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SYSTEMATIC REVIEW

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Evaluating the success rates and effectiveness of surgical and orthodontic interventions for impacted canines: a systematic review of surgical and orthodontic interventions and a case series

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Abstract

Objectives The goal is to gather more information on orthodontic traction of impacted canines in the arch or their extraction.

Methods We focused our search on English-language papers published between January 1, 2004, and July 24, 2024 in PubMed, Scopus, and Web of Science that were relevant to our topic. The search strategy employed the Boolean terms "impacted" AND "canine". In addition to the overview, this article discusses a number of clinical instances involving canine disinclusion.

Results The study analyzed 2748 papers from databases like Web of Science, PubMed, and Scopus, resulting in 1455 articles after eliminating duplicates. After examining titles and abstracts, 897 entries were removed. The remaining 558 papers were confirmed, with 543 items removed due to being off-topic. The study includes a qualitative analysis of the 15 final articles.

Conclusions This article concludes that both extraction and orthodontic traction are effective treatments for impacted canines, with the choice depending on patient-specific factors. Advances in surgical techniques and imaging technologies have improved outcomes, while a multidisciplinary, patient-centered approach remains essential. Future research should focus on refining treatment selection criteria and integrating genetic and technological advancements.

Keywords Canine, Impacted, Disinclusion, Extraction, Surgery, Orthodontic treatment, Mini-screw

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Introduction

Impacted canines as a dental anomaly: etiology and factors

Impacted canines represent a significant dental anomaly with far-reaching implications for both orthodontic and surgical interventions [1]. These teeth, crucial for functional occlusion and aesthetic harmony, often fail to erupt into their correct positions, leading to a range of clinical challenges [4]. Maxillary canines, in particular, exhibit a higher propensity for impaction, with prevalence rates reported to be between 1–3% in various populations [9]. This prevalence underscores the necessity for dental professionals to possess a thorough understanding of the aetiology, diagnosis, and management of impacted canines to optimize patient outcomes [14]. Etiologically, impacted canines can arise from a combination of genetic and environmental factors [19] [24]. Genetic predispositions may include familial patterns of dental anomalies, while environmental influences encompass discrepancies in dental arch space, abnormal tooth eruption paths, and the presence of physical barriers such as supernumerary teeth, odontomas, or cysts [26]. The multifactorial nature of canine impaction necessitates a comprehensive diagnostic approach [31].

Advances in diagnostic techniques

Accurate diagnosis typically involves a combination of clinical examination and radiographic imaging, with advanced techniques such as cone-beam computed tomography (CBCT) offering superior diagnostic accuracy by providing three-dimensional views of the impacted tooth and its surrounding structures [36]. Recent researches have advanced our understanding of the genetic components contributing to canine impaction [44]. Studies have identified specific genetic markers associated with increased risk, suggesting that early genetic screening could play a role in future diagnostic protocols [49]. Additionally, innovations in imaging technologies have enhanced our ability to detect and assess impacted canines with greater precision [54]. CBCT, in particular, has become a valuable tool in pre-surgical planning, allowing for detailed visualization of the impacted tooth's position relative to adjacent structures, which is critical for minimizing surgical risks [59].

Multidisciplinary treatment approaches

The management of impacted canines often necessitates a multidisciplinary approach, integrating orthodontic strategies to create space and guide eruption, alongside surgical procedures to expose or remove the impacted tooth [64]. Orthodontic techniques such as the use of palatal expanders and fixed appliances can be employed to create the necessary space for eruption, while surgical options may include surgical exposure with orthodontic guidance, or in some cases, extraction [69]. The timing of intervention is critical, as early detection and treatment can significantly reduce the complexity and duration of therapy [77]. Early intervention, particularly in patients with a familial history of dental anomalies, can facilitate more conservative management options and improve prognostic outcomes [82].

Surgical management and post-operative considerations

Hospitalization for the surgical management of impacted canines is generally minimal, with most procedures performed on an outpatient basis [87]. However, the complexity of the impaction and the presence of complicating factors such as cyst formation or severe crowding may necessitate more extensive surgical interventions, potentially requiring short-term hospitalization [92]. Post-operative care is crucial to prevent complications such as infection or excessive bleeding and to ensure proper healing and integration of orthodontic devices [97].

Comparing treatment modalities

This study carefully examines the results of different treatment modalities, such as early genetic screening, CBCT-guided surgical planning, and integrated orthodontic-surgical treatment techniques, in order to improve our understanding of the most successful therapies for impacted canines [102]. Key variables like treatment length, hospitalization rates, post-operative complications, and overall patient satisfaction will be the focus of the study's evaluation of patient outcomes [107]. The importance of biological factors such as: age of the patient, position of the canine, presence or absence of crowding, and iatrogenic factors as the ultimate goal of treatment are critical to the choice between extraction of the impacted tooth and guided traction in the arch of the latter [112]. Each approach has distinct advantages, limitations, and potential complications that must be considered to optimize patient outcomes [117]. By analysing these factors, the study seeks to provide evidence-based guidance for clinical decision-making, enhancing the quality of care for patients with impacted canines and determining the most effective and patient-centred treatment approach [122].

Extraction as primary option

When canines are severely dislocated, surrounding structures are affected, or there is not enough arch space to allow for guided traction, extractive treatment is thought to be the best course of action [127]. Its main advantage is the immediate resolution of the problem, reducing the risk of infection, cyst formation, and further dental damage, and potentially shortening the overall treatment time

[132]. However, extraction can lead to aesthetic concerns and functional issues, necessitating prosthetic replacements to maintain the appearance and occlusal function [137].

