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Risk Factors for Resorption of Lateral Incisors by Impacted Maxillary Canines: Systematic Review.

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ABSTRACT

Aim: The objective of this systematic review was to determine and list risk factors for lateral incisor resorptions by the impacted maxillary canines.

Methods: This systematic review followed the PRISMA guidelines. The selected clinical studies were collected from the following databases: MEDLINE (via PubMed), Science Direct, Scopus and Cochrane. The selection of studies spanned the last 10 years. Detailed search strategies were developed for each database using MeSH Terms. Selected studies were filtered by title, abstracť and full text.

Results: Among the 1783 selected publications, 22 were considered relevant, and met the eligibility criteria. These studies included a total number of 2961 patients; and identified general and local risk factors.

Conclusion: None of the studies showed that age was a significant risk factor, however, it can be linked to another local risk factor which is the stage of development of the root of the impacted canine.

Key words: Risk Factors, Impacted canine, Root resorption, Incisor.

Introduction:

The maxillary canine plays an important role both aesthetically and functionally, the position of the permanent maxillary canine is strategically important to maintain the harmony and symmetry of the occlusal relationship, it is the tooth with the longest and most tortuous evolutionary path. Maxillary canines are the teeth most frequently included after the third molars [1] with a prevalence between 1% and 3% [2], however, the exact etiology of this inclusion remains unknown. [3]

If left untreated, the included maxillary canines can shorten the arch, cause follicular cysts to grow, affect adjacent teeth's alignment, and raise the risk of recurring infections [4]. They can also create external resorption of surrounding teeth. This is an irreversible, aseptic and harmful sequelae that causes the progressive loss of the cement and dentin of adjacent teeth compared to the included maxillary canine [5].

Since the introduction of Cone Beam Computer Tomography (CBCT) in dentistry, which has increased the sensitivity and accuracy of the diagnosis of root resorption, previously thought to be rare (1-2% [6]), more resorptions have been found. [5]. Indeed, recent research using CBCT images as a diagnostic tool has revealed that up to 70% of the maxillary canines included result in at least one nearby tooth showing root resorption. [7,8]. The most affected tooth is the lateral incisor with a prevalence of 8.20% to 89.61% followed by the central incisor with a prevalence ranging from 1.19% to 35.06%, the first premolar may also be affected (4.48% to 11.72%) [9]. Resorption can potentially affect all upper incisors at the same time, although this is very unlikely [10].

In most cases, root resorption goes undiagnosed until much later, is clinically asymptomatic, and is very challenging to treat. [3] Determining the risk factors for the included canines' resorption of maxillary incisors is therefore essential for both early diagnosis and treatment planning. For patients with limited space, specific treatment options, like extracting a severely resorbed incisor, may be preferable to extracting intact premolars. [3]

This systematic analysis of the literature aimed to identify the various risk variables associated with maxillary canines resorption of the central and/or upper lateral incisors.

Methods:

We carried out a systematic review, that was developed based on a pre-determined protocol, and was reported in line with the updated version of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). (11) Following the PRISMA checklist's recommendation, the inclusion criteria conformed to the PICO framework: [11]

- P: Adult participants (over 18 years of age) who have been diagnosed with an included canine with a relationship to the lateral incisor.
- I: All the studies responding to the boolean equations ((impacted canine) OR (impacted cuspid) OR (unerupted canine)) AND (root resorption) AND (incisor) AND (risk factors); ("Tooth, Unerupted"[Mesh] OR "Tooth, Impacted"[Mesh]) AND "Cuspid"[Mesh] AND "Root Resorption"[Mesh] AND "Incisor"[Mesh] AND "Risk Factors"[Mesh]; "Tooth, Impacted"[Mesh]) AND "Cuspid"[Mesh] AND "Root Resorption"[Mesh]; chosen and elaborated from these key words (Risk Factors, Impacted canine, Root resorption, Incisor) have been included. There was a comparison group in every study that was analysed. The Cochrane Handbook for Systematic Reviews of Interventions was followed in the inclusion and management of studies including multiple interventions. [12]
- O: The selection process limited the number of research to those that looked at risk factors for maxillary canine lateral incisor resorption. This is made possible by the odds ratio (OR) for case-control studies, which uses confidence intervals to evaluate the data. The length of the study, the timing of the assessments, or the study context were not restricted.

