacted canine (palatally displaced) had a significant influence on the RR area of the maxillary central incisor in the coronal section. The impaction height was significant as well ($P < 0.05$), and the initial RR was also significant ($P = 0.003$) regarding RR in the maxillary lateral incisor (sagittal section). To further evaluate the specific influence of canine impaction location, this variable was categorized into 2 dummy variables: the first comparing bicortically impacted canines vs palatally and buccally displaced canines ($P > 0.05$), and the second comparing palatally displaced vs bicortically and buccally impacted canines ($P = 0.012$, for RR area of central incisors in the sagittal sections) (Tables VIII and IX).

DISCUSSION

Orthodontists face a great challenge when treating patients with highly complex impacted maxillary canines,[18] particularly when the treatment includes impacted canines close to or in contact with the roots of anterior teeth and when they are horizontally positioned,[25] because the risk for RR of incisors is higher.[31] For these reasons, the aim of this study was to determine

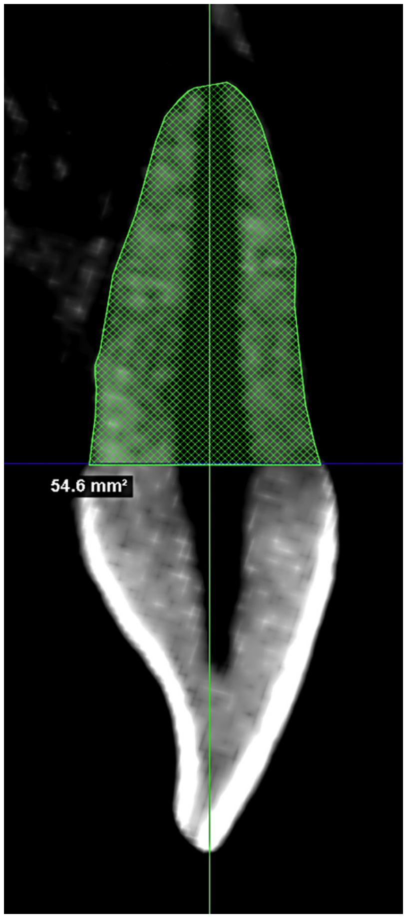

Fig 5. Assessment of the root area in the sagittal plane.

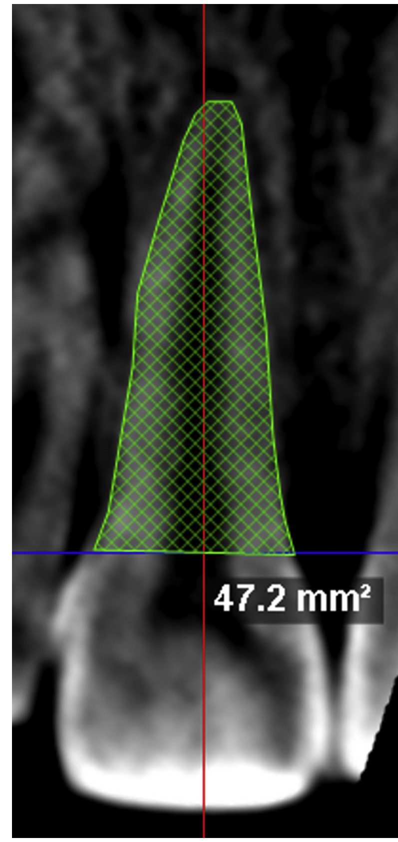

Fig 6. Assessment of the root area in the coronal plane.

the influence of the orthodontic traction complexity of impacted maxillary canines on the RR of incisors.

The use of CBCT for patients with impacted canines before and during orthodontic treatment, specifically after traction, is based on the ALARA principle.[32] The application of the same technique of traction, with nickel-titanium coil springs and reinforced anchorage ensures that the results can be compared between groups, although the direction of traction changes for each patient.[27] In addition, all patients were treated by 1 expert orthodontist (G.A.R.M.), with more than 20 years of experience with this type of impaction, reducing the possibility of operator bias in the study.