Traction and its benefits

Traction involves surgically exposing the impacted canine and using orthodontic techniques to guide it into position, preserving the natural tooth and maintaining aesthetic and functional integrity [142]. This method, while beneficial for retaining a natural and appealing smile, and ensuring proper occlusion, is complex, time-consuming, and requires meticulous orthodontic management and patient compliance. Surgical exposure also carries risks such as infection and potential damage to surrounding structures [152]. These randomized controlled trials aim to comprehensively compare extraction and traction by evaluating outcomes like treatment duration, hospitalization rates, post-operative complications, patient satisfaction, and long-term functional and aesthetic results. By analysing these factors, the study seeks to provide evidence-based guidance for clinical decision-making, enhancing the quality of care for patients with impacted canines and determining the most effective and patient-centred treatment approach [157].

Study objectives

This article outlines the methodology and presents the initial findings of our study on the management of impacted canines. By synthesizing recent research and clinical practices, we aim to provide evidence-based recommendations to enhance the clinician's ability to effectively address this common yet complex dental issue. Through an exploration of genetic insights, advancements in imaging technology, and multidisciplinary treatment strategies, we hope to contribute to the ongoing efforts to improve patient outcomes and quality of care in the management of impacted canines.

Materials and methods

Protocol and registration

This review was carried out in compliance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) criteria, and it was filed with the number CRD 577493 on PROSPERO (The International Prospective Register of Systematic Reviews) [163]. The primary research question of this review is to evaluate and compare the effectiveness of different surgical and orthodontic interventions for the management of impacted canines. Specifically, the review aims to assess the outcomes of extraction versus orthodontic traction in terms of treatment duration, patient satisfaction, post-operative complications, and overall success. In addition to the review, this article also deals with a series of clinical cases of canine disinclusion. Three patients between the ages of 9–14 (mean 11.5 years) with unerupted canines were selected and examined at the Department of Orthodontics, University of Bari. The participants and parents provided written informed consent to be involved in the study. Exclusion criteria included open and deep-bite, oral or systemic diseases, previous orthodontic treatment. The panoramic radiograph (a single-cut tomogram of the entire Maxilla and jaw) is the first radiographic record needed. The pre-treatment variables on the panoramic radiograph as alpha-angle (α), distance (d) and sector (s) were often evaluated [164]. The same method for worsening of mandibular canine was used.

Search processing

We limited our search to English-language papers published between January 1, 2004, and July 24, 2024, in PubMed, Scopus and Web of Science that were relevant to our topic. In the search approach, the Boolean keywords "impacted" AND "canine" were used. We chose these terms because they most correctly described our investigation's goal, which was to acquire greater knowledge into orthodontic traction of impacted canines in the arch or their extraction (Table 1).

Inclusion criteria

Three reviewers reviewed all relevant publications using the following criteria: (1) only human subjects research, (2) full text, and (3) scientific studies evaluating canine disengagement. The PICO model was created using the following steps:

- Criteria: Application in the present study;
- Population: Human subjects with impacted canine;

Table 1 Indicators for database searches

Articles screening strategy	KEYWORDS: "A": impacted; "B": canine; Boolean Indicators: "A" AND "B" Timespan: January 1, 2004, to July 24, 2024 Electronic databases: Pubmed; Scopus; Web of Science

- Intervention: Orthodontic treatment for to disinclude canines to bring them into the arch or extract them;
- Comparison: Control group;
- Outcome: Evaluation of successful canine disinclusion;
- Study design: Randomized Controlled Trials, observational study

Exclusion criteria

Exclusion criteria included non-English-language articles, ineligible research designs, ineligible outcome measures, ineligible populations, case studies, reviews, and animal studies.

Data processing

Author conflicts about the choice of articles were addressed and resolved.

Article identification procedure

Two reviewers, F.I. and F.P., independently evaluated appropriateness. An extra manual search was performed to boost the number of articles available for full-text analysis. English-language articles that fit the inclusion requirements were considered, and duplicates and non-qualifying items were identified with a rationale for exclusion.

Study evaluation

The reviewers separately evaluated the article data using a specific electronic form established according to the following categories: authors, year of study, aim of the study, materials and methods, and results.

Quality assessment

Two reviewers, F.P. and F.I., utilized the ROBINS-I tool to evaluate the quality of the included articles. ROBINS-I was developed to assess the risk of bias in non-randomized studies that compare the health effects of two or more medications. Each of the seven assessed points was given a bias degree. F.I., the third reviewer, was contacted in the case of a disagreement until a resolution was reached. To improve the impartiality and uniformity of the assessments, any differences or disagreements among reviewers were handled via discussion and consensus-building. When there was no consensus, a third reviewer made the final choice. It helped to improve the overall assessment of the quality and dependability of the results by identifying the strengths and shortcomings of the evidence base. By accounting for the likelihood of bias, the authors of this review were able to draw more informed interpretations and conclusions based on the evidence presented.

Fig. 1 First panoramic radiograph

Fig. 2 Panoramic radiograph after odontoma removal

Case series

Case 1

FA, a nine-year-old girl, presented an unerupted mandibular canine. After six months of observation lower-right-canine deciduous was still present. Panoramic radiograph was prescribed. Odontome was present in the area of permanent lower-right canine that was submerged in bone, far from its eruptive path. Deciduous canine has not root resorption. So, surgical enucleation of composite odontome was performed, and eruption of canine was expected. On panoramic radiograph canine presented a α angle of 19° a distance (d) of 18 mm and was located in sector (s) 3. After two months a panoramic radiograph was prescribed (Fig. 1).

Position of permanent canine was worsened. Its transposition was observed, canine was near the mandibular midline. On second panoramic radiograph canine presented a α angle of 38° a distance (d) of 17 mm and was located in sector (s) 3 (Fig. 2).

So orthodontic treatment with fixed appliance was chosen to start orthodontic traction of the impacted cuspid. The treatment of the canine was concluded with its extraction (Fig. 3).