All article that was judged to be an expert report, letter, commentary, or editorial was removed. After analysing the abstracts and critically reading the complete text, we removed articles that did not align with our research goals. Papers that were published before 2011 have not been included.

The research strategy ran from December 22, 2021 to March 21, 2022. The following electronic databases were consulted: Embase, Scopus, Science Direct, PubMed, Cochrane Library. The articles were first selected on their title, then on their abstract and finally on their full text. At each of these sorting steps, items were retained for their relevance in answering the questions asked and others were, conversely, discarded. This approach has allowed us to gradually reduce the number of items and filter them so that we can only read fewer items in line with our goal.

Data extracted from the included documents covered:

- Names of authors, year of publication, place of study
- Type of study
- Data acquisition means
- Participants
- Sex
- Middle age
- Risk factors studied

The studies selected were observational studies, the quality of these studies is assessed by STROBE (STrengthening the Reporting of Observational studies in Epidemiology).

Results:

Figure 1 shows the included studies at each phase of the review. A total of 1783 articles were screened by title and abstract, and 31 were assessed by full text. Twenty-two articles met the eligibility criteria and were included in this systematic review: 7 case-control studies ,7 cross-sectional studies and 8 retrospective studies. All the characteristics of these studies have been described in Table I.

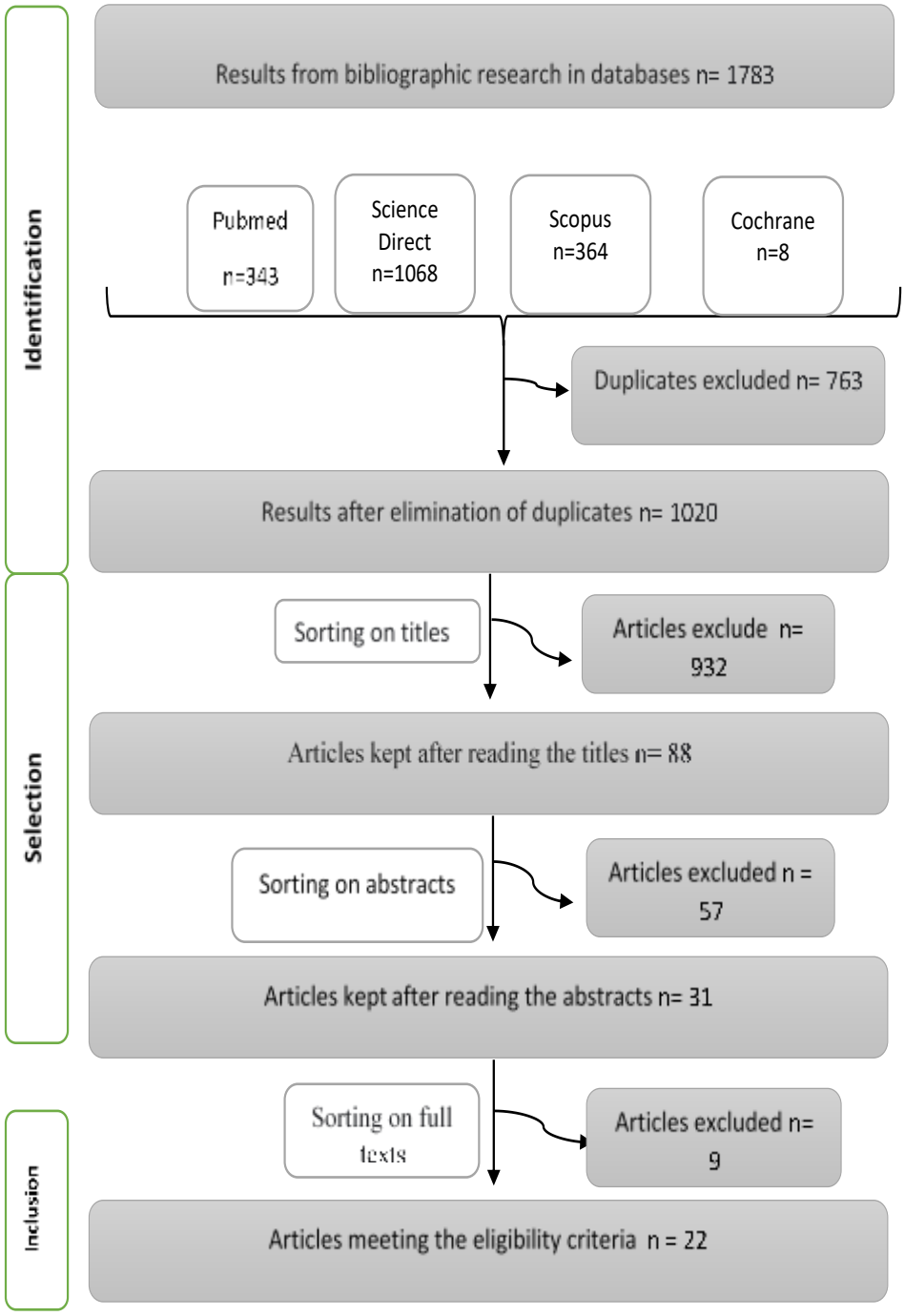

Figure 1. PRISMA flow diagram which included searches of databases (11)

Table I. Characteristics of the studies included

Title	**Author/Year**	**Type of study**	**Sample**	**Gender**	**Age**	**Means of acquisition**	**Risk Factors**	**Statistical analysis strategy**	**Conclusion**
