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Global and national prevalence of root canal dilacerations: A systematic review and meta-analysis

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Purpose: This systematic review and meta-analysis aimed to determine the prevalence of root canal dilaceration in Türkiye and the world. Additionally, the difference in the prevalence of root dilaceration between Türkiye and the world population has also been examined.

Methods: This systematic review and meta-analysis was registered with the Open Science Framework (OSF) to ensure transparency and reproducibility of the research process (Registration DOI: https://doi.org/10.17605/OSF.IO/5UBKA). Our study was conducted following PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statements. The MeSH terms and keywords were used to search articles published in three electronic databases PubMed, Web of Science, and Scopus. The search strategy was limited to English and Turkish articles published before 12 December 2024. In addition, the bibliographic references of the qualifying papers were manually searched. Data were collected according to the inclusion and exclusion criteria. The included studies were assessed by two independent reviewers using the Joanna Briggs Institute's critical appraisal checklist for prevalence studies.

Results: Forty-four observational studies are included in this meta-analysis. 35435 patients and 103948 teeth were examined in these studies. The overall prevalence of root dilaceration was 9.1% (95% CI=0.065-0.125) in patients and 2.3 % (95% CI=0.016-0.035) in teeth. We found the prevalence of root dilaceration to be 5.2% (95% CI=0.029-0.09) in Türkiye. There was no statistically significant difference between the prevalence in Türkiye and the world when comparing studies that assessed the number of patients with dilaceration (P=0.0545). However, there was a statistically significant difference when comparing studies that focused on the number of dilacerations of teeth (P=0.03).

Conclusion: Within the limitations of this meta-analysis, root dilaceration was observed in 9.3% of individuals and 3.1% of teeth globally, with a lower prevalence (5.2%) identified in Türkiye. Due to the diagnostic and therapeutic challenges posed by such teeth, accurate diagnosis and well-structured treatment approaches are essential. Further research utilizing standardized diagnostic criteria and including diverse population samples is needed to clarify the underlying causes and enhance clinical management strategies.

Keywords: Prevalence; root dilaceration; root morphology.

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Introduction

The term dilaceration was first defined in 1848 as a deviation or bending in the linear relationship between the crown and the root of a tooth (1). Throughout history, researchers have compared and described teeth with dilacerated roots using various shapes. For instance, Stewart (2) likened them to a police hand, while Moreau (3) described them as resembling a scorpion. The definition of root dilacerations varies in the literature (4,5). According to some authors, if there is an angle of 90 degrees or greater along the tooth or root axis, the tooth is considered to have mesial or distal dilaceration (4) however, another perspective defines dilaceration as a deviation of 20 degrees or more from the normal axis of the tooth at the apical portion of the root (6). The crowns of teeth with dilacerated roots are typically asymptomatic, and the diagnosis of these teeth can be made either through radiographic examination or during tooth extraction (6,7). There are certain limitations in detecting root canal dilaceration using two-dimensional radiographs. Periapical and panoramic radiographs provide information on mesiodistal curvature of the roots but do not offer insight into buccolingual curvature (7). In some cases, dental roots exhibit a ninety-degree curvature in the buccal or lingual direction, resulting in a characteristic "bull's-eye" or "target-like" appearance on radiographs, where a central round radiolucent area is surrounded by a radiopaque dentin border (8,9).

Various hypotheses have been proposed regarding the etiology of root dilaceration, with the leading hypothesis attributing its cause to mechanical trauma affecting primary teeth (10,11). Trauma occurring during the development of tooth roots negatively affects root development and leads to the formation of dilacerations in the roots. This hypothesis is challenged by recent literature in certain aspects, such as the inconsistency between childhood trauma and the incidence of dilacerations observed in tooth roots. The percentage of trauma experienced during childhood ranges from 11% to 30%, whereas the rate of dilaceration is significantly lower than this percentage (2,9,12). Another opposing view is that while traumas generally affect the anterior region, dilaceration is more commonly observed in the posterior teeth (4). The theory outside of trauma theory is the scar formation theory. In relation to primary teeth, developmental anomalies of the primary tooth germ, mechanical interaction during eruption, extraction of primary teeth, the effects of anatomical structures (maxillary sinus cortical bone, mandibular canal, or nasal fossa), pathological scar formation, cleft lip and palate, advanced root canal infections, ectopic development of the tooth germ, adjacent cysts, tumors, or odontogenic hamartomas, orotracheal intubation and laryngoscopy, tooth transplantation, and finally, hereditary factors have been identified in the scientific literature as factors contributing to the formation of root dilaceration (13–18). Some authors have reported in the literature that root dilacerations are associated with certain systemic diseases, such as Smith-Magenis syndrome (19), hypermobility type of Ehlers-Danlos syndrome (20), Axenfeld-Rieger syndrome (21), and congenital ichthyosis (22).

The access cavity during endodontic treatment should be prepared to provide as direct a pathway as possible to the apical foramen. The access cavity should be prepared in such a way that root canal instruments can be used comfortably without binding. The access cavity should be prepared in a shamrock shape to allow root canal instruments to easily reach the apex in a dilacerated root (23). After preparing the access cavity, the curvature and length of the canal should be assessed using scout files, and this information should be recorded for future sessions (23,24). Disposable files with passive tips should be preferred. During root canal shaping, clinicians should be cautious regarding complications such as canal blockage, apical transportation, apical perforation, and instrument fracture. If the lateral condensation technique is chosen for root canal obturation, it should be ensured that the spreader reaches 1 mm shorter than the working length, and the spreader used during the filling process should be made of a flexible metal that will not fracture. Some studies suggest that heat-based filling techniques are more successful in achieving an apical seal, while other studies oppose this view (23).