Case 2

DS, an eight-year-old girl, came in Department of Orthodontics, University of Bari for dental malocclusion evaluation. Patients presented many caries on deciduous teeth so the panoramic and cranium radiographies were prescribed. Panoramic evaluation showed that both maxillary canines presented an alpha angle unfavourable to physiologic eruption. Upper left canine presented an alpha angle worse than the right: canine 1.3 presented an α angle of 23° a distance (d) of 22 mm and was located in sector (s) 3, while 2.3 presented an α angle of 25° a distance (d) of 24 mm and was located in sector (s) 3. On both maxillary sides premolars and canine lost the eruptive line (Fig. 4). The patient's parents decided to postpone the treatment for several months. Eight months later patients returned in Orthodontics Department and new radiographs were prescribed. Both canines worsen their position. An orthodontic treatment with a fixed appliance was proposed and accepted by the patient. Treatment started in upper arch bonding the brackets on four upper incisors and positioning two orthodontic bands on upper molars. After three months of treatment a radiographic control was done. Right canine further worsen its position. The left canine remained in its position. Radiograph evaluation showed the follow values for both canines: 1.3 α angle of 25° a distance (d) of 24 mm and was located in sector (s) 3; 2.3 α angle of 54° a distance (d) of 24 mm and was located in sector (s) 3 (Fig. 5).


Fig. 3 Operating sequence of mandibular right canine extraction


Fig. 4 First panoramic radiograph

Case 3

AC, a twelve-year-old girl, came in Department of Orthodontics, University of for dental malocclusion evaluation. Radiographic evaluation was done. On panoramic radiography mandibular seconds premolars and two incisors agenesis was evaluated. The 2.3 showed a α angle of 53° a distance (d) of 25 mm and was located in sector (s) 2. The 1.3 presented a α angle of 49° a distance (d) of 29 mm and was located in sector (s) 1. In maxillary arch no agenesis was evaluated (Fig. 6).

On radiograph bilateral canines inclusion was present. Left canine had a worse position than right canine. Extraction of deciduous molars and fixed appliances on both arches (American Orthodontics, Sheboygan, WI, USA) was estimate. After three months of orthodontic treatment with fixed oral appliance a panoramic radiograph was prescribed before surgical treatment to hook both canines. On radiograph a worsening of left canine was evaluated. The 2.3 presented a α angle of 92° a distance (d) of 29 mm and was located in sector (s) 1; 1.3 presented an α angle of 32° a distance (d) of 11 mm and was located in sector (s) 2 (Fig. 7).

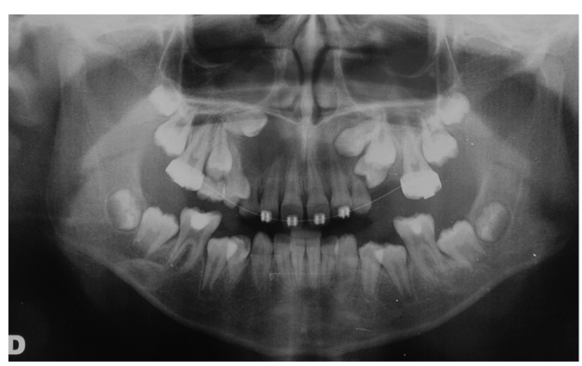

Fig. 5 Panoramic radiograph after three months of treatment

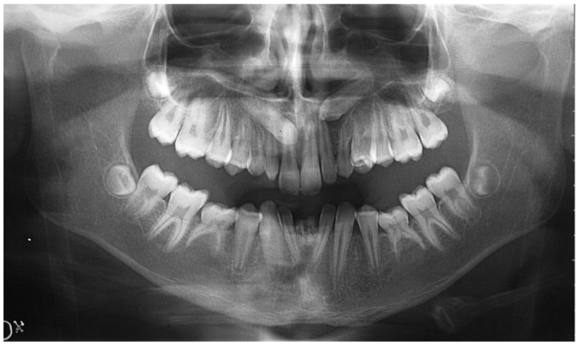

Fig. 6 First panoramic radiograph

Fig. 7 Panoramic radiograph where one can see the worsening of the position of the left canine

When imaging young patients, low-dose CBCT protocols should be implemented to minimize radiation exposure, in accordance with ALARA and ALADAIP principles, while still providing sufficient detail for procedures such as assessing impacted canines, as the latest CBCT devices offer effective low-dose imaging solutions [31].

Results

A total of 2748 papers were obtained from the databases Web of Science (796), PubMed (740), and Scopus (1212). This resulted in 1455 articles after eliminating duplicates (1293). 897 entries were eliminated after their titles and abstracts were examined. The writers were able to successfully obtain the remaining 558 papers and confirm their eligibility. 543 items were eliminated as a result of this process because they were off topic. The qualitative analysis of the 15 final articles is included in this study (Fig. 8). Each study's findings were presented in Table 2.

Quality assessment and risk of bias of included articles

Figures 9 and 10, showing the risk of bias in the included studies assessed using RoB 2 for randomized trials and ROBINS-I for the observational study. Figure 9 highlights the risk of bias in the included randomized controlled trials (RCTs). Most studies exhibit a high risk of bias due to issues in the randomization process and deviations from intended interventions. Measurement bias generally shows a low risk, indicating reliable outcome measurements. Many studies also show minimal bias from missing data. However, bias in the selection of reported outcomes is prevalent across most RCTs, impacting the robustness of their findings. Overall, the findings indicate that few RCTs maintain a low risk of bias, while several exhibit moderate to high risks.

Figure 10, illustrating the risk of bias in the observational study, shows that there is a serious risk of bias due to confounding and measurement of outcomes. Selection bias and deviations from intended interventions generally display low-risk levels, indicating adequate participant selection and adherence to intervention protocols. The observational study reveals moderate to serious bias levels overall, with a significant risk due to confounding and measurement inaccuracies, which may impact the interpretation of findings.

Discussion

Impacted canine control is an integral part of orthodontic treatment and involves a delicate balance between effectiveness, safety, and comfort for the patient. Impacted canines are relatively common dental anomalies that create a variety of diagnostic and treatment challenges for an orthodontist [180]. Recent advances in technology and treatment philosophies have altered the approach to managing impacted canines and added new and improved solutions to the clinician's armamentarium [185].