Root Resorptions on Adjacent Teeth Associated with Impacted Maxillary Canines [8]	Simic and al (2022)	Cross-sectional study	89	58F 31M	18.3 ±4.1	CBCT	Age , Gender Sagittal direction Vertical position Horizontal position Distance of occlusal plane Distance of midline Angle between canine and central or lateral incisor Angle between canine and the occlusal plane Angle between canine and the midline	Logistic regressions Spearman's correlation test Mann–Whitney test	Significant risk factors : Female gender Palate position Angle between canine and central or lateral incisor and/or ASM increased Distance between the cusp of the included canine and the occlusal plane of 11.7± 3.6 mm Distance between the cusp of the included canine and the midline of 9.25± 4.4 mm Horizontal position
Radiographic features in 2D imaging as predictors for justified CBCT examinations of canine-induced root resorption [14]	Andresen and al (2022)	Cross-sectional study	99	57F 42M	13	Panoramic radiography CBCT	Age Side of the inclusion Vertical position Stage of root development Riziform Lateral Incisor / Lateral incisor with distal tip Angle between canine and the occlusal plane Angle between canine and the midline Angle between canine and lateral incisor	Univariate logistic regression analysis	The included canine root development stage is a significant risk factor for root resorption of adjacent lateral incisors.
Risk factors for maxillary impacted canine–linked severe lateral incisor root resorption: A cone-	Wang and al (2020)	Case control study	163	_	_	CBCT	Age , Gender Canine angulation Mesio distal position Vertical and vestibulo lingual position Canine follicular bag	Cohen Kappa Test Kolmogorov Smirnov test Wilcoxon Test Chi square test Binary regression	Significant risk factors : Female gender Mesial position Vertical position Vertical angle between 0 and 30°