Despite numerous studies and reviews on the prevalence of dental root dilacerations in the population, to the best of our knowledge, there is no systematic review or meta-analysis in the current literature on this topic. The aim of this systematic review and meta-analysis is to determine the prevalence of dental root dilacerations in the population. Additionally, it seeks to test whether there is a significant difference in the prevalence of dilaceration between our country and the world population.

Materials and Methods

This systematic review and meta-analysis adhered to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (25) and was registered on the Open Science Framework (OSF) to promote transparency and reproducibility (Registration DOI: https://doi.org/10.17605/OSF.IO/5UBKA).

In our study, the population, outcome, and study design questions are as follows:

Population: Individuals with permanent teeth.

Outcome: Individuals and teeth with root dilaceration (root curvature).

Study design: Observational studies.

Inclusion criteria

Studies published before December 12, 2024, either as early or fully published in Turkish or English, were included. Among the studies retrieved from the searches, those that directly reported the prevalence of root dilaceration or could provide it through calculations were included.

Exclusion criteria

Case reports, theses, and conference proceedings related to the prevalence of root dilaceration were also excluded. Studies that did not provide clear results on the prevalence of root dilaceration and those where attempts to contact the corresponding authors for data retrieval were unsuccessful were excluded.

Databases and review strategies

Three databases commonly used for health-related publications (PubMed, Web of Science, and Scopus) were systematically searched by two independent authors (U.M., M.S.) up to December 12, 2024. The electronic search strategy was developed by combining the most frequently cited descriptors in previous publications on this topic, using both Medical Subject Heading (MeSH) terms and free-text keywords. The following terms were combined for the database search: "Permanent teeth," "Permanent tooth," "Root dilaceration," and "Prevalence." The Boolean operators "AND" and "OR" were applied to combine the terms. Additionally, manual searches were conducted for references of the included articles and previous reviews. To control for potential bias, two researchers carried out all processes independently (U.M., M.S.).

Study selection and data collection

The search results obtained from the databases mentioned above were imported into a reference management program (EndNote, Clarivate Analytics, Pennsylvania, USA). Duplicate publications were removed using this program. The remaining studies were transferred to Microsoft Excel, and any duplicate entries were manually excluded. The relevant studies were then selected based on the research criteria by reviewing the title, abstract, and full text in sequence. Full-text articles selected by two independent researchers were compiled into a single file. Disagreements between the researchers were resolved through discussions, and for studies where consensus could not be reached, the opinion of an experienced researcher (C.F.) was sought.

Data such as author, country, year, sample size, prevalence, method, study design, associated diseases, inter-observer evaluation, and diagnostic methods were extracted from the selected studies.

Methodological quality assessment of the studies

The methodological quality assessment of the studies included in this systematic review and meta-analysis was performed using the checklist for prevalence studies developed by the Joanna Briggs Institute (JBI) (26).

This checklist contains nine questions, and each question is evaluated by responding with "yes," "no," "unclear," or "not applicable." If fewer than four questions were answered with "yes," the methodological quality level was considered low; if five to six questions were answered with "yes," the methodological quality level was considered moderate; and if seven to nine questions were answered with "yes," the methodological quality level was considered high. No individual studies were excluded based on methodological quality. These procedures were conducted independently by two researchers. In case of disagreements, a final decision was made through discussion or by consulting a more experienced researcher.

Data Synthesis

To conduct this systematic review and meta-analysis, Comprehensive Meta-Analysis 3 (CMA) - Free Trial version was used. Heterogeneity among studies was analyzed using the Cochran Q and Higgins I^2 tests. If $I^2 \leq 50\%$, a fixed-effects model was applied; otherwise, a random-effects model was used (27). The statistical analysis was conducted using the number of cases reported in the included studies, and the pooled prevalence estimates were calculated and presented in the forest plots as event rates (proportions) with corresponding 95% confidence intervals. Additionally, meta-regression was performed to test if there was a difference in prevalence between our country and the global population. All tests were two-tailed, and a p-value of less than 0.05 was considered statistically significant. Bias assessment in the meta-analysis was tested using the Egger Regression method (28).

Results

Study selection and data collection

A total of 278 studies were identified from three databases using MeSH terms (Table 1). Twenty-eight duplicate studies were identified and removed using EndNote and manual screening. Two independent authors (U.M., M.S.) reviewed the titles of the remaining 250 studies and excluded 101 irrelevant studies. The abstracts of the remaining 149 studies were then screened, and an additional 101 irrelevant studies were excluded. Consequently, 48 full-