The most common forms of treating impacted canines include extraction and traction. This review compares the two approaches based on the most recent and best research and available clinical outcomes about their relative effectiveness and impact on patient care.

Technological advances in orthodontics

Computer-aided techniques significantly improved the safety and accuracy of orthodontic surgical intervention. Kivovics et al. (2024) confirmed the advanced presurgical planning process with individual presurgical guides to increase precision and safety, especially in complex cases [166]. Moreover, Björksved et al. (2021) stated that three-D imaging with pc-guided planning has better results in cases of hard anatomical systems since it reduces complications and gives better surgical effects [179]. The minimally invasive strategies in orthodontics have also advanced and involve laser technology [195]. According to Impellizzeri et al. in 2023, laser strategies have been found to lower bleeding and post-operative ache by approximately 30% and 20%, correspondingly, compared

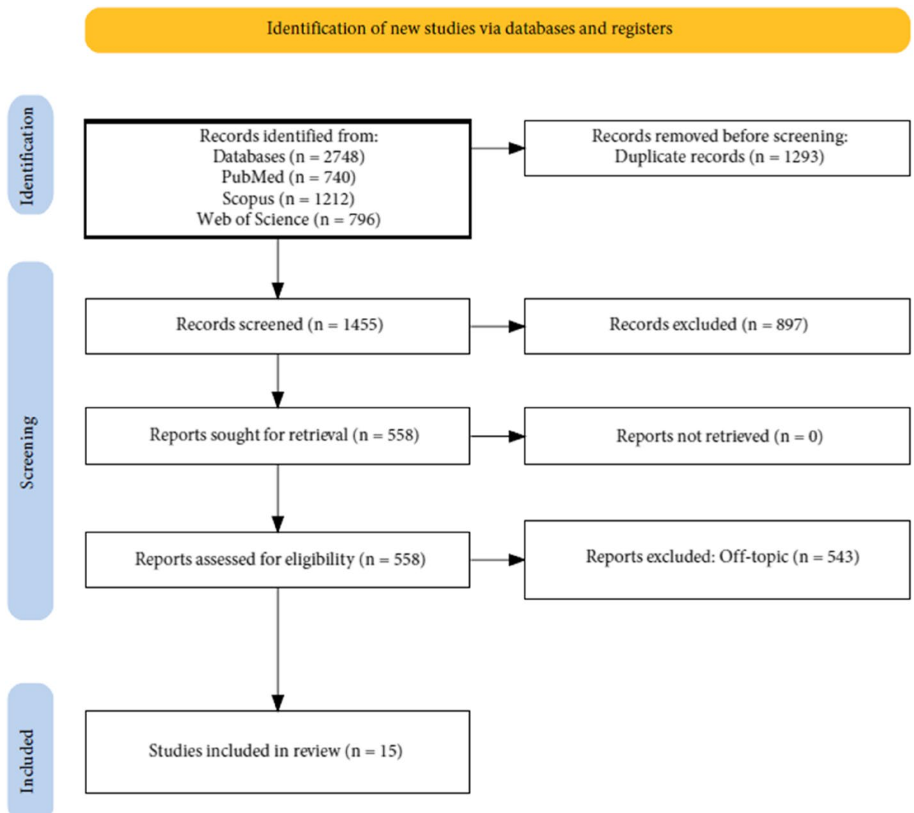

Fig. 8 PRISMA flowchart of the literature search and article inclusion process

to traditional techniques [40]. These strategies are also found to promote faster recovery and decrease the requirement of analgesia, thereby improving the comfort and recovery of patients [200]. This, therefore, becomes part of less invasive approaches in the best interest of patient well-being and satisfaction [204]. Corticotomy-assisted treatments were evaluated for their ability to increase tooth motion [207]. Mousa et al. observed that corticotomy could decrease orthodontic treatment time by approximately 40% [14]. However, Verma et al. found that this technique initiates regional acceleratory phenomenon, resulting in increased tooth movement with no evidence of periodontal health impairment [170]. These studies exemplify the changing face of orthodontic treatments, with a search toward more patient-friendly options.

Comparison of extraction and traction techniques

Impacted canines are managed by several techniques, including extraction and traction methods. A study by Hadler-Olsen et al. (2020) on the management of the palatally displaced canine compared the single and double extraction of primary teeth [174]. No significant difference in eruption rates was noted between these two methods. Both techniques proved useful, but critical factors toward success were initial canine angulation and space conditions [212]. Naoumova et al. (2015) reviewed deciduous canine extraction and noted that eruption rates in the extraction group were significantly greater than in the control group at 80% compared with 50% after 12 months, thereby supporting deciduous canine extraction as an effective interceptive measure [52]. Antunes et al. (2018) evaluated the effect of alveolar bone grafting on the eruption of impacted canines in patients with cleft lip and palate [176]. According to this study, while bone grafting usually provided for spontaneous eruption, 33.33% of them still needed orthodontic traction, emphasizing the need for individualized treatment plans. In a 2019 study, Parkin et al. compared the aesthetic and functional outcomes using closed and open surgical techniques for impacted canines [110]. While minor differences in the aesthetics of both closed and open surgical techniques have been noted, closed techniques involve less postoperative pain and promote faster recovery, making them more favorable for reducing discomfort [220]. Björksved et al. (2021) supported this by indicating that open surgical techniques demonstrated increased postoperative pain and functional impairment,

