

Scientific article

**Periodontal status after
autologous tooth
transplantation (ATT) of
premolars and wisdom teeth: A
systematic review**

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Keywords

Dental injury, Tooth transplantation, Wisdom tooth, Permanent tooth, External replacement resorption, Periodontics

Abstract

This study explored the clinical and radiological outcomes after autologous premolar and wisdom tooth transplantation, with a focus on periodontal status. A systematic search was conducted using all relevant databases up to April 5, 2024. The inclusion criteria were as follows: a) human participants, b) a sample size of at least five autotransplanted teeth, c) molar or premolar transplants, d) English language use, and e) at least 1 year of follow-up. The following parameters were assessed: probing pocket depth, recession, tooth mobility, ankylosis, bone level, and tooth loss. Our search identified 466 records, and after our selection process, 25 articles were suitable for analysis, with a total of 3732 teeth (569 premolars and 350 molars) with a mean follow-up duration of 6.1 years. The 10-year survival rate of autologous tooth transplants ranged from 33.8% to 100%, and the mean complication rates of root resorption and ankylosis were 8.9% (13 studies) and 14.0% (10 studies), respectively. Periodontal complications such as periradicular radiolucency, periodontal defects, and attachment loss occurred in less than 10% of patients. The premolars exhibited superior clinical and radiological outcomes compared with the molars. In conclusion, the survival rate and periodontal status after autologous tooth transplantation (ATT) of premolars and molars were consistent with those of traditional dental implants. Therefore, autotransplantation may be considered in cases where dental implants are indicated. As specific reports on periodontal complications are scarce, further research is warranted to identify the specific factors associated with periodontal complications in autologous transplant recipients.

Introduction

The history of tooth autotransplantation dates back to the 18th century (1). Since then, extensive knowledge on the topic and surgical techniques has been obtained. In the late 20th century, major steps forward in the understanding of the prognosis and associated risk factors of tooth autotransplantation were made. At this time, a standard surgical procedure was also proposed (2), including a wide array of indications such as traumatic tooth loss, replacement of teeth with poor prognosis, congenitally missing teeth, and the development of dental anomalies (3).

Autologous tooth transplantation (ATT), also referred to as autotransplantation, enables vital periodontium and continuous skeletal growth compared to immovable osseointegrated dental implants (4). The longevity and prognosis of autologous tooth transplants has been reported to be comparable to that of dental implants (5). However, this study has reported long-term survival rates of 75.3% to 91% for autotransplanted teeth, which is lower than the general long-term outcomes reported for dental implants, which are also based on studies involving larger sample sizes. Notably, the procedure is complex as it involves the transplantation of embedded, impacted, or erupted teeth from one part of the mouth to another in the same individual. Despite some evidence indicating overall favorable long-term survival rates and advantageous outcomes, autotransplantation is still not widely established in general practice (6), although relatively low overall failure rates ranging from 2.0% to 10.3% and five-year survival rates ranging from 81% to 98.2% have been reported. Moreover, a low rate of major complications, specifically ankylosis, has been noted, ranging from 1.2% to 6.2% (7).

Because autotransplantation has advantages, it can be considered a neglected approach that warrants further investigation (8). This includes a periodontium that functions physiologically, proprioception, and preservation of alveolar bone volume. Notably, in cases in which autotransplantation fails, the patient's bone and soft tissue remain favorable for subsequent treatment (9).

There are, however, some clinical limitations that must be considered: A review found that the most prevalently reported complications with the subsequent need for extraction are pulp necrosis, pulp obliteration, root resorption, and/or hypermobility (10). Notably, modifying factors influence longevity, including systemic antibiotic use, mature donor teeth, endodontic treatment, post-surgery tooth splinting, and complicated root morphology (11). In summary, the variability in treatment protocols and the limited data on esthetic outcomes and patient-reported outcome measures (PROMs) indeed make it difficult to classify the evidence on autotransplantation as broad.

To the best of our knowledge, available evidence does not synoptically focus on the periodontal status of transplanted teeth. Therefore, this systematic review aimed to analyze the literature published in the last 20 years, focusing on periodontal healing after tooth transplantation of premolars and wisdom teeth, with a clinical focus on probing pocket depth, recession, tooth mobility, ankylosis, bone level, and tooth loss. Based on these findings, recommendations for clinicians should be synthesized with a special focus on the periodontal situation and prognosis.

Materials and methods

This systematic literature search was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (12). The protocol for this review was registered in the International Prospective Register of Systematic Reviews (PROSPERO) (13).

Search Strategy

The participants, exposure, and outcomes (PEO) framework was adopted to devise the research question and identify search terms for employment in the search strategy (Table 1). The research question was formulated as follows: What is the periodontal status of patients following ATT of the premolars and wisdom teeth?

An independent reviewer conducted the literature search. Using the identified search terms, the electronic article databases PubMed, Cochrane Register of Controlled Trials (CENTRAL), Scopus, and EMBASE were systematically screened to retrieve a list of relevant literature for assessment on April 5, 2024. The search consisted of the following terms: (“tooth transplantation” OR “tooth auto-transplantation” OR “ATT”) AND (“premolar” OR “wisdom”) AND (“periodontal status” OR “probing depths” OR “recessions” OR “loosening” OR “ankylosis” OR “bone level” OR “stability” OR “bone loss”).

A manual search of bibliographies of the identified literature was also conducted. The referencing software EndNote X9 software was used to track citations and identify and remove duplicate studies. The resulting studies were manually evaluated to ensure relevance before comparison with the inclusion and exclusion criteria.