There are few methods that classify the complexity of orthodontic traction of impacted canines,[23,28] and even fewer using CBCT.[21] Moderate concordance has been reported when these methods have been compared with the clinical criteria of experts in this area.[21] The criteria to evaluate computed tomography scans to define the complexity of a patient with impacted canines in the sagittal sections are frequently based on the classification of Ericson and Kurol[23,28] or a modifications of it.[29] In sagittal sections, the classifications take into account the height of canine impaction, having as a reference the cusp tip or its root apex; additionally, in the axial section, some classifications evaluate the position of the impacted canine in relation to the line of occlusion to classify it as palatally, buccally, or bicortically centered. In our study, the classification of treatment complexity was made on the sagittal plane based on the impaction sector, classifying as most complex the impactions in sectors 3, 4, and 5 according to the method of Ericson and Kurol[23,28] due to their proximity to the midline. Regarding sector 3, we also included the measurement of α angle as a classification factor and defined as complex cases those with the highest horizontal tendency: ie, when the angle was greater than 40°. The location in the axial and coronal sections was considered as well, classifying the cases as palatally, buccally, or bicortically impacted, depending on the position of the crown of the impacted canine in relation to the incisor radius: ie, the occlusion line and based on a clear tomographic examination in both cuts, which was

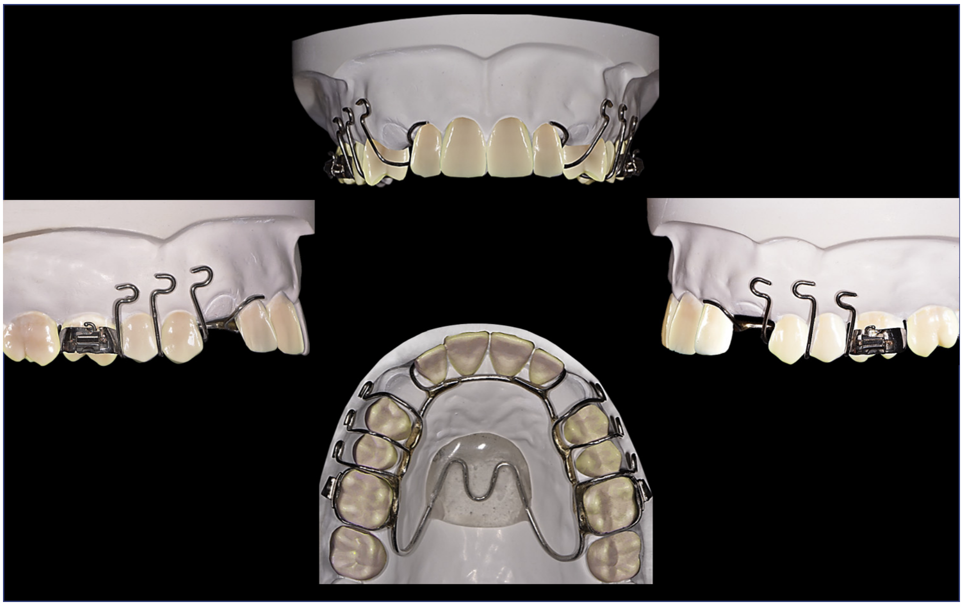

Fig 7. Graphic representation of the anchor including buccal extensions to favor the traction of impacted canines.

