Review Article

Prevalence of canine impaction in different cities of Saudi Arabia: A systematic review

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ABSTRACT

Background: To our knowledge, no systematic review assessed and gathered information about the prevalence of impacted canines among the Saudi population. The purpose of this study was to critically assess the previously published studies about the prevalence of canine impaction according to impaction type (buccal/ palatal), gender (male/female), and location (maxillary/mandibular, right/left), are among the Saudi population.
Methods: PubMed (MEDLINE), Scopus, the Web of Science, Dimensions, and Semantic Scholar databases were searched systemically for articles related to the topic of the study published between 1987 and 2022. The PRISMA statements were used to conduct a systematic review with the help of the Best Practice for Survey and the Public Opinion Research scales by the American Association for Public Opinion Research (AAPOR) to assess and evaluate the selected studies' quality.
Results: The initial search of the databases yielded 221 articles. After discarding duplicates, 161 were selected for further evaluation. Eventually, 16 articles were selected for inclusion in this study. Regarding the quality of the selected articles, all articles, except one, were of high quality. Only one was of medium quality.
Conclusion: It was found that the incidence of palatal canine impactions was higher than buccal impactions. Females had a higher prevalence of canine impactions as compared to males. There were more canine impactions in the maxilla than the mandible and more on the left side than the right one.

1. Introduction

Tooth impaction involves an eruption pathway obstruction or tooth malposition, resulting in the tooth failing to erupt in the oral cavity (Patil & Maheshwari, 2014). (Kotsomitis et al., 1996) Furthermore, (Baydaş et al., 2005) reported that etiological events and specific genes in the pre-and post-natal phase might cause dental anomalies to develop regarding the number, shape, position, structure, or even size of the teeth. (Basdra et al., 2000) Reported that tooth shape, position, and number anomalies could cause malocclusion and arch length problems in both maxillary and mandibular jaws and might significantly impact the orthodontic treatment plan of individuals. (Patil and Maheshwari, 2014) reported incidences of tooth impaction when there were delays in the mean age of tooth eruption time by at least two years. Moreover, (Lindauer et al., 1992) opined that if the tooth root formation was incomplete and the tooth did not erupt in the oral cavity or erupt six

months post-eruption of the contralateral one, it was considered to be impacted.

Tooth impaction is an important cause of malocclusion (Afify & Zawawi, 2012). (Ericson and Kurol, 2000) reported that the permanent maxillary canines have the tallest eruption path due to their development location, which is far from the dental arch and near the nasal cavity. (Chu et al., 2003) discussed the myriad of theories introduced to explain canine impaction incidence. Most of them focused on the jaw and tooth size discrepancy, which was later found to be dietary habits related and differed from one area to another. Phylogenetic, mendelian, and orthodontic theories have been frequently used to explain canine impaction incidence (Mustafa, 2014).

(Fonseca, 2000) reported that canines were the second most common teeth impacted after the third molars. (Kuftinec and Shapira, 1984; Miloro et al., 2011) reported that upper canine impaction prevalence was twenty times higher than lower. (Cooke and Wang, 2006) In a

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gender-wise comparison, tooth impaction affected the female population twice as much as the male population. It was attributed to the different patterns of skeletal growth among females, leading to a smaller skull, maxillary, and mandibular size than the males (Archer & Hjørting-Hansen, 1975). (Dachi and Howell, 1961) mentioned that palatal canine impactions were more common than buccal impactions. (Ericson and Kurol, 1988) Opined that impaction should be suspected if there was the presence of a bulge palatally and the absence of a labial bulge with distally tipped or proclined lateral incisors in patients older than ten years.

(Dachi and Howell, 1961; Grover and Lorton, 1985) reported that canine impaction prevalence was between 0.8 and 2.8 %, while (Haralur et al., 2017) reported that the incidence was 3.41 % in the Saudi population. (Jung et al., 2012) reported that in the case of a canine impaction, a detailed assessment of its orientation, location, and angulation was critical in the orthodontics treatment plan as the impaction might alter the whole treatment plan.

(Bishara and Ortho, 1992) mentioned that certain signs could indicate an impending or possible canine impaction, such as delayed eruption of permanent canines, retained primary canines, no labial bulge, palpable bulge palatially, and delayed eruption or distal tipped lateral incisors (Grisar et al., 2020; Izadikhah et al., 2020). The interceptive approach could be used if the maxillary canine impaction was managed early. At the same time, surgical exposure, extraction, or transplantation could be carried out for older children or adults.

To our knowledge, a study synthesizing the prevalence of impacted canines among the Saudi population is yet to be conducted. The purpose of this study was to report canine impaction prevalence according to the impaction type (buccal or palatal), gender (female or male), location (maxillary or mandibular, right or left) are among the Saudi population.

2. Materials and method

2.1. Search strategies

To identify relevant studies for this study, a systematic electronic literature search was carried out via PubMed (MEDLINE), Scopus, the Web of Science, Dimensions, and Semantic Scholar databases using the primary keywords presented in Table 1 (Higgins & Green, 2019). We have used a combination of keywords and MeSH terms related to our study. The SR-Accelerator tool was used to develop polyglot searching and tested it on multiple databases (Clark et al., 2020). Articles

Table 1
Search strategy and items for the search.