Table 2 A descriptive item selection summary

Authors	Type of study	Aim of the study	Matherials and Methods	Results	Sample Sizes	Study Groups	Clinical Parameters for Effectiveness
M. Kivovics et al. (2024) [166]	randomized clinical trial	To assess the feasibility of computer-assisted open exposure of palatally impacted canines (PICs)	Patients aged 11–30 years who required orthodontic eruption for the full palatal impaction of their canines	Computer-assisted surgery is a feasible method for open exposure of PICs, which decreases the duration of surgery compared to the free-hand method	34 participants	Orthodontic patients requiring exposure of palatally impacted canines	Surgery duration compared between computer-assisted and free-hand methods; shorter times indicated higher feasibility
M. Björksved et al. (2021) [167]	randomized clinical trial	To evaluate the costs of open and closed surgical exposure and subsequent orthodontic treatment for the correction of palatally displaced canines (PDCs)	One hundred twenty adolescents between 9 and 16 years of age. Cost analysis was performed including costs for surgery, orthodontic treatment, emergency visits and material, as well as costs for transports and time spent in connection with every appointment	The two different surgical exposures and following orthodontic treatments did not differ significantly in terms of costs	120 participants	Randomized into two groups: open vs. closed surgical exposure	Cost parameters included surgery, treatment, and other related expenses to assess overall cost-effectiveness of both methods
A. Impellizzeri et al. (2023) [168]	randomized clinical trial	To show the effectiveness of laser technology for the exposure of PICs, using a CO2 or diode laser, and to evaluate the possible bio-stimulation effect of the laser on the spontaneous eruption of the canine	27 patients, divided randomly into three groups: treated with a CO2 laser (Group A), treated with a diode laser (Group B), and treated with a cold blade (Group C). Monitoring was performed at 1, 8, and 16 weeks after surgery, through photo and digital scans performed with a CS3500 intraoral scanner	The average total eruptions are 4.55 mm for Group A, 5.36 mm for Group B, and 3.01 mm for Group C. The difference in eruption between groups A and B is not significant. Comparing the laser groups with the control group, it has emerged that the difference in eruption is statistically significant	27 participants (3 groups)	Group A: CO2 laser, Group B: Diode laser, Group C: Cold blade	Canine eruption measured in millimeters; significantly higher eruption in laser groups compared to the control (cold blade group)

Table 2 (continued)

Authors	Type of study	Aim of the study	Matherials and Methods	Results	Sample Sizes	Study Groups	Clinical Parameters for Effectiveness
M. R. Mousa et al. (2023) [169]	randomized clinical trial	To evaluate the effectiveness of a minimally-invasive corticotomy-assisted (MICA) treatment of PICs compared with the traditional method by evaluating treatment time, the velocity of movement, and the associated dentoalveolar changes	Forty-six patients with upper PICs were distributed into two groups: the corticotomy-assisted traction group and the traditional treatment group. The closed surgical approach was used in both study groups	The traction movement velocity of the PICs can be increased using MICA orthodontic treatment. The side effects of the acceleration procedure were minimal and almost similar to those of the traditional technique	46 participants	Group 1: MICA-assisted traction, Group 2: Traditional treatment	Velocity of canine movement measured; faster movement with MICA technique indicated higher effectiveness. Minimal side effects noted
S. Verma et al. (2023) [170]	randomized clinical trial	To evaluate the success rate, treatment duration, and pain perceived during forced eruption of maxillary PICs using the K9 and Ballista springs	30 unilateral PICs of moderate and difficult category were enrolled. Group 1 comprised canine impactions managed with K9 springs, and Group 2 comprised Ballista springs	The IC of moderate and difficult category were erupted with a 100% success rate and similar treatment duration with both interventions. The pain scores of Ballista springs were greater after 24 h of force application	30 patients	Group 1 (K9 springs) vs Group 2 (Ballista springs)	Success measured by eruption rate and pain perception, with Ballista springs causing higher pain scores while both methods achieved full eruption
M. Björksved et al. (2018) [171]	randomized clinical trial	To compare treatment time, patients' perceptions during orthodontic treatment, dental fear and side effects, between open and closed surgical exposures in patients with PDCs	125 patients from three different orthodontic centers were randomized into one of the two intervention arms, open or closed surgical exposure	The closed exposure group experienced more pain and discomfort mostly during active orthodontic traction	125 patients	Two groups: open surgical exposure vs closed surgical exposure	Patient perception and discomfort during orthodontic traction were primary parameters, with the closed exposure group reporting higher pain levels
J. Cunha-Cruz (2015) [172]	randomized clinical trial	To determine the best course of action for an 11-year-old girl with suspected impacted using the five steps of Evidence-based practice: Ask, Acquire, Appraise, Apply, and Assess	The orthodontist selected three studies: a case report, a cohort study, and a randomized controlled trial (RCT). The RCT was chosen for its lower risk of bias, as it randomly allocated patients to treatment and control groups	Extraction of DC increased the likelihood of permanent canine eruption by 80%	Single case study	N/A	Efficacy measured by eruption probability, with an 80% increase in likelihood of permanent canine eruption following deciduous tooth extraction

Table 2 (continued)

Authors	Type of study	Aim of the study	Matherials and Methods	Results	Sample Sizes	Study Groups	Clinical Parameters for Effectiveness
H. Jang et al. (2021) [173]	randomized clinical trial	To investigate the effects of palatal stents in patients who underwent supernumerary tooth removal through a palatal approach and to suggest the optimal stent thickness and material	144 patients were divided into a control group and compressive palatal stent group each distinguished by the thickness and material of the thermoplastic acrylic stent used	Compressive palatal stents reduce discomfort by decreasing pain and alleviating swelling. Although a stent is effective regardless of its thickness and material, 2-mm hard stents maximized such positive effects with minimal discomfort	144 patients	Control group vs compressive palatal stent group	Effectiveness measured by reduction in discomfort, pain, and swelling. The 2-mm hard stents were found to provide optimal results
Hadler-Olsen et al., (2020) [174]	Randomized Controlled Trial	Compare effectiveness of double vs single primary tooth extraction for PDCs	32 children with 48 PDCs; PDCs were split into two groups at random: the double-extraction group (DEG) and the single-extraction group (SEG). Until the canine emerged or orthodontic treatment was initiated, logistic regression was used to examine the factors impacting PDC emergence at baseline and six-month intervals. Clinical and radiographic exams emergence (yes/no), emergence into a favorable position (yes/no), and MC positional shift (angulation and sector) were the outcome measures	No significant difference in PDC emergence; both groups showed significant distal movement. In order to assist PDC eruption into the oral cavity and into a desirable position in the dental arch, single or double primary tooth extraction methods are similar. Early evaluations of canine angulation and spacing may be utilized to forecast the success of PDC eruption	32 children (48 PDCs)	DEG (double extraction) vs SEG (single extraction)	Canine angulation and spacing were key clinical parameters determining the success of canine eruption following primary tooth extraction