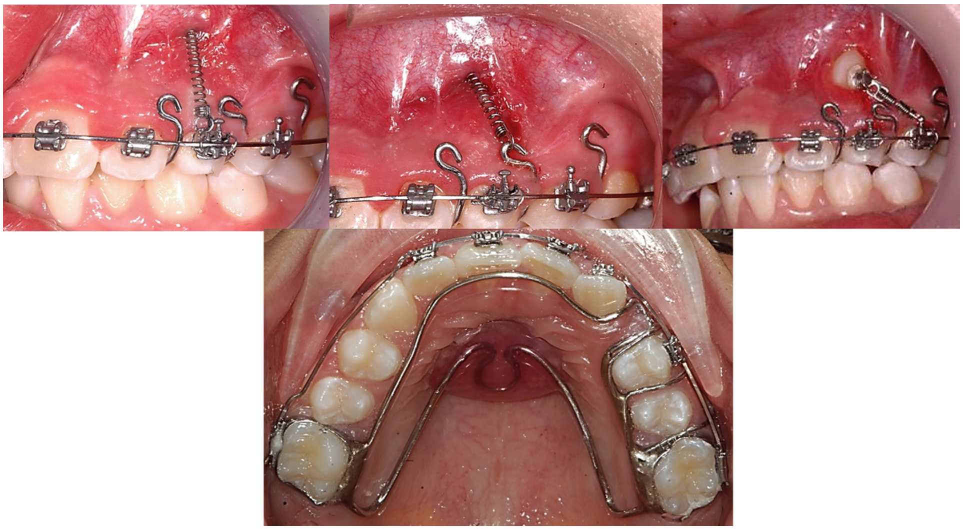

Fig 8. Example of impacted canine traction and rigid temporary anchorage device placed on permanent first molars with rigid palatal acrylic button.

reliable as shown by perfect interobserver agreement using the kappa test. Patients with bicortically impacted canines (in the middle of the 2 cortical bones)[17,18] (Fig 10) were defined as more complex, due to their proximity to the incisor roots (close to the midline, sectors 4 and 5)[23,28] before orthodontic treatment. Although buccally and palatally impacted canines were included in both groups, bicortically impacted canines were included only in the high complexity group. Additionally, in all cases of close proximity or physical contact, RR was observed before starting canine traction. However, after finishing traction, this RR did not increase significantly and did not show differences compared with the RR after traction in the low complexity group. Nevertheless, future studies including only subjects with bicortical

Fig 9. Example of bilateral impacted canine traction.

Table V. Comparison of RR of maxillary incisors and area according to orthodontic traction complexity, sagittal section

		Low complexity (n = 20)		*High complexity (n = 25)*			*95% CI*		
Tooth	*Measurements*	*Mean*	*SD*	*Mean*	*SD*	*Mean difference*	*Lower limit*	*Upper limit*	P
Maxillary lateral incisor	Root resorption (mm)	1.27	1.09	1.28	0.95	−0.01	−0.63	0.60	0.964
	Resorption area (mm^2)	2.93	3.09	3.15	2.52	−0.22	−1.91	1.46	0.791
Maxillary central incisor	Root resorption (mm)	1.45	1.18	1.56	1.03	−0.11	−0.78	0.55	0.731
	Resorption area (mm^2)	3.62	3.14	3.44	3.18	0.17	−1.74	2.09	0.858

Independent *t* test.

Table VI. Comparison of RR of maxillary incisors and area according to orthodontic traction complexity, coronal section

		Low complexity (n = 20)		*High complexity (n = 25)*			*95% CI*		
Tooth	*Measurement*	*Mean*	*SD*	*Mean*	*SD*	*Mean difference*	*Lower limit*	*Upper limit*	P
Maxillary lateral incisor	Root resorption (mm)	1.58	1.03	1.28	1.13	0.30	−0.35	0.96	0.355
	Resorption area (mm^2)	3.26	2.37	2.45	1.85	0.81	−0.46	2.07	0.205
Maxillary central incisor	Root resorption (mm)	1.55	1.05	1.32	1.02	0.23	−0.39	0.86	0.454
	Resorption area (mm^2)	3.47	3.41	4.08	3.09	−0.61	−2.57	1.35	0.532

Independent *t* test.

Table VII. Comparison of the area (mm^2) of RR of maxillary incisors at the cervical and middle thirds according to orthodontic traction complexity, axial section

		Low complexity (n = 20)		*High complexity (n = 25)*			*95% CI*		
Tooth	*Measurement*	*Mean*	*SD*	*Mean*	*SD*	*Mean difference*	*Lower limit*	*Upper limit*	P
Maxillary lateral incisor	Cervical third	0.43	0.53	0.99	1.42	−0.57	−1.24	0.11	0.166
	Middle third	0.81	0.94	1.48	1.80	−0.67	−1.57	0.23	0.534
Maxillary central incisor	Cervical third	0.69	1.00	1.15	1.62	−0.46	−1.30	0.37	0.341
	Middle third	1.36	1.91	1.67	2.70	−0.31	−1.75	1.13	0.768

Mann-Whitney U test.