Scopus (n = 145) Limits: Publication date: 2022–10-28	TITLE-ABS-KEY-AUTH ("canine impaction*" OR "impacted canine*" OR "displaced canine*" OR "Canine Teeth*" OR "Teeth, Canine*" OR "Canine Tooth*" OR "Tooth, Canine*" OR "Cuspids*") AND AFFILCOUNTRY ("Saudi Arabia" OR "Kingdom of Saudi Arabia")
Web of Science (n = 24) Limits: Publication date: 2022–10-28	TS= ("canine impaction*" OR "impacted canine*" OR "displaced canine*" OR "Canine Teeth*" OR "Teeth, Canine*" OR "Canine Tooth*" OR "Tooth, Canine*" OR "Cuspids*") AND CU= ("Saudi Arabia" OR "Kingdom of Saudi Arabia")
PubMed (n = 20) Limits: Publication date: 2022–10-28 Species: Humans	("canine impaction*" OR "impacted canine*" OR "displaced canine*" OR "Canine Teeth*" OR "Teeth, Canine*" OR "Canine Tooth*" OR "Tooth, Canine*" OR "Cuspids*")) AND ("Saudi Arabia"[Affiliation])
Dimensions (n = 22) Limits: Publication date: 2022–10-28	["canine impaction*" OR "impacted canine*" OR "displaced canine*" OR "Canine Teeth*" OR "Teeth, Canine*" OR "Canine Tooth*" OR "Tooth, Canine*" OR "Cuspids*"] AND ["Saudi Arabia"]
Semantic Scholar (n = 11) Limits: Publication date: 2022–10-28	("canine impaction*" OR "impacted canine*" OR "displaced canine*" OR "Canine Teeth*" OR "Teeth, Canine*" OR "Canine Tooth*" OR "Tooth, Canine*" OR "Cuspids*") AND ("Saudi Arabia")

published from 1987 to 2022 were included.

2.2. Study selection

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statements were followed in the search and the reporting process to conduct this systematic review (Haddaway et al., 2022) (Fig. 2). Two investigators assessed the entire process, and articles were thoroughly scrutinized to evaluate each article's eligibility. Favourable titles and abstracts were further reviewed. Any study is unrelated to the topic was excluded. Furthermore, the reference lists of the full-text papers were also screened for any relevant studies that might have been missed. The full-text papers were then examined by two investigators, separately and together, according to the predetermined inclusion and exclusion criteria.

2.3. Inclusion criteria

Studies that matched the following inclusion criteria were included: (1) English language published studies, (2) Cross-sectional, retrospective, prospective, and clinical trials studies on human subjects with impacted canine, (3) Saudi population only, (4) all ages were included in the study.

2.4. Exclusion criteria

Studies with the following criteria were excluded: (1) published articles not in the English language, (2) grey articles not published by traditional means (Schöpfel, 2010), (3) impaction studies that did not mention the prevalence of impacted canines, (4) any syndromes, incomplete presentation-related case studies, or abstracts (5) non-Saudi population.

2.5. Data extraction

After the initial search, the Rayyan tool, an automated deduplication tool, was used for screening the publications for a systematic review's eligibility process (Guimarães et al., 2022). Backward and forward citations were used with the automatic tool CitationChaser to ensure no relevant publications were missed (Haddaway et al., 2021). The data were screened and selected by a brief examination of the abstract and title of each study. In the next step, the full text of the selected articles was reviewed, and articles meeting the inclusion and exclusion criteria predefined earlier were highlighted. The data extraction forms recorded each study's main findings and characteristics. Each author examined the articles independently to improve the quality of publications chosen for the review and to minimize bias and errors. An online search of each study supplemented the bibliography and hand-searching of each study to ensure that it fulfilled the chosen inclusion criteria.

2.6. Assessment of strengths and limitations of the included studies

The articles' strengths and limitations were assessed by two reviewers independently and then discussed collectively. Any disagreement presented was resolved by consensus. In the case of a disagreement between the two, the third author made the final decision.

2.7. Synthesis of results

The results of the selected studies were collected based on their radiographic and clinical data, highlighting any canine impaction prevalence. The chosen studies included information regarding the prevalence of impacted canines, the canine impaction type (buccal or palatal), the gender of the patients (female or male), the location of the impaction (maxillary or mandibular, right or left), only among the Saudi population. The quality of the selected studies was assessed by two

independent reviewers using the Best Practice for Survey and Public Opinion Research by the American Association for Public Opinion Research (AAPOR) (Bruce et al., 2018; Woodman et al., 2022). Data analyses were performed using SPSS (George & Mallery, 2013). Meta-analysis was not applicable as the available data were not of comparable type.

3. Results

Two hundred twenty-one articles were retrieved from the selected databases and uploaded into the Rayyan website tool (Guimarães et al., 2022); 60 duplicates were identified and removed. The evaluators evaluated the remaining 161 studies in different stages. First, the articles were screened with titles and abstracts. One hundred forty-two irrelevant articles were thus excluded as they did not fulfill the inclusion criteria. Second, the remaining 19 studies were exported and uploaded on Mendeley and further examined by analyzing their full text. The most relevant studies for the systematic review were selected, as shown in the PRISMA flowchart (Haddaway et al., 2022) (Fig. 1). Consequently, 16 articles were chosen for assessment and final review, and three were excluded after reviewing their full text due to the reasons shown in Fig. 1.