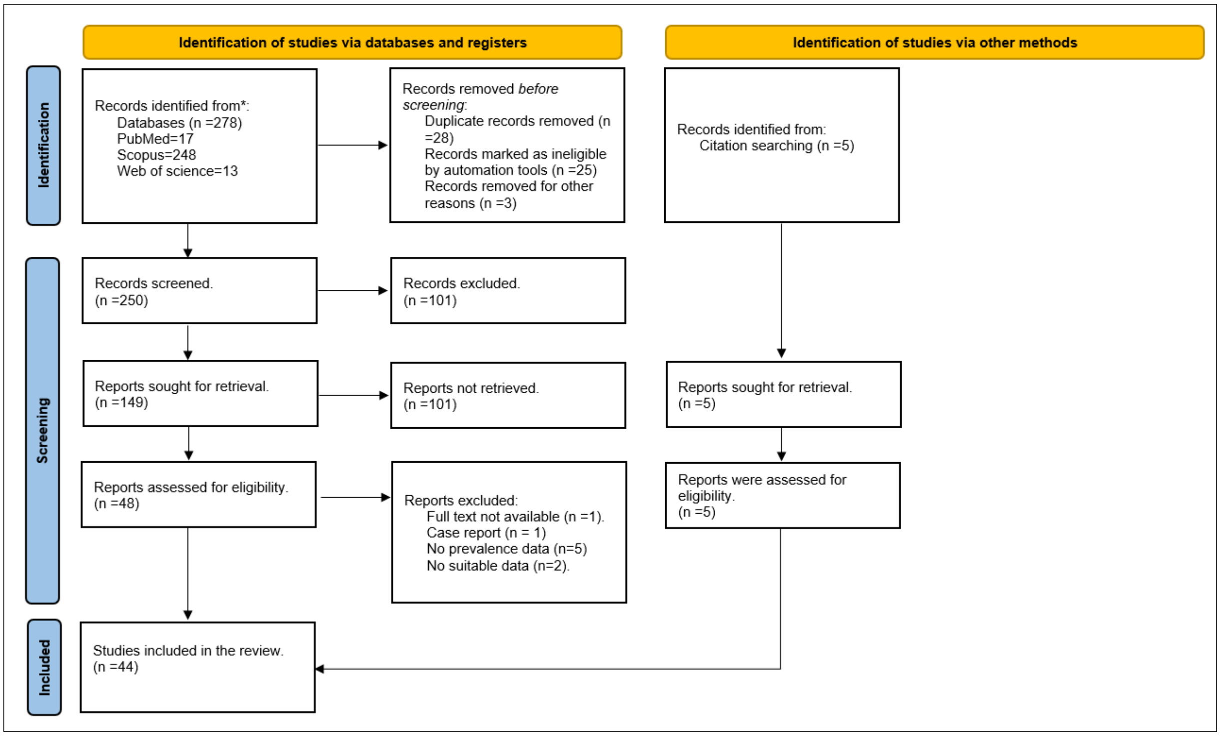

Fig. 1. Flow diagram of literature search and selection criteria (adapted from the PRISMA 2020 flowchart).

text articles were retained for further evaluation.

Of the 48 studies assessed in the full-text review, nine were excluded for the following reasons: Five studies (29–33) lacked prevalence data, one study (20) was a case report, and another study (7) was excluded due to the unavailability of the full text as it had been removed from the database. In addition, one study (34) contained data unsuitable for meta-analysis, and despite attempts to contact the authors for clarification, no response was received. Another study (35) was excluded because the data on root dilaceration were reported subjectively by observers rather than providing definitive quantitative values.

Table 1. Search results by databases

Pubmed database search results			
1	P	Permanent teeth OR permanent tooth Filters: English	30.943
2	O	Root dilaceration Filters: English	303
3	SD	Prevalence Filters: English	3,900.861
4	Totally	1 AND 2 AND 3 Filters: English	17
Scopus database search results			
1	P	Permanent teeth OR permanent tooth Filters: English	3,878,777
2	O	Root dilaceration Filters: English	423
3	SD	Prevalence Filters: English	86,662
4	Totally	1 AND 2 AND 3 Filters: English	248
Web of science database search results			
1	P	Permanent teeth OR permanent tooth Filters: English	15,783
2	O	Root dilaceration Filters: English	118
3	SD	Prevalence Filters: English	1,147,861
4	Totally	1 AND 2 AND 3 Filters: English	13

P: Population, O: Outcome, SD: Study Design.

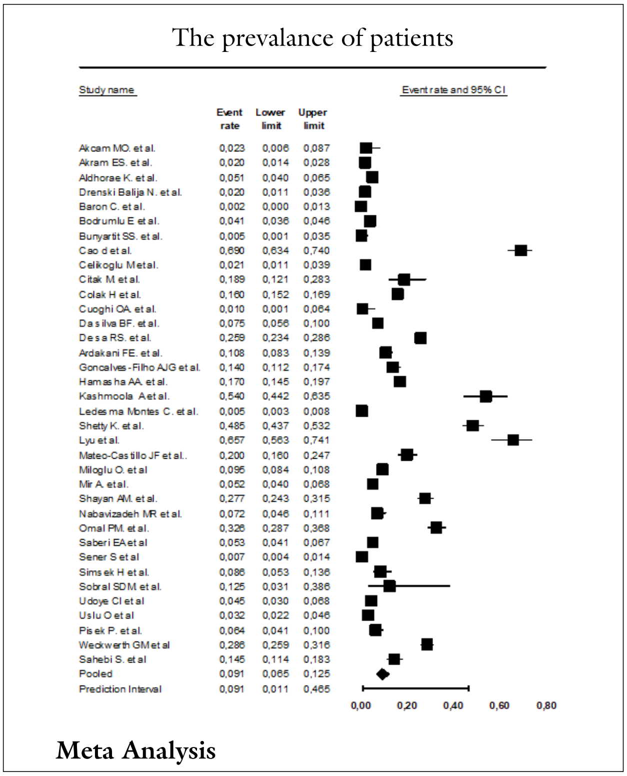

Fig. 2. Forest plot showing the prevalence of patients with root dilaceration.