impaction should be carried out to confirm our results. Canine impaction height is not an exclusive complexity criterion, since an impaction with low height but close to the midline would be difficult to treat, whereas a patient with a higher canine impaction in sector 1 would not have an increased risk of RR of the anterior teeth because the canine has no contact with their roots. Orthodontists frequently treat impacted canines with RR in the maxillary incisors.[33] This condition is only a caution factor, demanding the use of efficient

Table VIII. Multiple linear regression analysis of RR (mm) and area of maxillary incisors, sagittal section

	Maxillary lateral incisor		*Maxillary central incisor*	
Predictor variable	β	P	β	P
Root resorption (mm)				
Constant		0.298		0.206
Orthodontic traction complexity	−0.01	0.970	0.68	0.085
Sex	0.03	0.867	−0.29	0.173
Age	−0.07	0.698	−0.02	0.901
Duration of traction	−0.18	0.366	0.11	0.589
Dummy 1 (palatine and buccal vs bicortical)	−0.33	0.200	0.07	0.796
Dummy 2 (palatine vs buccal and bicortical)	0.24	0.357	−0.39	0.170
Sector of impacted canine	0.43	0.218	−0.33	0.364
Initial root resorption	0.78	0.003*	0.03	0.896
Angle α of impacted canine	−0.45	0.303	−0.63	0.165
Angle β of impacted canine	0.58	0.062	−0.09	0.805
Height of impacted canine	−0.23	0.486	0.58	0.107
Initial root length	0.15	0.535	−0.07	0.822
r^2	0.197		0.155	
Area of root resorption (mm^2)				
Constant		0.082		0.029*
Orthodontic traction complexity	0.10	0.784	0.70	0.056
Sex	−0.14	0.489	−0.49	0.010*
Age	0.06	0.747	0.01	0.925
Duration of traction	−0.15	0.442	0.06	0.727
Dummy 1 (Palatine and Buccal vs Bicortical)	−0.30	0.219	−0.19	0.385
Dummy 2 (Palatine vs Buccal and Bicortical)	−0.01	0.982	−0.59	0.012*
Sector of impacted canine	0.42	0.219	−0.29	0.340
Initial root resorption	0.34	0.168	0.27	0.249
Angle α of impacted canine	−0.71	0.094	−0.76	0.053
Angle β of impacted canine	0.53	0.084	−0.05	0.864
Height of impacted canine	−0.05	0.882	0.69	0.024*
Initial root length	−0.04	0.870	−0.25	0.308
r^2	0.242		0.380	

Dummy 1, location of impacted canine (palatine and buccal vs bicortical).
Dummy 2, location of impacted canine (palatine vs buccal and bicortical).
*Statistically significant at $P < 0.05$.

biomechanics with optimal forces to prevent greater radicular resorption. In the high complexity treatment group, 60% of the patients had initial RR, making treatment even more difficult, compared with 15% of the patients with this condition in the low complexity group. We considered that the initial RR of adjacent permanent teeth during maxillary canine eruption could be, according to the literature, more an effect of the physical contacts between the erupting canine and the adjacent tooth than the action of the dental follicle size.[34,35] Likewise, although in the high complexity group the RR condition was more frequent at the beginning of treatment, the RR after traction was similar in both groups; therefore, it is not apparently a risk factor. However, more studies evaluating this condition must be carried out.

The amount of RR in both groups (high complexity vs low complexity) was similar and smaller than 2 mm. This amount of RR does not depict risk for oral or tooth health that could lead to tooth loss. The RR was approximately 1 to 1.5 mm and was smaller than 4 mm^2 in the sagittal and coronal sections; for the axial section, no significant differences were found.