Identification of studies via databases and registers

Identification

Records identified from*:
- Databases (n = 221)
- Scopus (n = 145)
- Web of Science (n = 24)
- PubMed (n = 20)
- Dimensions (n = 22)
- Semantic Scholar (n = 10)

Records removed *before the screening*: Duplicate records removed (n = 60)

Screening

Records screened (n = 161)

Records excluded** (n = 142)

Reports sought for retrieval (n = 19)

Reports not retrieved (n = 3)

Reports assessed for eligibility (n = 16)

Reports excluded:
Full-text not available (n = 3)

Included

Studies included in the review. (n = 16)

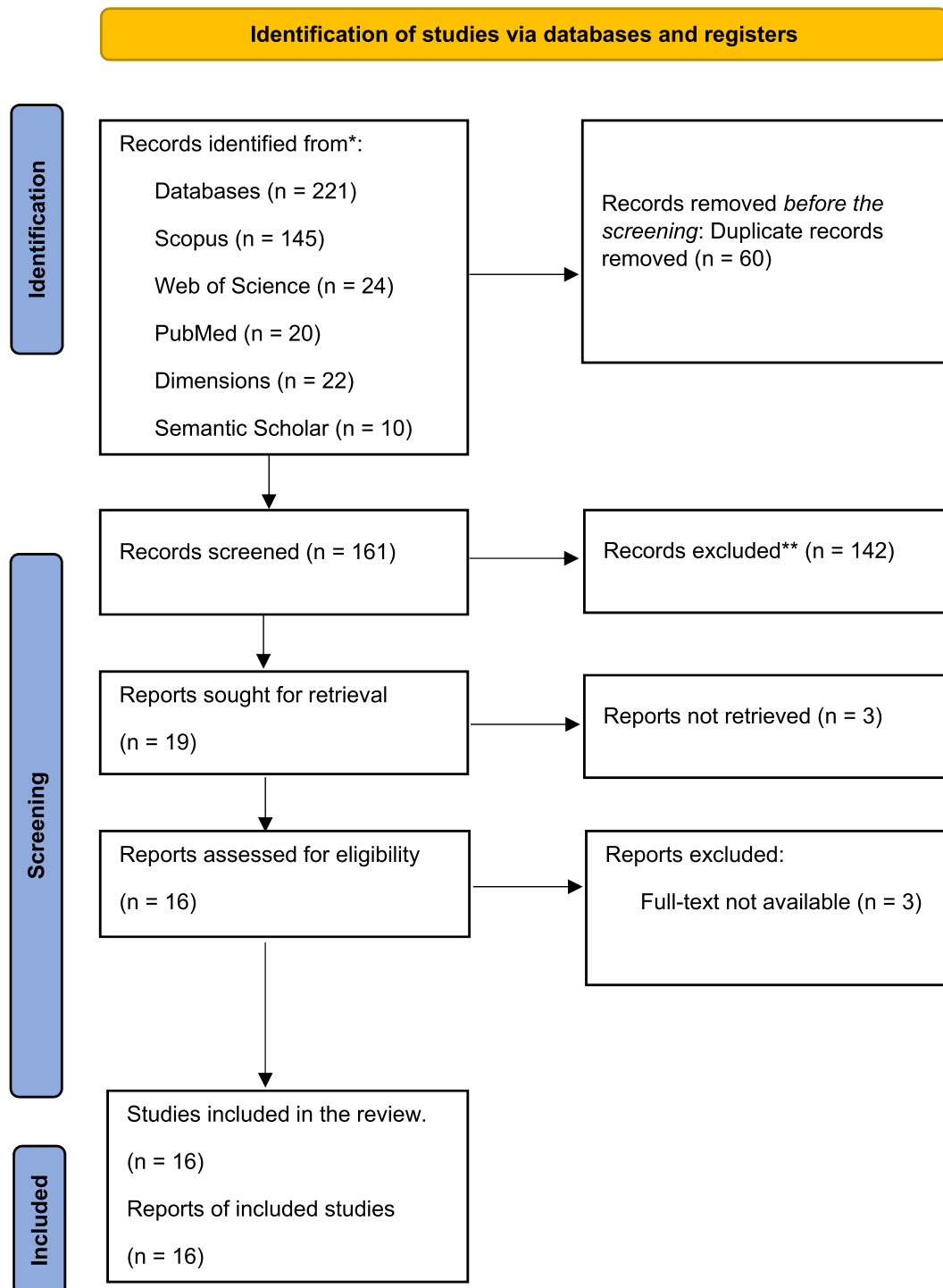Reports of included studies (n = 16)
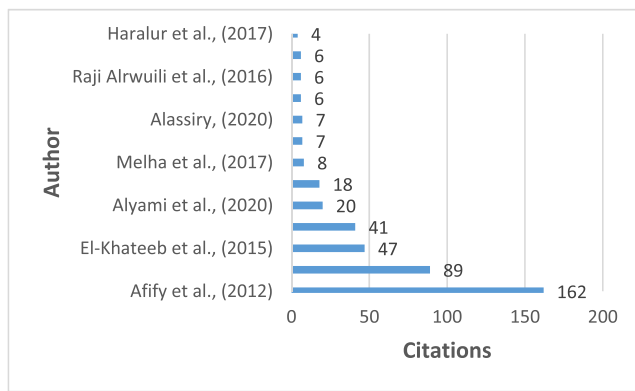
Fig. 1. PRISMA Flowchart.