Table 2 (continued)

Authors	Type of study	Aim of the study	Matherials and Methods	Results	Sample Sizes	Study Groups	Clinical Parameters for Effectiveness
Parkin et al., (2013) [175]	Randomized Controlled Trial	Evaluate esthetic outcomes of closed vs open surgical exposure of PDCs	The study included 67 participants, with laypeople identifying the operated tooth only 49.7% of the time, and orthodontists identifying the treated canine with certainty only 60.7%. Both panels assessed the unoperated canine's appearance better than the contralateral operated canine, but no differences were found	Aligning a PDC has an aesthetic impact, but it is largely subtle and unlikely to be seen by the general public. Regardless of whether the canine was made visible through an open or closed surgical procedure, the aesthetic impression was the same	67 participants	Closed vs open surgical exposure	Aesthetic outcomes were judged by laypeople and professionals. No significant differences were observed between closed and open procedures in terms of aesthetics
Antunes C. et al. (2018) [176]	Observational Study	Investigate eruption patterns of impacted teeth after alveolar bone graft in cleft lip and/or palate (CLP) patients	Between 2004 and 2011, 42 patients were treated at a facility, with the most impacted being 9–11 year olds. The most common cleft was unilateral (85.71%). The most common impacted tooth was the MC, and orthodontic traction was required for 64.3 and 35.7% respectively	Higher incidence of CLP in males; Following the implantation of the bone graft, all impacted teeth in the preforamen incisor cleft spontaneously erupted. The canine teeth were the most common, primarily associated with the TIC. IC spontaneously erupted during secondary alveolar bone grafting in CLP	42 CLP patients	Single group (CLP patients with impacted teeth)	Effectiveness measured by spontaneous eruption following alveolar bone grafting, with maxillary canines being the most commonly impacted and responsive to treatment

Table 2 (continued)

Authors	Type of study	Aim of the study	Matherials and Methods	Results	Sample Sizes	Study Groups	Clinical Parameters for Effectiveness
Naoumova et al., (2015) [177]	Prospective Randomized Clinical Longitudinal Trial	Evaluate effect of DC extraction on PDC eruption	67 children aged 10–13 with maxillary unilateral or bilateral periodontal disease, persisting DC and no previous experience of orthodontic treatment. The patients were randomly assigned to extraction or non-extraction, underwent clinical examinations and cone beam computed tomography at baseline, 6 months, and 12 months. Outcome measures included eruption, positional changes, eruption duration, and root resorption. Extraction group vs control group; monitored radiographic changes over time	The extraction group experienced more spontaneous eruptions of PDCs than the control group, with rates of 69% and 39%, respectively. Differences were found in all variables except for the sagittal angle, with larger changes in canine cusp-tip distances and apex changes	67 children	Extraction group vs non-extraction control group	Spontaneous eruption rate and positional changes in the canine cusp and apex were measured to determine effectiveness of DC extraction for PDC management
Mousa et al., (2023) [14]	Randomized Controlled Trial	Compare periodontal outcomes of MICA technique vs conventional traction for PDCs	Individuals with unilaterally affected canines participated in a randomized controlled experiment to examine periodontal characteristics. Accelerated therapy (CAT) and conventional treatment (CT) groups were created for the participants. Two weeks following the fixed orthodontic appliance's removal, post-treatment measurements were obtained	The study involved 46 patients in either the CT or CAT groups for expedited therapy. The differences in periodontal outcomes were not statistically significant. The combined PPD values for neighboring teeth were almost identical, and the two study groups had very low gingival recession level (GRL) values	46 patients	Group 1 (MICA) vs Group 2 (conventional traction)	Periodontal outcomes, specifically probing pocket depth (PPD) and gingival recession level (GRL), were measured to assess treatment effectiveness, with no significant differences noted between groups

Table 2 (continued)

Authors	Type of study	Aim of the study	Matherials and Methods	Results	Sample Sizes	Study Groups	Clinical Parameters for Effectiveness
Mousa et al., (2022) [178]	Randomized Controlled Trial	Assess patient-centered outcomes of conventional vs accelerated minimally invasive corticotomy-assisted orthodontic treatment for PDCs	A study of 52 patients with unilateral PICs, divided into two groups, measured pain, discomfort, and functional issues using a visual analog scale 24 h, 4 days, 7 days, 14 days, and 28 days after the surgical exposure procedure	The study did not find any statistically significant differences between the two therapy groups. On the first day following surgery, pain and discomfort were somewhat greater in the traditional group compared to the corticotomy-assisted group. Four days were needed for recovery for edema, mastication issues, swallowing issues, and speech abnormalities, whereas seven days were needed for other outcomes	52 patients	Group 1 (minimally invasive corticotomy-assisted) vs Group 2 (conventional treatment)	Patient-centered outcomes, including pain and discomfort levels, were tracked post-surgery. Minimally invasive corticotomy-assisted therapy resulted in marginally better pain management early on
Björksved et al., (2021) [179]	Multicenter Randomized Controlled Trial	Compare postoperative outcomes of closed vs open surgical exposure of PDCs	119 consecutive patients from three orthodontic centers who underwent surgical exposure. The procedures involved elevating a full-thickness mucoperiosteal flap, removing bone covering, and suturing the flap back. To prevent gingival overgrowth, a tissue window was excised and glass ionomer cement was applied. Patient perceptions were assessed using questionnaires	Open technique associated with more postoperative pain and impairment; no significant difference in surgery time	119 patients	Group 1 (closed surgical exposure) vs Group 2 (open surgical exposure)	Postoperative pain and impairment were the primary clinical parameters, with the open surgical exposure group reporting more pain and functional limitations compared to the closed exposure group