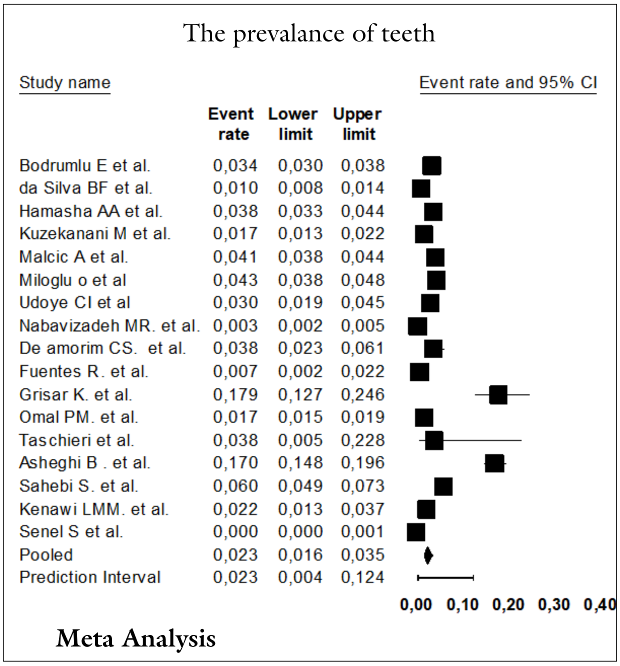

Fig. 3. Forest plot showing the prevalence of teeth with root dilaceration.

Following the screening process, thirty-nine studies remained. Additionally, five studies were added because of manual searching of references of selected studies and reviews, resulting in a total of 44 articles for analysis (Appendix 1; Fig. 1). Thirty-six studies (4,36–70) were analyzed using patient data and seventeen studies (4,5,41,55,57,58,61,64,67,70–77) were analyzed using teeth data. The data from nine studies (4,41,55,57,58,61,64,67,70) were based on both the number of patients and the number of teeth.

Characteristics of Included Studies

Our analysis was conducted with study results from nineteen countries across five continents. There were nine studies from Türkiye (36,41,44–46,55,61,65,68). A total of 35435 patients and 103948 teeth were examined in these studies. Six studies (43,53,70,73,74,77) utilized CBCT as the method, while one study (76) used both CBCT and two-dimensional radiography, and the remaining studies employed two-dimensional radiography. In fourteen studies (36,38,42,43,45,47,54,59,65,68–70,72,77) compared observers. The included studies generally involved populations with cleft lip and palate (36,59,69), Down's syndrome (47), tooth agenesis (44,45), obesity (65), impacted teeth (43,53,73), Kabuki's syndrome (66) and orthodontic patients (68). Retrospective methodology was predominantly chosen as the study design.

Meta-Analysis Results

The meta-analysis was conducted based on two types of data. The first type included studies that were based on the number of affected individuals in studies. A total of 36 studies were included in this analysis. The results of this analysis were determined as I^2=98.76 and Tau=1.050. Since I^2>50, a random-effects model was selected. The mean effect size was found to be 0.091, with a confidence interval of 0.065–0.125 (Fig. 2).

Based on the affected teeth, a total of 17 studies were included in the analysis. The results of this analysis were found to be I^2=98.566 and Tau=0.807. Since I^2>50, a random-effects model was selected. The mean effect size was determined as 0.023, with a confidence interval of 0.016–0.035 (Fig. 3).

Of the nine studies conducted in Türkiye (36,41,44–46,55,61,65,68), all studies reported data based on patient prevalence, while only three studies reported tooth prevalence. The analysis of the nine studies based on patient prevalence was I^2=98.61, Tau=0.873. Since I^2>50, a random-effects model was selected. The mean effect size was 0.052 with a confidence interval of 0.029–0.090 (Fig. 4). Three studies (41,55,61) have been carried out on the

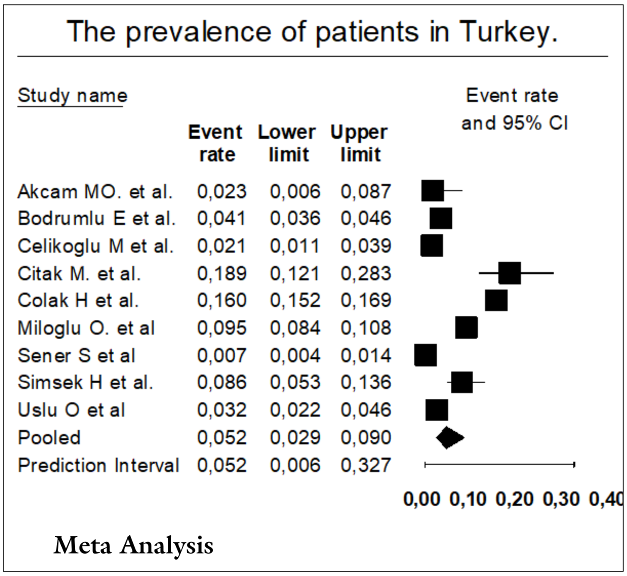

Fig. 4. Forest plot showing the prevalence of root dilaceration in Türkiye based on the number of patients.

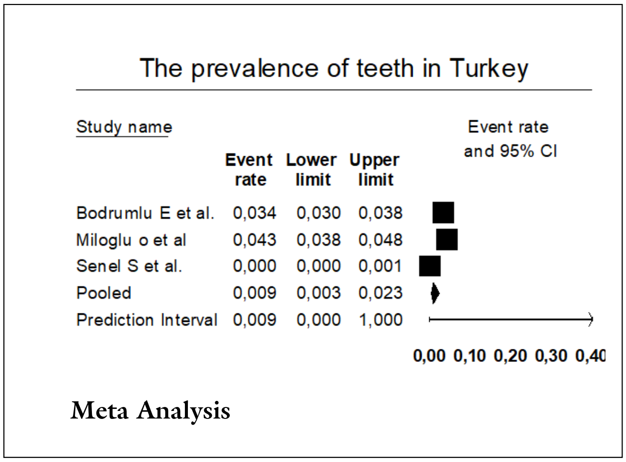

Fig. 5. Forest plot showing the prevalence of root dilaceration in Türkiye based on the number of teeth.

prevalence of teeth with root dilaceration in Türkiye. The analysis of these studies was I2=99.136, Tau=0.879, mean effect size 0.009 with a confidence interval of 0.003–0.023 (Fig. 5).