Fig. 2. Top cited articles and several citations.

4. PRISMA flow diagram of the search process

4.1. Data extraction

The following quantitative data items were extracted from the chosen studies as outlined in Table 2: the names of the authors of the study and the year of the publication; objectives of each study; study population; sample size, year, age, and gender; the instrument for diagnosing canine impaction; summary of the findings; and conclusions (Table 2).

(Afify and Zawawi, 2012; Alamri et al., 2020; Alassiry, 2019, 2019; Alhammadi et al., 2018; Alhumaid et al., 2020; Almarhoumi et al., 2022; Alyami et al., 2019; Al-Zoubi et al., 2017; Baidas et al., 2022; Elkhateeb et al., 2015; Fawzan et al., 2017; Haralur et al., 2017; Melha et al., 2017; Mustafa, 2014; Patil and Maheshwari, 2014).

4.2. Quality assessment

The AAPOR analysis was selected to assess the overall quality of the articles selected for this study. The 10 guiding questions provided by the American Association for Public Opinion Research (AAPOR) used in this study to assess the quality of survey research, covering aspects such as research question clarity, sample representativeness, ethical treatment of subjects, and transparency for evaluation and replication (Draugalis et al., 2008). We have used VOSviewer, a Java-based software, to depict keyword analysis of this research (Van Eck and Waltman, 2010). 15 out of the 16 that were selected were of high quality, and only one was found to be of medium quality (Table 3).

5. Discussion

This systematic review was conducted to gather and summarize the prevalence of canine impaction among the Saudi population. Sixteen articles were chosen after a comprehensive search of the available literature. Thirteen had been cited in various publications as per Google Scholar, but one was cited the highest times, the highest among thirteen publications. The number of citations is shown in Fig. 2), and three had been recently published in 2022 and remained uncited. The highest number of citations was observed for an article by Afify and Zawawi published in 2012, with 162 citations. On the other hand, an article by Haralur et al., published in 2017, had the lowest number of citations, receiving only four (Fig. 2). The subsequent grouping of keywords, as depicted in Fig. 3, indicates that the topic of canine impaction was consistently addressed in the articles reviewed, spanning the years 1987 to 2022. Each color signifies a distinct cluster, organized by the strength of their connections and frequency of occurrence. The keyword co-occurrence network peaked at five mentions, specifically: 'canine impaction,' 'maxillary canine impaction,' 'orthodontics,' 'prevalence,' and 'Saudi Arabia.' There are four clusters, each represented by a different color, that has established connections. Cluster one exhibits the

strongest network connections, followed by clusters two to four in descending order. Consequently, the bubble size represents the extent of the relationship, determined by the strength of the links and their occurrences. The three keywords with the highest overall link strength are 'Canine' (link strength: 10), 'Prevalence' (link strength: 9), and 'Orthodontics' (link strength: 6). These results corroborate the prevalent incidence of canine impactions within the Saudi Arabian population (Ali et al., 2023; Woodman et al., 2022).

This study aimed to assess the canine impaction prevalence among the Saudi population. As their methodologies were heterogeneous, each study was evaluated and assessed to a certain format, allowing a structured summary of the data presenting the prevalence of canine impaction according to the impaction type, gender, location are among the Saudi population. Not all chosen studies fit this format perfectly because of the myriad study designs and methods. However, best efforts were made to assess the literature included in this study systematically. A summary with the key details of all sixteen studies is presented in Table 2.

Canine impaction often presents challenges in a patient's orthodontics treatment plan. Orthopantomagrams (OPG) are routinely used to locate the impaction position, orientation, and angulation for the initial assessment of canine impaction. A higher cost and radiation exposure approach would be using Cone beam computed tomography (CBCT), an advanced technology used to visualize the exact angulation and location of the impacted canines (Jung et al., 2012). Among the sixteen articles presented in this study, twelve relied on the OPGs to detect the prevalence of canine impactions, three relied on both OPGs and CBCT, and only one relied on the CBCT to assess canine impaction prevalence.

In the present study, four articles have discussed impaction positions and have reported the same results: palatal impactions were more prevalent than buccal impactions. These results are similar to what has been previously reported by (Manne et al., 2012). The reason behind this high prevalence of palatal impactions is still unknown. The genetic theory and the guidance theory are two theories that have been introduced to explain the causes of palatal canine impactions (Baccetti, 2009; Jacoby, 1983; Peck et al., 1994; Richardson & Russell, 2000) reported that 85 % of palatal canine impactions had enough eruption space, while only 17 % of labial canine impactions had enough eruption space. It leads one to conclude that arch length discrepancies could be the primary etiological factor for labial canine impactions (Mitchell, 2007).