beam computed tomography study [15]									Relative angle (the angle between the included canine and the adjacent incisor axis) between 0 and 60° Follicular bag widened between 1 and 3 mm
Predictive factors for resorption of teeth adjacent to impacted maxillary canines [16]	Cuminetti and al (2017)	Retrospective study	25	_	21 ±7,5	CBCT	Age, Gender Sagittal location of the canine crown/ the dental arch Vertical location of the canine cusp Transverse location Follicular bag dimension Shape of the follicular bag	Chi-2 test Variance Analysis Test (Anova) Covariance Analysis Test (ANCOVA)	The combination of the sagittal and vertical situation is a predictor of the risk of root resorption
Prevalence and risk factors of root resorption of adjacent teeth in maxillary canine impaction, among untreated children and adolescents [17]	Rafflenbeul et al (2018)	Retrospective study	60	_	Average age 12.2 years	CBCT	Age, Gender Size of follicular bag Alpha angle (formed at the intersection of the occlusal line and the longitudinal axis of the canine) Relative position of the canine included in the arcade Mesio Distal position Contact with adjacent roots Lateral incisor: normal, agenesis or riziform Inclusion of single or bilateral canine	Descriptive statistics and multiple logistic regressions	Contact between the canine and root of adjacent teeth was the only statistically significant risk factor identified
Predisposing factors for severe incisor root resorption	Chaus hu et al (2015)	Case control study	57	_	12 ± 1.4	Panoramic radiography CBCT	Age, Gender Buccolingual localization Mesiodistal location	multivariate statistical analysis	Severe root resorption of the incisor was significantly higher in female subjects

associated with impacted maxillary canines [18]							the overlap of the adjacent incisor the vertical height of the crown Width of canine dental follicle Lateral incisor anomalies		with enlarged dental follicles, and normal lateral incisors
Location and severity of root resorption related to impacted maxillary canines: a cone beam computed tomography (CBCT) evaluation [19]	Doğra macı and al (2015)	Cross-sectional study	85	60F 25M	_	CBCT	Age Gender Inclusion site	Unidirectional analysis of variance Chi 2 test Kruskal Wallis test Poisson regression	No significant correlation between age, gender, site of inclusion and risk of resorption
Cone-beam computed tomography findings of impacted upper canines [20]	Da Silva Santos and al (2014)	Cross-sectional study	79	56 F 23 M	Average age 22 years	CBCT	Gender Sagittal position Width of canine follicular bag	Chi-2 test Fisher's exact test	An association between the presence of root resorption of adjacent teeth and the location of the canine included, as well as the sex and size of the follicular sac was not statistically significant
Effects of impacted maxillary canines on root resorption of lateral incisors A cone beam computed tomography study [21]	Ucar et Al (2017)	Case control study	46	30F 16M	F : 19.44 ± 5.77 M : 19.53 ± 6.66	CBCT	Gender Lateral incisor volume Sagittal position Mesiodistal position	Intraclass Correlation coefficients The independent sample t test	Gender, location and different degrees of canine angulation did not influence the amount of root resorption.
Incisor root resorption associated with palatal displaced maxillary canines:	Alemam et Al (2019)	Case control study	82	19 H 63 F	20.84 ± 6.54	CBCT	Size of canine follicles Contact with adjacent incisors Associated dental abnormalities	Chi-2 test Variance Analysis Test (Anova)	Predictive factors: Canine contact with adjacent incisor Size of canine follicle Riziform lateral incisor

Analysis and prediction using discriminant function analysis [22]							Sector analysis Vertical relationship of canine to adjacent root Angulation and tip of the lateral incisor Available space for the canine in the dental arch		
Relationship of Angulation of Maxillary Impacted Canines with Maxillary Lateral Incisor Root Resorption [23]	Ardakani et Al (2020)	Case control study	40	32F 8M	18.2 ± 6.55	Panoramic radiography CBCT	Alpha Angle The ß angle (formed at the intersection of the cervical line and the longitudinal axis of the canine) The cervical line (the line connecting the anterior and the lower points of C2 (cervical vertebra)) Sagittal position The impacted canine quadrant	Chi-2 test T test Pearson Correlation Test Mann-Whitney Spearman Test Exact fisherman's test	The angles α and ß, the impacted canine quadrant and the sagittal position had no significant correlation with the presence/absence of root resorption in the adjacent lateral incisor
Impacted maxillary canines and root resorption of adjacent teeth: A retrospective observational study [10]	Guarnieri et al (2016)	Cross-sectional study	50	28F 22M	11.7	CBCT	Angulations of the canines: angle a : the canine inclination relative to the midline angle b: the inclination of the canine in relation to the axis of the lateral incisor angle g: the inclination of the canine in relation to a horizontal line through the incisive edge of the permanent central incisor and the occlusal plane of the	Binary logistic regression Chi-2 test	Angle b has the greatest influence on the prediction of root resorption (the probability of resorption is greater than 61% if angle b>54°)