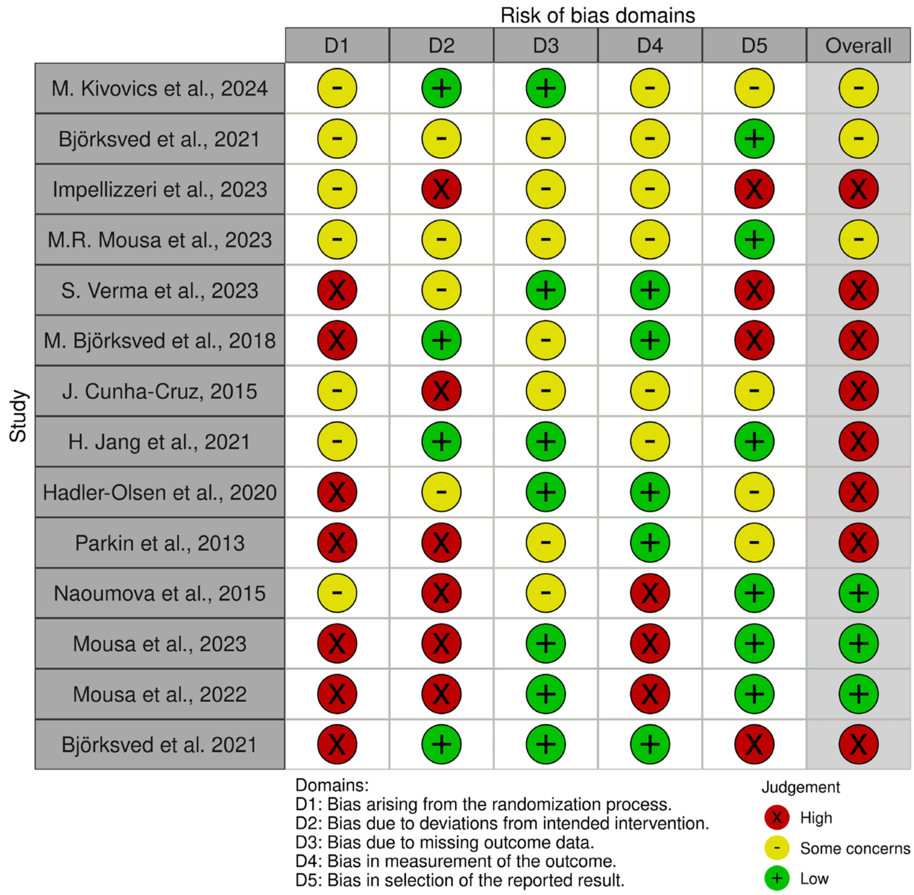

Fig. 9 Bias assessment by RoB 2 for randomized trials

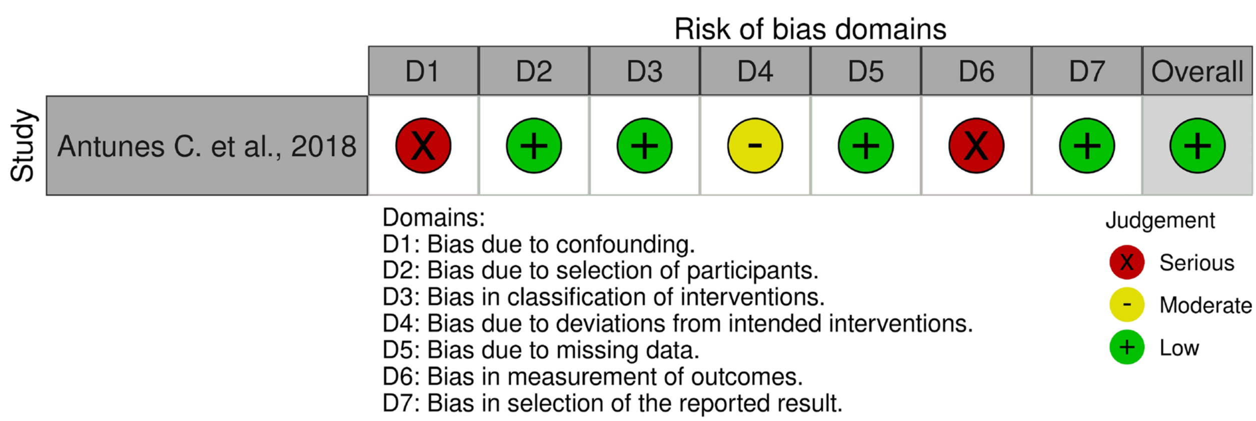

Fig. 10 Bias assessment by ROBINS-I for the observational study

especially in bilateral cases, and thus closed technique had to be preferred since it causes less pain and has fewer major complications [167]. Mousa et al. (2023) reviewed the periodontal outcomes of corticotomy-assisted versus conventional closed-flap traction, finding no significant differences in periodontal health parameters between the two modalities, with minimal negative effects on periodontal tissues [169]. These findings have been supported by Verma et al. (2023), which stated that corticotomy-assisted techniques surely accelerate tooth movement significantly and positively, with the maintenance of good periodontal health, and therefore turn into a feasible alternative to conventional techniques of traction [170]. Cunha-Cruz et al. in 2015 and Jang et al. in 2021 further emphasized the role of evidence-based practice in orthodontics, advocating for the integration of available evidence into clinical practice to make informed treatment decisions and improve patient outcomes [172]. Björksved et al. (2021) highlighted the significance of patient-centered care, stating that treatment should be based on patient preference and clinical concerns [179]. From a perspective of individualized care, this care should be oriented toward fulfilling individual needs and expectations for improved results and satisfaction [226].