As for the gender distribution of canine impaction, it was found that out of the 16 articles, 12 reported higher canine prevalence among females compared to males. This finding was similar to what has been previously reported by researchers (Becker, 1995; Fardi et al., 2011). Different growth pattern in females compared to males with the canine complex pattern of eruption offers an explanation for having a higher prevalence in females (Cooke & Wang, 2006). However, three studies have reported a higher prevalence of canine impaction incidence in males.

All articles in the present study reported that maxillary canine impactions were higher than mandibular impactions. This finding agrees with what has been previously reported by (D'Amico et al., 2009; Hasan et al., 2022). (Bishara and Ortho, 1992) reported a summary of Moyer's theory and explained the causes of maxillary canine impactions, which were divided into primary and secondary causes. Primary reasons included premature root closure, deciduous tooth bud trauma, tooth eruption sequence disturbance, limited space arch availability, rotation of tooth buds, cleft cases, and low deciduous tooth root resorption rate. Secondary reasons included vitamin D deficiency, muscle pressure, febrile diseases, and endocrine disturbances.

For canine impaction location, it was found that the upper left side was the most common site of impaction in 11 out of the 16 studies included in the present study, as agreed by (Alfaleh & Al Thobiani, 2020; Rodríguez-Cárdenas et al., 2021). However, this result disagrees with (Bequette, 2014), who reported a higher canine impaction prevalence

Table 2
Synthesis of included studies.

First Author Year	Objectives of the study	Type of the study	Study population, City.	Sample (size, year, gender, age)	Instrument to diagnose canine impaction	Summary of the findings	conclusion
Study 1 (2012)	Investigates dental anomalies prevalence that might cause malocclusion.	Cross-sectional retrospective study	Saudi population, Jeddah.	878 (females and males). Period:2002–2011 Age:12–30 years.	OPGs	Twenty-nine maxillary-impacted canines present (16 females and 13 males).	Canine impaction is more prevalent in females.
Study 2 (2014)	Reports canine impaction prevalence among Saudi population.	Retrospective study	Saudi population, Abha.	3800 (females and males). Period:2009–2011 Age:18–45 years.	OPGs	55 impacted canines present with a ratio of (69:1) patients.Male to female ratio was 43:12 (3.58:1). Maxillary canine (52), mandibular canine (3), with a ratio of 17.33:1.	Males had a higher prevalence than females.Maxillary-impaction was more prevalent than mandibular.
Study 3 (2015)	Investigates impaction and associated pathosis prevalence in Saudi population.	Retrospective study	Saudi population Al-Madinah.	359 (males). Period:2013–2015 Age:20–40 years.	OPGs	8 had impacted canines (6 maxillary and 2 mandibular). Mandibular canine prevalence was 1 %, while maxillary was 4.6 %.	Maxillary-impacted canines were more prevalent than mandibular.
Study 4 (2016)	Investigates canine tooth impaction prevalence among orthodontic patients.	Retrospective study	Saudi population, AlJouf.	2239 (females and males). Period:2012–2015 Age:15–59 years.	Intraoral examination, occlusal, periapical, and OPGs. Dental CT.	97 (4.33 %) canine impactions present, 89 (91.75 %) on the upper arch, and 8 (8.25 %) on the lower arch. Lower impacted canines were buccally in 5 out of 8 cases (62.5 %)Within the maxilla, 75 (84.27 %) unilateral impacted canines were present, while 14 were bilateral. Out of the 75, the left side had 59 (66.3 %) impactions, while the right had 16.The maxillary left quadrant and mandibular right were 59/89 (66.23 %) and 5/8 (62.5 %).	Females showed higher impaction in comparison to males. Most of the upper canines were palatally impacted, while most lower impacted canines were buccally located. Maxillary-impacted canines were more prevalent than mandibular ones. The most common affected sites were the maxillary left and mandibular right quadrant.
Study 5 (2017)	Investigates maxillary canine impaction prevalence by the seven-subtype classification system	Descriptive, cross-sectional, and retrospective study	Saudi population, Madinah.	14,000 (females & males). Period:2011–2015 Age:14–70 years.	OPGs	In the maxilla, the total number of impacted canines was 351, 205 (58.4 %) on the left side and 146 (41.6) on the right. Of them, 184 were Females, while 167 were male patients.In the mandible, the total number of impacted canines was 49, 29 (59.1 %%) on the left and 20 (40.9 %%) on the right.	There is a higher prevalence of impacted canines on the maxillary left side. Females showed higher upper impacted canine compared to male patients.
Study 6 (2017)	Investigates canine impaction prevalence among orthodontic patients.	Retrospective study	Saudi population, Riyadh.	507 (females and males). Period:2014–2016 Age:13–32 years.	OPGs	Upper canine prevalence was 38 (7.5 %); 15 (3 %) were in males and 23 (4.5 %) in females. Unilateral impactions were 24 (63.2 %) out of 38 cases of impaction (9 in males and 15 in females).16 (66.7 %) out of these 24 were found to be on the left (6 in male, 10 in female)	Females showed higher upper impacted canine compared to male patients. Unilateral and left-side impaction incidence was higher than bilateral and right-side impactions.
Study 7 (2017)	Investigates maxillary impacted canine location, prevalence, and mean impaction angle to the occlusal plane.	Retrospective study	Saudi population, Riyadh.	8517 (females and males). Period:2010–2014 Age:18–45 years.	OPGs, CBCT, and anterior occlusal radiographs	291 (3.41 %) patients present with upper canine impactions, 113 (38.83 %) males, and 178 (61.16 %) females. Only Forty-four had CBCT or anterior occlusal radiographs to evaluate labial or palatal impaction position.Among these 44, seven cases (15.91 %) had labial impactions; two (28.57 %) were in males, and five (71.43 %) were in females. 37 (84.1 %) had palatal impactions.15 (40.54 %) palatal impactions were found with male patients and 22 (59.46 %) with female patients.	Females showed higher upper impacted canine compared to male patients. Palatal side canine impactions were higher, with 84.1 %, compared to labial side impactions.
Study 8 (2017)	Investigates canine impaction prevalence among Riyadh population of Saudi Arabia.	Retrospective study	Saudi population, Riyadh.	2157 (females and males).	OPGs	Seventy-nine impacted canines present 3.65 % of the total sample size: 35 male patients (3.25 %) and 44 female patients (4.04 %).	Females showed higher impaction prevalence compared to males.