To compare the prevalence of root dilaceration between Türkiye and the global average, a meta-regression analysis was conducted. Although the prevalence of root dilaceration in Türkiye (0.052, 95% CI: 0.029-0.090) was lower than the global prevalence (0.091, 95% CI: 0.065-0.125), this difference was not statistically significant (P=0.0545) (Fig. 6). However, when comparing studies evaluating the prevalence of teeth, there was statistically significant difference between the dilaceration of Türkiye and the global

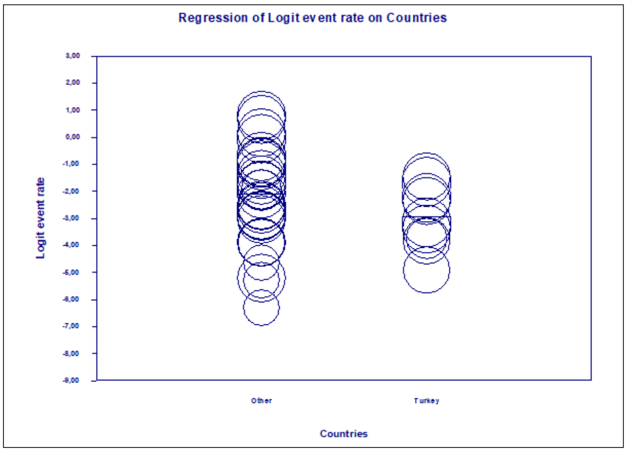

Fig. 6. Meta-Regression Between Türkiye and Other Countries (prevalence of patient).

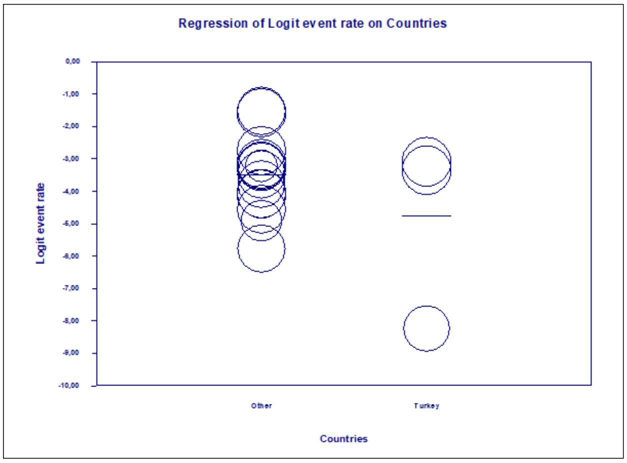

Fig. 7. Meta-Regression Between Türkiye and Other Countries (prevalence of teeth).

prevalence (P=0.03) (Fig. 7). Among the countries evaluated, the lowest prevalence of root dilaceration was observed in France (0.2%, 95% CI=0.000–0.013), whereas the highest prevalence was reported in China (68.1%, 95% CI=0.633–0.725).

Methodological quality assessment of the studies

In our meta-analysis, the presence of publication bias was tested using the Egger Regression Method. According to this analysis, the p-value was found to be 0.13 for studies based on affected individuals and 0.76 for studies based on affected teeth. Therefore, no publication bias was detected in these comparisons.

To assess publication bias in individual studies, the Joanna Briggs Institute (JBI) critical appraisal checklist for prevalence studies was used. In our analysis, 44 studies were included (Appendix 2). Among these: 8 Studies (37,48,53,56,61,64,71,76) answered "yes" to only one question, 7 studies (39,51,54,68,69,72,73) answered "yes" to only two questions, 15 studies (4,5,40,41,44,46,49,50,55,60,62,66,67,74,75) answered "yes" to three questions, 11 studies (36,38,43,45,47,52,57,58,63,70,77) answered "yes" to four questions. These studies were categorized as low methodological quality evidence.

Two studies (59,65) answered "yes" to six questions. These studies provided moderate methodological quality evidence. One study (42) answered "yes" to seven questions. This study provided high methodological quality evidence. Twenty-nine studies had a sample framework appropriate for the target population. Five studies (42,52,57,58,63) had participants appropriately sampled. Four studies (42,43,59,65) met the sample size sufficiency criteria. Twenty-nine studies fully described the study subjects and the geographic region where prevalence was determined. Three studies (42,43,65) adequately covered the defined sample in their data analysis. All studies used valid methods for case identification. Thirteen studies measured the condition reliably and consistently across all participants. Two studies (51,59) conducted appropriate statistical analysis. None of the studies met the response rate sufficiency criterion.

Discussion

Our study utilized the three most preferred databases for publishing dentistry-related studies (PubMed, Scopus, Web of Science). A total of 278 publications were screened from these databases, and an additional five studies were identified through manual search. In meta-analysis studies, it is recommended that searches cover all relevant databases without language restrictions. However, a limitation of our study is that the search was conducted in only three databases and included publications in English and Turkish. The included studies were conducted among dental patients, which prevents our findings from providing definitive evidence regarding the root morphology of an entire population or ethnicity. For conclusive evidence, data should be collected from all individuals within a population. Therefore, our analysis is based solely on data obtained from dental patients and does not fully represent the general population. Another limitation of our study is that the included studies do not cover all ethnicities worldwide and do not exhibit an evenly distributed representation. While some countries contributed multiple studies, others had no research available on this topic. These factors define the limitations of our study. Despite these constraints, our meta-analysis included 44 studies from 19 countries across five continents.