							first permanent molar on the affected side. 2-Lateral/canine incisor overlap 3- Lindauer analysis		
Evaluation of impacted canines' localization and adjacent lateral incisors' root resorption with orthopantomography and cone-beam computed tomography [24]	Akkuc et al (2020)	Cross-sectional study	343	207 F 136 M	10	CBCT	Contact between the included canine and the lateral incisor Follicle size Location of the canine in the transverse direction Vertical location of the canine cusp included	Chi-2 test	Resorption of the lateral incisor correlates with direct contact with the included canine and its vertical location
Incidence of lateral incisor root resorption associated with impacted maxillary canines [25]	Lipshatz et al (2021)	Case control study	133	86F 47M	20	CBCT	Age , Gender Type of inclusion Angulation of the long axis of the impacted canine relative to the vertical line between the upper central incisors Canine overlap on lateral and central incisors	logistic regression: linear mixed models generalized	The radiographic level of incisor overbite by the impacted canine in the mesiodistal direction is a risk factor
Predictors of root resorption associated with maxillary canine impaction in panoramic images [26]	Alqerban et al (2016)	Cross-sectional study	306	188 F 118 M	Average age 14.7 years	Panoramic radiography CBCT	Age , Gender Temporary canine root resorbtion Overcrowding in maxillary upper anterior region Optimal apical zone Sufficient MD space Canine macrodontia Open canine apex Location of the canine Type of impaction (horizontal or vertical)	Fisher's exact and Mann–Whitney U-tests Chi-2 test	The gender, the apex of the canine, the vertical position of the crown and macrodontia of the canine were the strongest predictive factors of root resorption

							Complete canine development The presence of abnormalities, such as mesiodens or supernumerary teeth, riziform lateral incisor, agenesis of permanent teeth and impaction of other permanent teeth Canine angulation relative to midline, occlusal plane and lateral incisor Vertical position of the canine crown Distal canine overbite with lateral incisor		
Impacted maxillary canines and root resorptions of neighboring teeth: a radiographic analysis using cone-beam computed tomography [27]	Lai and al (2013)	Cross-sectional study	113	74 F 39 M	19.35	CBCT	Age , Gender Development stage of canine root Size of canine follicle Sagittal position Transverse position Vertical position Location of canine in relation to bone and soft tissue Morphology of the lateral incisor Contact or proximity relationship with the adjacent incisor	Cohen kappa test Logistic regression	This study found a statistically significant correlation between root resorption of adjacent teeth and: - The location of the impacted canine relative to bone or soft tissue - The vertical location of the canine in relation to the long axis of the adjacent incisor - Development stage of canine root (open or closed apex) - The contact relationship
Maxillary canine impaction increases root resorption risk of adjacent teeth: A problem of physical proximity [4]	Yan et al (2015)	Case control study	170	_	14.5	CBCT	Age , Gender Development stage of canine root Contact relationship with adjacent incisors	Cohen kappa test Intraclass correlation test Chi 2 Test Wilcoxon Test “stepwise forward” logistic regressions	The significant risk factors are: Contact relationship < 1 mm between canines and teeth affected, the mesio-distal position of the canine, the