Table 2 (*continued*)

First Author Year	Objectives of the study	Type of the study	Study population, City.	Sample (size, year, gender, age)	Instrument to diagnose canine impaction	Summary of the findings	conclusion
				Period:2014–2015 Age:15–40 years.		Seventy-three upper canine impactions, 3.37 % of the total population (31 males and 42 cases females), are present.Mandibular canine impaction was found in 8 patients (5 males and three females).	Maxillary impaction prevalence was higher than mandibular impactions.
Study 9 (2018)	Investigates the Saudi population's maxillary impacted canine prevalence, severity, and complexity of orthodontic treatment.	Retrospective Cross-sectional Study	Saudi population, Jazan.	937 (females and males). Years have yet to be recorded. Age:14—40 years	OPGs	Upon the scanned x-rays, maxillary canine impaction occurred in 1.9 % of the cases. The maxillary to mandibular impaction ratio was about 10:1.30 (22.3 %) out of 134 patients had bilateral canine impaction. 92.5 % of the cases had only upper-impacted canines, while 7.5 % had upper-impacted canines and other impacted teeth.	The right and left sides did not significantly differ in prevalence. However, based on the quadrant distribution, the highest area was the upper left (53 %), while the lowest was the lower left quadrant (3 %).
Study 10 (2018)	Investigates canine impaction prevalence using CBCT among the Saudi population	Retrospective study	Saudi population, Aljouf.	439 (females and males). Years not recorded. Age:15–62 years.	CBCTs	13 presented with canine impaction with a 3.03 % prevalence. Among them were 7 (2.90 %) males and 6 (3.03 %) females.Of these 13, 9 were found to be in the maxillary jaw (3 on the right and 6 on the left) , while only 4 were noted in the mandibular jaw (2 on the right and 2 on the left).	Maxillary impaction prevalence was higher than mandibular impactions. The upper left side was the highest in prevalence.Males were higher in prevalence.
Study 11 (2020)	Investigates canine impaction prevalence in Saudi patients and compare gender-wise.	Cross-sectional study	Saudi population, Eastern Province.	539 (females and males).	OPGs	Seventy-one patients were found to have at least one tooth impaction, with a 13.2 % prevalence from the total impactions.49 (9.1 %) of 539 patients presented with at least one canine impaction in the maxillary and the mandibular jaws (67 impacted canines presented in 49 of the patients). Fifty-eight maxillary-impacted canines were present, while only 9 mandibular-impacted canines were present. Canine impactions were found in 20 (28.2 %) males and 51 (71.8 %) females. Maxillary canine impaction prevalence was 27 on the right and 31 on the left, while mandibular canine impaction was 5 on the right and four on the left.	Maxillary canine impactions were higher in prevalence. Females showed higher impaction prevalence.Higher canine impaction prevalence was found on the upper left and lower right sides.
Study 12 (2020)	Investigates maxillary canine impaction (MCI) pattern and Prevalence.	Descriptive, cross-sectional, and retrospective study	Saudi population, Najran.	5000 (females and males). Period:2016–2019 Age:14–40 years.	OPGs	One hundred seventy-three individuals had maxillary canine impaction, representing 3.46 % of the studied population.101 (58.38 %) upper impacted canines prevalence presented in females and 72 (41.62 %) in males.In males, 53 % of impacted canines are on the right and 47 % on the left. In females, 55 % of the impacted canines are left and 45 % on the right.	Higher maxillary canine impaction prevalence was presented in the females compared to the males.The overall evaluation showed higher impaction prevalence on the left side (52 %) compared to 48 % canine impaction on the right.
Study 13 (2020)	Investigates canine impaction prevalence among Saudi patients.	Retrospective study	Saudi population, Al-Qassim.	1500 (females and males). Period:2013–2018 Age:13–30 years.	OPGs	89 (5.9 %) patients were identified, totaling 187 impacted canines in different locations.Forty-eight cases (25.7 %) of the cases were located on the right side, while 64 of the cases (34.2 %) were located on the left side.Sixty-eight cases (36.4 %) had upper-impacted canines, while 7 cases (3.7 %) had lower-impacted canines.45 (50.56 %) of the cases were males, with a	Left-side impactions were higher in prevalence compared to the right-side. Maxillary canine impactions were higher in prevalence. Females showed higher impaction prevalence compared to males.