The multivariate analysis did not identify a common risk factor, including the influence of the orthodontic traction complexity. We only detected the influence of sex, indicated by a higher risk of resorption in male patients. The effect of sex is controversial and considered in few studies evaluating RR after traction of impacted canines.[36-38] One study found no significant differences regarding sex.[36] Recent studies have concluded that after conventional orthodontic treatment without treating impacted canines, sex does not influence RR of the incisors.[39,40] Nevertheless, this information cannot be extrapolated to treatments with canine impaction. In our study, the influence of sex was seen only for some comparisons: specifically, the maxillary central incisor. However, an explanation that supports the appearance

Table IX. Multiple linear regression analysis of RR and area of maxillary incisors, coronal section

	Maxillary lateral incisor		*Maxillary central incisor*	
Predictor variable	β	P	β	P
Root resorption (mm)				
Constant		0.939		0.047*
Orthodontic traction complexity	0.34	0.330	0.52	0.120
Sex	−0.18	0.334	−0.45	0.020*
Age	−0.20	0.211	−0.06	0.704
Duration of traction	0.37	0.054	0.02	0.914
Dummy 1 (palatine and buccal vs bicortical)	0.18	0.424	−0.54	0.053
Dummy 2 (palatine vs buccal and bicortical)	0.03	0.888	−0.29	0.207
Sector of impacted canine	−0.11	0.719	−0.31	0.305
Initial root resorption	0.30	0.290	0.17	0.449
Angle α of impacted canine	−0.40	0.321	−0.30	0.427
Angle β of impacted canine	−0.07	0.827	−0.24	0.417
Height of impacted canine	−0.05	0.862	0.53	0.078
Initial root length	0.53	0.022*	−0.26	0.384
r^2	0.338		0.387	
Area of root resorption (mm^2)				
Constant		0.083		0.034*
Orthodontic traction complexity	0.14	0.665	0.40	0.255
Sex	−0.50	0.014*	−0.63	0.003*
Age	−0.22	0.155	0.19	0.236
Duration of traction	0.22	0.200	0.04	0.815
Dummy 1 (palatine and buccal vs bicortical)	−0.14	0.513	−0.28	0.228
Dummy 2 (palatine vs buccal and bicortical)	−0.05	0.815	−0.23	0.329
Sector of impacted canine	−0.01	0.980	−0.23	0.470
Initial root resorption	0.16	0.435	−0.10	0.627
Angle α of impacted canine	−0.09	0.811	−0.02	0.959
Angle β of impacted canine	−0.42	0.139	−0.49	0.086
Height of impacted canine	−0.10	0.731	0.43	0.164
Initial root length	0.26	0.225	−0.31	0.171
r^2	0.412		0.332	

Dummy 1, location of impacted canine (palatine and buccal vs bicortical).
Dummy 2, location of impacted canine (palatine vs buccal and bicortical).
*Statistically significant at $P < 0.05$.

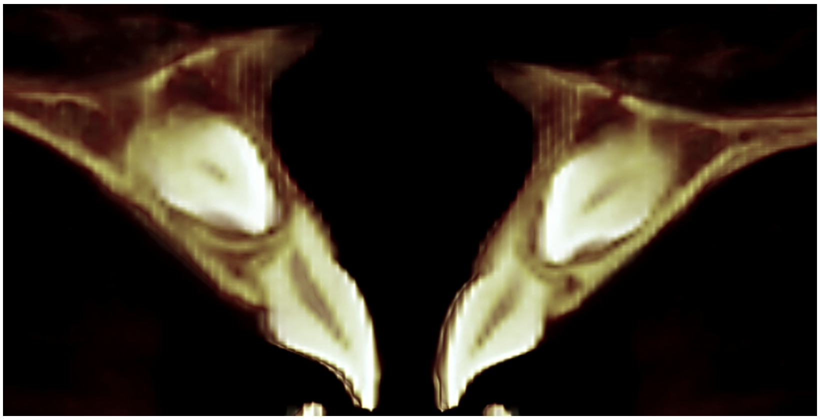

Fig 10. Example of maxillary impacted canine in intermediate position or centered bicortically.

of the RR in this tooth can only be based on future studies with larger samples of both sexes. If any predictor variable is truly a risk factor for RR, its influence should have been consistent across all CBCT scans analyzed and could be present in both incisors and not only one.

In this study, the null hypothesis was accepted: there is no significant difference in the amount and area of RR of the maxillary incisors after orthodontic traction of impacted canines with different levels of complexity. This RR behavior could allow the orthodontist to treat patients with impacted canines in complex positions, since there is not a greater risk of RR.

CONCLUSIONS

The orthodontic traction complexity of impacted maxillary canines is not a risk factor for greater RR of the maxillary incisors.

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