							Position of the canine in the mesiodistal direction Position of the canine in the vestibulolingual direction Distance between the included canine and the median axis of the affected tooth Angle between the included canine and the affected tooth axis Distance between canine included and occlusal plane Distance between the included canine and the median sagittal axis		distance between the canine included and the affected teeth and the distance between the included canine and the median sagittal plane are significant risk factor for the resorption of the central incisor. Development stage of canine root included
The prevalence of root resorption of maxillary incisors caused by impacted maxillary canines [28]	Strbac et al (2013)	Cross-sectional study	440	288 F 152 M	Average age 24.7 years	CBCT	Contact relationship with adjacent incisors Sagittal position Shape and width of canine follicular bag Position of the canine included in relation to the cortical of the alveolar bone and in relation to the root of the temporary canine	-Chi 2 Test -Wilcoxon Test - Wilcoxon ranksum test - Kruskal-Wallis tests - Spearman test	The presence of root resorption of the central and lateral maxillary incisors is significantly correlated with an existing contact relationship with impacted maxillary canines
The position of maxillary canine impactions and the influenced factors to adjacent root resorption in the Korean population [29]	Kim et al (2012)	Cross-sectional study	148	89F 59M	_	Panoramic radiography CBCT	Gender Side of the affected canine: right or left Vestibulo lingual position Mesio distal position Canine angulation included: angle formed	- The ordinal logistic regression analysis model - test t -chi-2 test - Single analysis of variance	The sagittal and mesiodistal positions have been determined as significant factors

							between the long axis of the canine included and the two condylar line		
Root resorption of adjacent teeth associated with maxillary canine impaction in the saudi arabian population: A crosssectional cone-beam computed tomography study [30]	Alassiry et Hakami (2022)	Cross-sectional study	169	98F 71M	20.34 ± 8.9	CBCT	Age , Gender Type of impact: unilateral or bilateral Impact side: left or right	- ANOVA statistics - The Kruskal– Wallis test - Chi 2 test - The Poisson regression model	A significant association was found between gender, type of impaction and root resorption. Women with bilateral canine impaction were more affected by root resorption.
Prediction of maxillary lateral-incisor root resorption using sector analysis of potentially impacted canines [31]	Schindelet Sheinis (2013)	Cross-sectional study	40	-	-	Panoramic radiography CBCT	Included Canine Distal Mesio Position: classified in sectors I, II, III, IV of distal in mesial	- Logistic regression	There was significantly more root resorption in sectors III and IV when combined and compared to sectors I and II
Impacted maxillary canines and their relationship with lateral incisor resorption: A cone beam computed tomography study [32]	Yilmaz et al (2020)	Cross-sectional study	169	73F 96M	17.9 1 ± 6.52	CBCT	Vertical, mesiodistal and sagittal position	-Student t-test and ANOVA Mann Whitney U test and the Kruskal-Wallis test Chi 2 test	The risk of resorption of the lateral incisors increased when the included maxillary canines approach the mid-palatine line or are on the palatine side. The resorption of the lateral incisors was not related to the included vertical position of the maxillary canine

The risk of bias of the included studies was assessed by measuring the quality of the observational studies with the STROBE tool (STrengthening the Reporting of OBservational studies in Epidemiology) summarized in Table II.

Table II. STROBE Evaluation

Av: Average G: Good M: Mediocre

Studies		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
STROBE Item:	1-a	0	1	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
	1-b	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	3	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
	4	1	1	1	0	0	1	0	1	0	1	1	1	1	0	0	0	1	0	0	1	1	1
	5	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
	6	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	0	0
	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	9	1	1	1	1	0	0	1	0	1	1	0	0	1	0	0	1	1	0	1	0	0	0
	10	0	1	1	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0	1	0	0	0
	11	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	12-a	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	12-b	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	12-c	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	12-d	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0
	12-e	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	0	1
	13-a	0	1	1	0	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
	13-b	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	13-c	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	14-a	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	0	1
	14-b	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	15	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	16-a	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	1	1
	16-b	1	1	0	0	0	0	1	0	0	0	1	0	1	0	1	0	0	1	0	0	0	1
	16-c	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	17	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	19	0	1	1	0	1	1	1	0	0	1	1	0	1	1	1	1	1	0	0	0	0	0
	20	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	21	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	1
	22	1	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0
Total		20	27	23	18	18	18	19	17	20	23	21	18	25	18	20	20	21	17	20	18	15	18
Percentage		62.5	84.3	69.6	56.2	56.2	54.5	59.3	53.1	60.6	69.6	63.6	56.2	78.1	54.5	62.5	62.5	63.6	53.1	62.5	56.2	45.4	56.2
Grades of methodological quality		Av	G	Av	Av	Av	Av	Av	Av	Av	Av	Av	Av	G	Av	Av	Av	Av	Av	Av	Av	M	Av