Table 2 (*continued*)

First Author Year	Objectives of the study	Type of the study	Study population, City.	Sample (size, year, gender, age)	Instrument to diagnose canine impaction	Summary of the findings	conclusion
						prevalence rate of 3, while 44 (49.44 %) were females, with a 2.9 prevalence rate.	
Study 14 (2020)	Evaluates canine impaction patterns and Prevalence in the southwestern region of Saudi Arabia.	Retrospective study	Saudi population, southwestern region.	2000 (females and males). Years not recorded. Age:15–75 years.	OPGs and CBCT.	107 (5.35 %) cases present with impacted canines. Sixty-nine females and 38 males, with a ratio of 1.8:1.Upper-impacted canines were 99 (92.5 %), while mandibular canines were 8 (7.5 %). 60 (56.1 %) Palatal impactions were seen, while 47 (43.9 %) were labial. Females showed 39 (36.5 %) palatal impactions and 30 (28.0 %) labial impactions, while males showed 21 (35.5 %) palatal impactions and 17 labial impactions.	Maxillary canine impactions were higher in prevalence. Impaction prevalence happened more unilaterally on the left side than on both sides. Females showed higher impaction prevalence.Palatal impactions were noticed to be higher in prevalence compared to buccal ones.
Study 15 (2022)	Assesses the prevalence and distribution pattern of maxillary and mandibular impacted canines (MxIC & MnIC).	Cross-sectional retrospective study	Saudi population, AlMadinah.	7466 (females and males). Period:2014–2018 Age:15 years and older.	OPGs	One hundred seventy-three had at least one IC. Eighty-three females and 90 males present with impaction. MxIC only occurred in 86.71 % of the cases, while MnIC only occurred in 8.67 %. The MxIC frequency was found to be 2.1 %, while the MnIC was found to be 0.3 %. 4.62 % had at least one IC in each jaw. 89.2 % of the cases were unilateral IC with left-side maxillary predominance, while 10.8 % were bilateral. Females showed more frequent bilateral impaction than males (64.7 % and 35.3 %, respectively). Bilateral impactions were higher in MnIC than MxIC (17.4 %), with only 100 % occurring in males.	Males showed higher impaction prevalence compared to females. Maxillary canine impactions were higher in prevalence.Unilateral impactions were higher in prevalence.
Study 16 (2022)	Assesses maxillary impacted canine severity, complexity of treatment, bucco-palatal location, and gender and age group relationship.	Retrospective cross-sectional study.	Saudi population, Riyadh.	3350 (females and males). Period:2017–2021 Age:14–30 years	OPGs	There were 171 with upper impacted canines, 99 (57.9 %) females and 72 (42.1 %) males.132 (77.2 %) palatal upper impacted canines and 39 (22.8 %) buccal presented.89 (52 %) impacted canines were on the left, while 82 (48.9 %) were on the right.	Palatal impactions were more severe and higher than buccal impactions. Females presented a higher proportion within the 14–18 age group than male subjects of the same age group. Left-side impaction was higher in prevalence.

Note: OPG: orthopantomogram; CBCT: cone beam computed tomography; IC: impacted canine; MxIC: maxillary impacted canines; MnIC: mandibular impacted canines.

Table 3
Reviewers.

Author, Year	Reviewer	Was there a clearly defined research question?	Did the authors select samples that well represent the population to be studied?	Did the authors use designs that balance costs with errors?	Did the authors describe the research instrument?	Was the instrument pretested?	Were quality control measures described?	Was the response rate sufficient to generalize the results to the target population?	Were the statistical, analytic, and reporting techniques appropriate to the data collected?	Was evidence of ethical treatment of human subjects provided?	Were the authors transparent to ensure evaluation and replication?	Quality of survey studies
Afify & Zawawi, (2012)	R1	x	v	v	X	x	V	v	v	v	v	M
	R2	x	v	v	X	x	V	v	v	v	v	
Mustafa, (2014)	R1	v	v	x	V	v	V	v	v	v	v	H
	R2	v	v	x	V	v	V	v	v	x	v	
El-Khateeb et al., (2015)	R1	v	v	v	V	v	V	v	v	v	v	H
	R2	v	v	?	V	v	V	v	v	v	v	
Raji Alrwuili et al., (2016)	R1	v	v	v	V	v	V	v	v	v	v	H
	R2	v	v	v	V	v	V	v	v	v	v	
Al-Zoubi et al., (2017)	R1	v	v	x	V	v	V	v	v	v	v	H
	R2	v	v	x	V	v	V	v	v	v	v	
Fawzan et al., (2017)	R1	v	v	x	V	v	V	v	v	v	v	H
	R2	v	v	x	V	v	V	v	v	x	v	
Haralur et al., (2017)	R1	v	v	v	V	v	V	v	v	v	v	H
	R2	v	v	v	V	v	V	v	v	x	v	
Melha et al., (2017)	R1	v	v	v	V	x	V	v	v	v	v	H
	R2	v	v	?	V	v	V	v	v	x	v	
Alhammadi et al., (2018)	R1	v	v	v	V	v	V	v	v	v	v	H
	R2	v	v	v	V	v	V	v	v	v	v	
Patil et al., (2018)	R1	v	v	v	V	v	V	v	v	v	v	H
	R2	v	v	v	V	v	V	v	v	v	v	
Alamri, et al., (2020)	R1	v	v	x	V	v	V	v	v	v	v	H
	R2	v	v	x	V	v	V	v	v	v	v	
Alassiry, (2020)	R1	v	v	v	V	v	V	v	v	v	v	H
	R2	v	v	x	V	v	V	v	v	v	v	
Alhumaid et al., (2020)	R1	v	v	x	V	v	V	v	v	v	v	H
	R2	v	v	x	V	v	V	v	v	v	v	
Alyami et al., (2020)	R1	v	v	x	V	v	V	v	v	v	v	H
	R2	v	v	x	V	v	V	v	v	x	v	
Almarhoumi, (2022)	R1	v	v	v	V	v	V	v	v	v	v	H
	R2	v	v	v	V	v	V	v	v	v	v	
Baidas et al., (2022)	R1	v	v	v	V	v	V	v	v	v	v	H
	R2	v	v	x	V	v	V	v	v	v	v	