There are differences in the methods used to detect root dilacerations in the included studies. While seven studies utilized cone-beam computed tomography (CBCT) with three-dimensional imaging for detection, thirty-eight studies employed orthopantomography and periapical radiographs. Since three-dimensional radiographic techniques allow for the evaluation of tooth roots in three dimensions, they may provide more accurate and precise results. However, there is no definitive evidence regarding the superiority of one method over the other in detecting root dilacerations. Therefore, future studies should focus on evaluating the accuracy and reliability of different diagnostic methods for detecting root dilacerations.

Among the included studies, twenty-seven studies assessed root dilaceration based on patients rather than the number of affected teeth. Eight studies, on the other hand, reported their findings based solely on the number of affected teeth without considering the number of patients. Additionally, nine studies provided information on both the number of affected teeth and the number of affected individuals. Future studies should report both the localization and number of affected teeth, as well as the proportion of affected individuals, to facilitate more precise analyses and improve the accuracy of future meta-analyses.

In the analyzed studies, the most frequently referenced diagnostic approach for identifying root dilacerations was that described by Hamasha et al. (4). However, upon closer examination, it became evident that Hamasha et al. (4) did not introduce a novel diagnostic method but rather adopted the well-established technique developed by White and Pharoah (9). According to this approach, a tooth was considered to present with dilaceration when the angle formed between the long axis of the tooth and the deviated portion of the root exceeded 20°. This threshold has been widely utilized in the literature due to its reproducibility and clinical applicability. Deviations of 90° or greater along the tooth or root axis were classified as indicators of severe dilaceration, particularly in the mesial or distal directions (4).

A few studies (64,70,77) employed alternative diagnostic methods derived from four different studies (6,78–80), which demonstrated variations in angle thresholds and in the classification of curvature severity (mild, moderate, severe). Some researchers adopted Schneider's method, originally developed for assessing root canal curvature, while others utilized digital measurement tools such as AutoCAD or specialized imaging software, offering greater precision and reproducibility compared with manual protractor-based technique. In addition to diagnostic variability, differences in dilaceration prevalence were observed depending on tooth type. Maxillary central incisors were the most frequently affected teeth, a finding often associated with trauma to their primary predecessors (12). Posterior teeth demonstrated lower prevalence but were also affected in specific patient populations, such as those with craniofacial anomalies including cleft lip and palate (36,47,59,66,69). From a clinical perspective, these findings emphasize the importance of thorough radiographic evaluation, particularly in patients with a history of dental trauma, craniofacial developmental disorders, or orthodontic treatment needs. Maxillary incisors and multi-rooted posterior teeth, which are more susceptible to dilaceration, may present significant challenges during endodontic and orthodontic procedures; therefore, clinicians are advised to exercise particular caution when managing these tooth types.

The methodological quality of the included studies, except for three, was observed to provide low-quality evidence. This finding highlights the lack of utilization of available checklists in these studies. To achieve higher methodological quality, it is recommended that existing checklists for observational studies available in the current literature be employed.

Although numerous reviews on root dilacerations exist, no meta-analysis has previously been conducted on this topic. The comparison of the prevalence of dilaceration in our country with the global prevalence, as well as its association with syndromes and diseases, represent a strengths of our study. Furthermore, the calculation of both patient-based and tooth-based prevalence provided more detailed findings, and the observed difference between these two prevalence rates (with tooth-based prevalence being lower) demonstrated that not every tooth is affected when dilaceration is present. In the patient-based analysis, no statistically significant difference was observed between Türkiye and the global average in terms of root dilaceration prevalence. However, in the tooth-based analysis, the prevalence of root dilaceration in Türkiye was found to be lower than the global average. To clarify the reasons for this discrepancy, future studies comparing different countries within the same patient populations are warranted.

Conclusion

Root dilaceration was detected in 9.3% of individuals and 3.1% of teeth globally, with a lower prevalence observed in Türkiye (5.2%). Considering the diagnostic and therapeutic challenges posed by such teeth, clinicians should ensure accurate diagnosis and adopt carefully planned treatment strategies. Future research with standardized diagnostic criteria and diverse population samples is warranted to better understand the etiological factors and to improve clinical management approaches for root dilacerations.

Authorship Contributions: Concept: E.B.C., F.C., M.U.; Design: M.U.; Supervision: S.M.; Fundings: F.C.; Materials: E.C.; Data: S.M., E.C.; Analysis: M.U., F.C., E.C.; Literature Search: M.U., F.C., E.B.C.; Writing: M.U., S.M.; Critical Revision: F.C., E.B.C., E.C.

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Informed consent: Not applicable.

Authorship Declaration: We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

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Appendix 1. The characteristic features of the studies

Author Name	Country	Year	Sample Size	Prevalence	Method	Study Design	Associated Diseases	Inter-Observer Assessment	Diagnostic Methods
Akcam et al. (36)	Türkiye	2010	87 P	2 P	OPG	Retrospective study	Cleft lip and palate	+	Hamasha et al. (4) (Sharp curve of 90 degrees or more)
Akram et al. (37)	Pakistan	2019	1500 P	30 P	Radiographic examinations	Retrospective study	Dental developmental alterations	-	-
Aldhorae et al. (38)	Yemen	2019	1202 P	61 P	OPG	Retrospective study	-	+	-
Ardakani et al. (39)	Iran	2007	480 P	72 P	OPG	Retrospective study	Dental developmental alterations	-	White et al. (9) (90° or more from the normal long axis of the tooth)
Asheghi et al. (77)	Iran	2023	927 T	158 T	CBCT	Retrospective study	-	+	Chohayeb et al. (6) Santana et al. (78) (20 degrees on the root surface)
Baron et al. (40)	France	2018	551 P	1 P	OPG	Retrospective study	-	-	-
Bodrumlu et al. (41)	Türkiye	2013	5504 P 9406 T	225 P 323 T	OPG	Retrospective study	-	-	White et al. (9) (90° or more from the normal long axis of the tooth)
Bunyarit et al. (42)	Bangladesh	2017	200 P	1 P	OPG	Retrospective study	Gender Dimorphism	+	-
Cao et al. (43)	China	2021	290 P	200 P	CBCT	Retrospective study	İmpacted canines	+	-