There will be two categories of general risk factors: gender and age:

- Gender : According to Simic et al [8], Wang et al [15], Alqerban et al [26], Alassiry and Hakami [30], female gender was a significant risk factor.
- Age: None of the studies demonstrated that age was a significant risk factor

Local risk factors involved the canine included, adjacent incisors and their relationships

- **Risk factors relative to the included canine**

Root development of the canine: According to Yan [4], Alqerban [26], Lai [27] and Andresen [14], The probability of root resorption on the central and lateral incisors was approximately twice as high in maxillary quadrant sites with closed canines compared to those with an enclosed canine with an open apex.

Site of the inclusion: According to Dogramaci [19], the site of the impaction, whether in the right or left maxilla, had no significant effect on the incidence of resorption lesions. Unlike Alassiry and Hakami [30], which raised a significant association between the site of impaction and root resorption.

Three-dimensional position of the canine included in the sagittal, vertical and mesio-distal direction: According to Yilmaz et al [32], and Simic et al [8], the risk of resorption of the lateral incisors increased when the maxillary canines included were on the palatine side. Unlike Kim et al [29], who report that this risk increased when the canine was in the vestibular position.

Simic et al [8] reported that the risk increases at a distance between the cusp of the included canine and the occlusal plane of 11.7 3.6 mm, thus increasing the risk in the apical region. This was confirmed by Wang [15] et al.

As reported by Kim [29], Wang [15], Schindel [31], and Yilmaz [32] , the mesio-distal position was a significant risk factor, this risk increased in the mesial position.

Canine inclination: Based on Wang [15], Guarnierie [10] and Simic [8] the included canine tilt relative to the long axis of the lateral incisor had the greatest influence on the prediction of root resorption.

Width of canine follicular bag: According to Wang [15], Alemam et al [22], the wider the follicular bag, the greater the risk of resorption.

- **Risk factors relative to the adjacent incisors**

As reported by Alemam et al [22], the presence of lateral incisors with shape abnormalities is a negative predictor of resorption.

- **Risk factors based on the relationships between the canines and adjacent incisors**

Yan [4], Rafflenbeul [17] Alemam [22] and Akkuc [24], reported that the resorption of the lateral incisor was correlated with direct contact with the included canine.

Discussion

The objective of this systematic review was to investigate the various risk variables for maxillary canines included in lateral incisor resorptions. Regarding general risk factors including age and gender, none of the studies showed that age was a significant risk factor, however, it can be linked to another local risk factor which is the stage of development of the root of the impacted canine. This study focused on recent scientific research by emphasising articles published between 2011 and 2022.

These variables fell into two categories: general factors and local factors. The former refers to the elements involving the included canines, while the latter deals with the factors involving the nearby incisors.

Most local factors have been determined radiologically, such as the position and inclinations of the canine, the width and shape of the follicular sac, or the proximity to the incisor roots. The selected studies [4,8,14–22,24,25,27,28,30–32] evaluated these risk factors based on 3D CBCT imaging. Grybienė et al [34] conducted a literature review summarizing baseline diagnostic methods and treatment strategies for 23 included maxillary canine studies. In their study [34], it was reported that panoramic imaging could help predict the incidence of maxillary canines while CBCT could accurately locate the included maxillary canines. A study by Jawad et al [35] supported a 63% improvement in the detection rate of root resorption with the use of CBCT compared to 2D imaging. Other studies [14,26] have sought to determine predictive radiological factors from 2D images to reduce radiation exposure from the CBCT.