R1: reviewer 1; R2: reviewer 2; H = high quality; M = medium quality; L = low quality.

? = unclear; X = no; V = yes.

Scoring: **High quality** (score ≥8), **Medium quality** (5≤ score <8), **Low quality** (score <5).
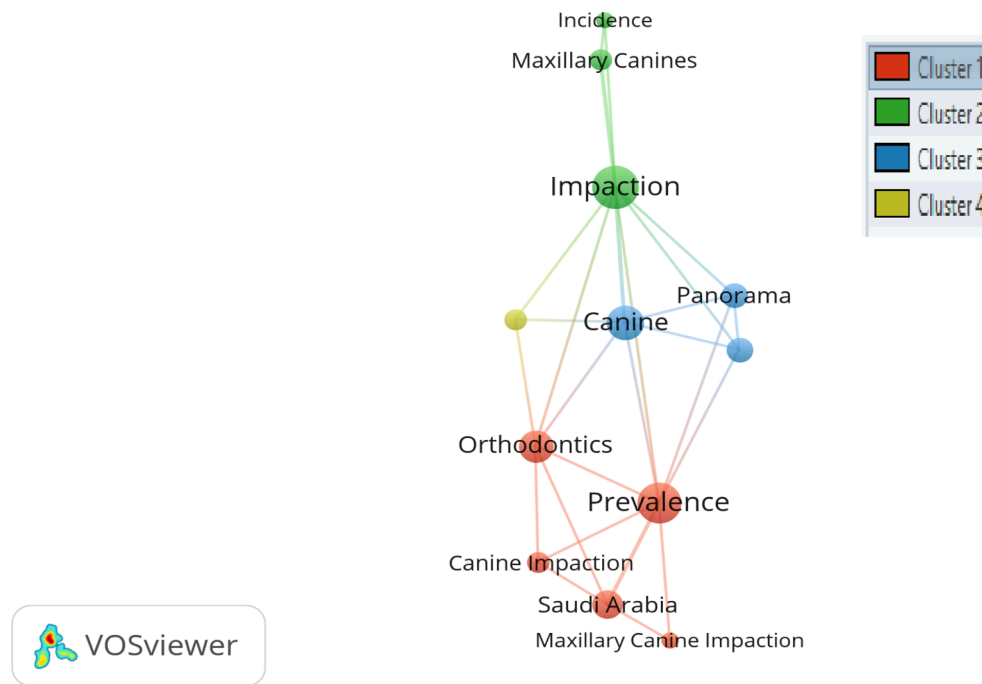
Fig. 3. Co-occurrence network of keywords used in this study (1987–2022).

on the right side compared to the left. While several studies in our analysis concur that the prevalence of left maxillary canine impaction is higher than that on the right side, the literature does not offer a compelling rationale for this left-side impaction predominance (Almarhoumi et al., 2022).

6. Conclusion

Canine impaction is considered one of the significant anomalies that orthodontists face in their clinics. In the present study, canine impaction was higher in the palatal region and the Saudi female population. Also, maxillary canine impactions and left side region were higher in prevalence. Canine impactions require immediate attention either as an interceptive treatment at an early age or as a surgical approach in advanced cases. A good understanding of the determinants of canine impaction is necessary to set a treatment protocol for such cases.

Ethical Statement.

An ethical statement is not required for this manuscript.

CRediT authorship contribution statement

Abdulaziz Alamri: Review & editing, Visualization, Supervision, Resources, Project administration. **Sarah Alqanas:** Conceptualization, Data curation, Writing – original draft, Writing – review & editing, Visualization, Formal analysis, Methodology, Resources. **Yousif AlJar:** Conceptualization, Data curation, Writing – original draft, Writing – review & editing, Visualization, Formal analysis, Methodology, Resources. **Faisal Alqahtani:** Conceptualization, Data curation, Writing – original draft, Writing – review & editing, Visualization, Formal analysis, Methodology, Resources. **Shakil Ahmed:** Data curation, Visualization, Investigation, Validation, Formal analysis, Methodology, Supervision, Resources, Project administration, Software.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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