Celikoglu et al. (44)	Türkiye	2011	374 P Study Group 98 P Control Group	7 P Study Group 3 P Control Group	OPG	Retrospective study	Third molar agenesis	-	Hamasha et al. (4) (Sharp curve of 90 degrees or more)
Citak et al. (45)	Türkiye	2016	90 P	17 P	OPG	Retrospective study	Maxillary lateral incisor agenesis	+	Hamasha et al. (4) (Sharp curve of 90 degrees or more)
Colak et al. (46)	Türkiye	2012	6912 P	1108 P	OPG	Retrospective study	-	-	Hamasha et al. (4) (Sharp curve of 90 degrees or more)
Cuoghi et al. (47)	Brazil	2016	105 P	1 P	OPG	Retrospective study	Down's Syndrome	+	-
Da Silva et al. (64)	Brazil	2012	548 P 3948 T	41 P 41 T	OPG	Retrospective study	-	-	Schneider (79) Santana et al. (78) Erlich et al. (80) (The deviations greater than 20°)
de Amorim et al. (71)	Brazil	2018	423 T	16 T	PR	Retrospective study	Dental trauma	-	Hamasha et al. (4) (Sharp curve of 90 degrees or more)
de Sá et al. (48)	Brazil	2021	1111 P	288 P	OPG	Retrospective study	Dental developmental alterations	-	-
Drenski et al. (49)	Croatia	2022	506 P	9 T	OPG	Retrospective study	-	-	-

Fuentes et al. (72)	China	2017	412 T	3 T	OPG	Cross-sectional descriptive study	-	+	Hamasha et al. (4) (Sharp curve of 90 degrees or more)
Goncalves-Filho et al. (50)	Brazil	2014	478 P	67 P	OPG	Retrospective study	-	-	-
Grisar et al. (73)	Belgium	2018	162 T	29 T	CBCT	Retrospective study	İmpacted canines	-	-
Hamasha et al. (4)	Jordan	2002	814 P 4655 T	138 P 176 T	OPG	Retrospective study	-	-	White et al. (9) (90° or more from the normal long axis of the tooth)
Kashmoola et al. (51)	Malaysia	2021	100 P	54 P	OPG	Cross-sectional study	-	-	-
Kenawi et al. (74)	Saudi Arabia	2022	630 T	14 T	CBCT	Retrospective study	-	-	-
Kuzekanani et al. (75)	Iran	2019	3150 T	52 T	OPG	Retrospective study	-	-	Hamasha et al. (4) White et al. (9) (Sharp curve of 90 degrees or more)
Ledesma-Montes et al. (52)	Mexico	2016	3522 P	19 P	OPG	Retrospective study	-	-	-
Lyu et al. (53)	China	2018	108 P	71 P	CBCT	Retrospective study	Impacted central incisors	-	-
Malčić et al. (5)	Croatia	2006	15073 T	616 T	OPG PR	Retrospective study	-	-	Hamasha et al. (4) (Sharp curve of 90 degrees or more)

Mateo-Castillo et al. (54)	Brazil	2019	330 P	66 P	OPG	Retrospective study	Non-syndromic Pierre Robin Non-syndromic Cleft palate	+	-
Miloglu et al. (55)	Türkiye	2010	2251 P 6386 T	214 P 276 T	OPG	Retrospective study	-	-	Hamasha et al. (4) (Sharp curve of 90 degrees or more)
Mir et al. (56)	India	2018	1000 P	52 P	OPG PR	Radiographic study	-	-	-
Nabavizadeh et al. (57)	Iran	2013	6146 T 250 P	19 T 18 P	PR	Retrospective study	-	-	Hamasha et al. (4) (Sharp curve of 90 degrees or more)
Omal et al. (58)	India	2012	506 P 16192 T	165 P 269 T	OPG	Retrospective study	-	-	-
Pisek et al. (59)	Thailand	2013	280 P	18 P	OPG	Cross-sectional study	Cleft lip	+	-
Saberi et al. (60)	Iran	2016	1172 P	62 P	OPG	Retrospective study	-	-	-
Sahebi et al. (70)	Iran	2023	400 P 1537 T	58 P 92 T	CBCT	Retrospective study	-	+	Chohayeb et al. (6) Santana et al. (78) (Curvature of greater than 20 degrees from the longitudinal axis of the tooth)
Sener et al. (61)	Türkiye	2011	34169 T 1100 P	9 T 8 P	OPG	Retrospective study	-	-	-
Shayan et al. (62)	Iran	2022	602 P	167 P	OPG	Retrospective study	-	-	-
Shetty et al. (63)	The United Arab Emirates	2017	425 P	206 P	OPG	Retrospective study	-	-	-

Simsek et al. (65)	Türkiye	2019	186 P	16 P	OPG	Retrospective study	Obesity	+	-
Sobral et al. (66)	Brazil	2013	16 P	2 P	PR	Retrospective study	Kabuki syndrome	-	-
Taschieri et al. (76)	Italy	2012	26 T	1 T	PR CBCT	Retrospective study	Endodontic surgery	-	White et al. (9) (90° or more from the normal long axis of the tooth)
Udoye et al. (67)	Nigeria	2009	465 P 706 T	21 P 21 T	PR	Retrospective study	-	-	Hamasha et al. (4) (Sharp curve of 90 degrees or more)
Uslu et al. (68)	Türkiye	2009	900 P	29 P	OPG PR	Retrospective study	Orthodontic patients	+	Hamasha et al. (4) (Sharp curve of 90 degrees or more)
Weckwerth et al. (69)	Brazil	2016	974 P	279 P	OPG	Retrospective study	Nonsyndromic cleft lip and/or palate	+	Hamasha et al. (4) (Sharp curve of 90 degrees or more)