Key insights and clinical implications

Studies have shown that extraction of primary teeth, especially the deciduous canines, as discussed in Naoumova et al., greatly facilitates the eruption of impacted canines [76]. The simplicity and minimal invasiveness of the technique associated with high success rates and a low complication rate make it an option whose efficiency may differ in different patients; therefore, treatment must be planned on an individual basis [231]. On the contrary, traction methods, particularly corticotomy-assisted techniques following surgical intervention, are potent alternatives that do not seem to compromise periodontal health. These are useful in patients in whom simple extraction may prove inadequate. According to Mousa et al., conventional and accelerated traction methods are comparable in terms of comfort and periodontal outcomes, with no significant differences in pain or functional impairment [178]. The results from Björksved et al. study, on closed vs. open surgical exposure techniques, outline the benefits of the former in terms of less postoperative pain and fewer functional impairments [171]. This is important information to have at hand when being faced with clinical decisions that involve patient comfort and recovery as major concerns. Parkin et al. commented on the aesthetics-related outcomes of the techniques involved in their study, outlining that both methods have similar effects concerning aesthetics, with slight advantages of the closed techniques being possible in the clinical setting [113]. This reiterates the incorporation of variables specific to the patient, such as aesthetic priorities and general comfort, in order to decide upon which approach is best for every patient. Timing of intervention also had its importance, from the study by Antunes et al., wherein effectiveness in alveolar bone grafting for patients with cleft lip and palate indicated benefits toward improved eruption outcomes [176]. This suggests that in order to maximize patient outcomes, orthodontic treatment planning must be done in a timely and planned manner.

In conclusion, he comparison between extraction and traction techniques in orthodontics delineates the fact that several factors, like patient preferences, clinical conditions, and evidence-based practice, have to be considered in order to arrive at the most appropriate and effective treatment plan. The trend toward less invasive and more patient-friendly techniques, such as corticotomy-assisted treatments and closed surgical methods, is one of improvement in patient comfort and recovery with successful outcomes.

Limitations and future directions

The majority of orthodontic research is restricted by a number of critical limitations that significantly compromise the reliability and practicality of findings [236]. First, many studies have small sample sizes, with short follow-up, similar to those conducted by Hadler-Olsen et al. in 2020 and Naoumova et al. in 2015, that could compromise the ability to detect long-term problems and generalize findings [174]. Additionally, there is significant variability in study designs and protocols, making it difficult to compare results across different studies, as evidenced by the discrepancies between the methods utilized by Parkin et al. (2013) and Björksved et al. (2021) [175]. The subjectivity in measurements of outcomes, mainly related to aesthetic assessments, implies possible bias and inconsistency in the results obtained, which was actually confirmed by Parkin et al. (2013) [175]. Moreover, there is a lack of literature regarding the effectiveness of various techniques and related complications in the long term. For instance, Mousa et al. (2023) present short-term results [169]. In this context, the response of each patient to, for example, bone grafting or application of traction is very different, as stated by Antunes et al. (2018), hence too subjective to predict the outcomes, and thus requires a specific and unique treatment plan in each case [176].

Future studies should give priority to the extension of works involving larger samples with diversified populations to increase the generalizability of findings [239]. Long-term, multi-center trials with an extension of follow-up may explore durability and efficacy accruable to various treatment techniques [242]. Also, standardization of the research protocols is needed regarding uniformity in standards for outcome assessments with respect to aesthetic and functional measures and standardized pain and discomfort rating scales. Future prospects include developments in imaging technology that presently incorporate 3D CBCT. Patient-centered outcomes, such as quality of life, satisfaction with treatment, and functional and aesthetic results in the long term, are parameters that should be monitored to keep the patient close to the treatment plan [146]. Investigating combined treatment techniques may also reveal new insights into optimizing care, and developing predictive models using data analysis and machine learning could lead to more personalized and efficient treatment planning. Addressing these limitations and future directions will drive progress in orthodontics, ultimately enhancing treatment options for impacted canines and improving patient care.

Conclusions

This systematic review highlights the critical factors in the management of impacted canines, emphasizing the importance of tailored treatment approaches. Both extraction and orthodontic traction are effective options, each with specific advantages depending on the severity of impaction and patient-specific factors. While extraction provides a faster solution and reduces risks of complications, it may lead to aesthetic and functional issues requiring prosthetic solutions. On the other hand, traction, though more complex and time-consuming, preserves the natural tooth and aesthetic integrity. Advances in surgical techniques, such as the use of laser technology and minimally invasive corticotomy, have improved outcomes by reducing surgical time and enhancing the speed of tooth eruption, with minimal side effects. The integration of advanced imaging technologies like CBCT has also enhanced diagnostic accuracy and surgical planning, reducing risks and improving patient outcomes. The review underscores the necessity of a patient-centered, multidisciplinary approach to treatment, considering the multifactorial etiology of canine impaction, which includes both genetic and environmental factors. Early genetic screening may play a future role in predicting impaction risks and guiding timely interventions. The findings advocate for further research, particularly randomized controlled trials, to refine treatment selection criteria and incorporate emerging genetic and technological advancements into clinical practice.

Abbreviations

α	Alpha-angle
CBCT	Cone-beam computed tomography
CLP	Cleft lip and/or palate
IC	Impacted canines
d	Distance
DC	Deciduous canine
DEG	Double-extraction group
GRL	Gingival recession level
PIC	Palatally impacted canines
PDC	Palatally displaced canines
PPD	Periodontal pocket depth
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PROSPERO	The International Prospective Register of Systematic Reviews
RCT	Randomized controlled trial
s	Sector
SEG	Single-extraction group

Supplementary Information

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Supplementary Material 1.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
This study was approved by Ethics Committee of "Azienda Ospedaliero Universitaria Consorziale Policlinico", Bari, Italy (0015987, 17 February 2022).

Competing interests
The authors declare no competing interests.

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