According to Andersen et al [14] the canine included at a later stage of root development (completely or almost completely formed) appears to be associated with a higher risk of moderate to severe root resorption. This was reasonable since a canine included with a nearly or completely developed root represented a later eruption stage compared to a canine with a shorter root length than its crown. Therefore, there is a greater likelihood of proximity between the included canine and the root of the lateral incisor, and therefore a higher risk of resorption.

The gender factor should be considered with caution because of the high female/male ratio. The fact that women make up the majority of the selected studies is probably due, on the one hand, to the recruitment of patients (women consult more often than men for orthodontic problems, especially in

adulthood.) and, on the other hand, differences in genetics and cranial-facial development leading to more frequent canine impaction in female subjects [16]. Walker et al [36] hypothesized that the difference in overall cranio-facial growth and development between the genders, as well as genetics, could explain this result. According to several authors [8,15,26,30], The included canines have been shown to be significantly more likely to resorb adjacent incisors when a female is involved, as for Chaushu et al [18] root resorption was more common in women but the number of people affected in this study was insufficient to draw valid conclusions. On the basis of the molecular mechanism, hypotheses have been suggested suggesting a biosynthesis of inflammatory mediators, such as leukotrienes, higher in women [37]; it has been suggested that leukotriene may positively affect the differentiation of osteoclasts and thus promote bone resorption. Therefore, the hypothesis that the osteoclasts of the patients were more active than those of the male patients was issued and thus, the roots of the incisors in the women were more likely to be resorbed under the influence of adjacent canines. Female patients with bilateral canine inclusion were more affected.

The side and location of the included maxillary canine alone were identified as probable risk factors for the development of root resorption of neighbouring incisors when it came to local risk variables. A significant association was found by el Alassiry and hakami [30] between the type of impaction and root resorption. For root resorption and three-dimensional localization of the included canines, only physical proximity between the roots of the lateral incisors and the impacted canines significantly affected the incidence of associated root resorption. Resorptions from adjacent roots could be caused by direct physical damage, increased pressure at the root, or a concentration of resorption molecules linked to the canine eruptive follicle. This physical pressure exerted by the erupting canine can lead to the activation of the dental resorption cells, the cenmentoclasts and odontoclasts, which leads to the loss of cementia or dentin on the surface of the tooth, causing root resorption [27]. The results of a meta-analysis examining the relationship between root resorption of incisors and inclusion of adjacent canines [9] showed a high prevalence of root resorptions on lateral incisors, especially when in direct contact with an included canine. The shape and width of the included canine follicular bag were also considered as local risk factors involving the included canine. According to Wang et al [15], the included enlarged canine follicular sac between 1 and 3 mm is a significant risk factor, this is in agreement with Chaushu et al [18] who reported that dental follicles wider than 2 mm increased the risk of resorption by 8.3 times compared to normal dental follicles.

For local risk factors involving adjacent incisors, Rafflenbeul et al [17] identified lateral incisor agenesis as risk factor of root resorption of the homolateral central incisor, but the normal shape and size or riziform of the lateral incisor were not risk factors for resorption of incisors by the included canines; this is consistent with other studies [22,26,29].

According to Chaushu et al [18], severely angulated canines positioned on the middle third of the root of the adjacent incisor should be considered with suspicion as to the risk of resorption of adjacent teeth. Examining the combination of multiple characteristics as a potential risk factor for lateral resorption is an intriguing concept. The probability of root resorption was predicted by the combination of the sagittal and vertical situation: There's a higher chance of mechanical obstruction by the apex of the lateral incisor when the canine is flush with the apex of the root in an intermediate position near the mid-palate suture.

Conclusion

Several risk factors must be considered to avoid resorption of lateral incisors by the impacted maxillary canines. Regarding general risk factors including age and gender, none of the studies showed that age was a significant risk factor. The sagittal and vertical situations together predicted the likelihood of root resorption: When the canine is straight with the root apex in an intermediate position close to the mid-palate suture, there is a greater likelihood of mechanical obstruction by the lateral incisor apex.

Conflict of interest

The authors declare no conflict of interest.

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