P: Patient, T: Teeth, OPG: Orthopantomography, PR: Periapical radiography, CBCT: Cone-beam computed tomography

Appendix 2. Methodological quality assessment

Author Name	Was the sample framework appropriate to address the target population?	Were the study participants appropriately sampled?	Was the sample size adequate?	Were the study topics clearly defined?	Was the data analysis conducted in a way that sufficiently covered the defined sample?	Were valid methods used to identify the condition?	Was the condition measured in a standard and reliable manner for all participants?	Was an appropriate statistical analysis conducted?	Was the response rate sufficient, and if not, was the low response rate properly addressed?	Methodological quality
Akcam et al. (36)	Y	N	U	Y	N	Y	Y	N	NA	LOW (4)
Akram et al. (37)	N	N	U	N	U	Y	N	N	NA	LOW (1)
Aldhorae et al. (38)	Y	N	U	Y	U	Y	Y	N	NA	LOW (4)
Ardakani et al. (39)	Y	N	U	N	U	Y	N	N	NA	LOW (2)
Asheghi et al. (77)	Y	N	U	Y	U	Y	Y	N	NA	LOW (4)
Baron et al. (40)	Y	N	U	Y	U	Y	N	N	NA	LOW (3)
Bodrumlu et al. (41)	Y	N	U	Y	U	Y	N	N	NA	LOW (3)
Bunyarit et al. (42)	Y	Y	Y	Y	Y	Y	Y	N	NA	HIGH (7)
Cao et al. (43)	N	N	Y	N	Y	Y	Y	N	NA	LOW (4)
Celikoglu et al. (44)	Y	N	U	Y	U	Y	N	N	NA	LOW (3)
Citak et al. (45)	Y	N	U	Y	U	Y	Y	N	NA	LOW (4)
Colak et al. (46)	Y	N	U	Y	U	Y	N	N	NA	LOW (3)
Cuoghi et al. (47)	Y	N	U	Y	U	Y	Y	N	NA	LOW (4)
da Silva et al. (64)	N	N	U	N	U	Y	N	N	NA	LOW (1)

de Amorim et al. (71)	N	N	U	N	U	Y	N	N	NA	LOW (1)
de Sá et al. (48)	N	N	U	N	U	Y	N	N	NA	LOW (1)
Drenski et al. (49)	Y	N	U	Y	U	Y	N	N	NA	LOW (3)
Fuentes et al. (72)	N	N	U	N	N	Y	Y	N	NA	LOW (2)
Goncalves-Filho et al. (50)	Y	N	U	Y	U	Y	N	N	NA	LOW (3)
Grisar et al. (73)	N	N	U	Y	U	Y	N	N	NA	LOW (2)
Hamasha et al. (4)	Y	N	U	Y	U	Y	N	N	NA	LOW (3)
Kashmoola et al. (51)	N	N	U	N	U	Y	N	Y	NA	LOW (2)
Kenawi et al. (74)	Y	N	U	Y	U	Y	N	N	NA	LOW (3)
Kuzekanani et al. (75)	Y	N	U	Y	U	Y	N	N	NA	LOW (3)
Ledesma-Montes et al. (52)	Y	Y	U	Y	U	Y	N	N	NA	LOW (4)
Lyu et al. (53)	N	N	U	N	U	Y	N	N	NA	LOW (1)
Malčić et al. (5)	Y	N	U	Y	U	Y	N	N	NA	LOW (3)
Mateo-Castillo et al. (54)	N	N	U	N	U	Y	Y	N	NA	LOW (2)

Miloglu et al. (55)	Y	N	U	Y	U	Y	N	N	NA	LOW (3)
Mir et al. (56)	N	N	U	N	U	Y	N	N	NA	LOW (1)
Nabavizadeh et al. (57)	Y	Y	U	Y	U	Y	N	N	NA	LOW (4)
Omal et al. (58)	Y	Y	U	Y	U	Y	N	N	NA	LOW (4)
Pisek et al. (59)	Y	N	Y	Y	U	Y	Y	Y	NA	MODERATE (6)
Saberi et al. (60)	Y	N	U	Y	U	Y	N	N	NA	LOW (3)
Sahebi et al. (70)	Y	N	U	Y	U	Y	Y	N	NA	LOW (4)
Sener et al. (61)	N	N	U	N	U	Y	N	N	NA	LOW (1)
Shayan et al. (62)	Y	N	U	Y	U	Y	N	N	NA	LOW (3)
Shetty et al. (63)	Y	Y	U	Y	U	Y	N	N	NA	LOW (4)
Simsek et al. (65)	Y	N	Y	Y	Y	Y	Y	N	NA	MODERATE (6)
Sobral et al. (66)	Y	N	U	Y	U	Y	N	N	NA	LOW (3)
Taschieri et al. (76)	N	N	U	N	U	Y	N	N	NA	LOW (1)
Udoye et al. (67)	Y	N	U	Y	U	Y	N	N	NA	LOW (3)
Uslu et al. (68)	N	N	U	N	U	Y	Y	N	NA	LOW (2)
Weckwerth et al. (69)	N	N	U	N	U	Y	Y	N	NA	LOW (2)