Inclusion and exclusion criteria

Studies were included under the following premises: a) clinical studies with human participants; b) a sample size of at least five autotransplanted teeth; c) molar or premolar transplants; d) published in the English language; e) at least 1-year follow-up period; and f) published in the last 20 years. Review articles were excluded from the systematic review.

Data extraction

A data extraction form was prepared according to the PRISMA recommendations (12). It was built around the study characteristics, with the following parameters specifically extracted: author and year; study design; number of sample teeth; tooth type; mean follow-up duration; 10-year survival rate; prevalence of complications such as ankylosis and resorption; and any other notable outcomes including pulp necrosis, pulp obliteration, root resorption, and/or hypermobility.

Risk of bias and quality assessment

The Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) tool was used to investigate the risk of bias in the included literature. This approach considers

certainty ratings, as detailed in Table 2, to evaluate the risk of bias for each study. The initial rating of the literature was based on the study design, with randomized controlled trials deemed high-quality evidence, and observational studies deemed low-quality evidence. These ratings were then altered by the reviewer, with the primary reasons for downgrading being imprecision, inconsistency, indirectness, and publication bias (14).

Results

Identification of the literature

Twenty-five studies relevant to the aims and objectives of this systematic review were identified (Figure 1). The primary rationale for exclusion was the study design of the identified records; 56 articles were review literature or qualitative studies centered on patient experiences, 21 studies included animal models of periodontal status, and 10 studies were published outside of the predefined inclusion criteria.

Study characteristics

Finally, the clinical and radiological outcomes of 3732 teeth, including 569 premolars, 350 molars, 49 canines, and 4 incisors, were analyzed. The mean follow-up duration across the studies was 6.1 years (range, 1–17 years). Twenty-two studies were retrospective (88%), two were cases control studies (8%), and one study was prospective (4%). Table 3 provides an overview of the relevant literature.

Clinical and periodontal status

The overall 10-year survival rate after autologous tooth transplantation varied from 33.8% to 100%. However, several studies have reported on the survival of both premolar and molar transplants, with premolar transplants yielding a greater survival rate than molar transplants. The most prevalent complications reported in literature include root resorption, radiolucency, intrabony periodontal defects, and ankylosis.

An overview of these data in relation to radiological and other clinical outcomes is presented in Table 4. The prevalence of periodontitis was reported in only four studies and ranged from 1.6% to 16.7% (15,18,22,33). Data regarding attachment loss as a reason for failure were provided in one study only, accounting for 54.9% of cases (33). The mean probing depth was < 3 mm. Only one study reported on increased probing depths (from 0.04 to 0.49 mm depending on the probing location) of autotransplanted teeth (31).

Risk of bias and quality assessment

None of the included studies had a high risk of bias (Table 5). An unclear risk of bias was deduced in nine studies, which was mainly related to inconsistency, indirectness, and publication bias. The majority deemed to have an unclear risk of bias were downgraded because of inconsistencies in the evidence.

Discussion

Our review explored the clinical and radiological outcomes of autologous premolar and wisdom tooth transplantation, with a distinct focus on periodontal conditions. Our findings indicated high overall survival and success rates, and a low incidence of complications associated with this procedure. Notably, the greater 10-year survival rate of autologous transplantations of premolars was compared with that of molars. This discrepancy may result from the challenge associated with the atraumatic removal of molars, leading to a higher risk of ankylosis and other infections (32). In summary, autologous tooth transplants are – under optimal clinical conditions - comparable to traditional implants, with the available literature supporting the recommendation that this procedure should be considered a promising alternative for the treatment of tooth loss (28-34). Autotransplantation may offer advantages especially in young patients where bone volume is limited or a biologically conservative approach is preferred. In contrast, implants are ideal for adults with completed skeletal growth, providing a stable, predictable solution in edentulous areas where donor teeth aren't available. Tailoring the choice to each patient's age, growth stage, and clinical needs is therefore important. A prerequisite for successful tooth transplantation is the atraumatic removal of the transplant and the skillful preparation of the recipient region in conjunction with an adequate three-dimensional transplantation of the tooth in functional occlusion. To support periodontal soft tissue integration, a flexible titanium trauma splint and good wound management leading to first intentional healing are required.

The success of ATT is underpinned by several factors, each contributing to patient prognosis. These include the stage of root formation, integrity of the periodontal ligament, surgical technique employed, extra-alveolar time of the transplanted tooth, and quality of the recipient socket (40). Collectively, these factors contribute to periodontal healing, the process by which damaged periodontal tissues, including the gingiva, periodontal ligament, and alveolar bone, undergo repair and regeneration after an injury or disease. It is often measured using various clinical parameters such as probing depth reduction, gingival attachment gain, reduction in inflammation, and radiographic assessment of bone regeneration, providing quantitative indicators of tissue repair and functional restoration (41, 42). Periodontal healing commences with the restoration of gingival attachment, a process typically finalized within 1 week. Subsequently, reformation of the periodontal ligament fibers occurs within a timeframe ranging from 2 to 4 weeks post-injury (43). Successful transplantation comprises several criteria, including periodontal health (evidenced by a consistently traceable periodontal ligament visible on radiographs, normal percussion sound, healthy gingiva, absence of pathologically increased probing depths, and no non-physiological tooth mobility) and vital pulp status (determined by obliterated/narrowed pulp and/or progressing root growth). Pathological conditions were defined as probing depths exceeding 3 mm, while tooth mobility grades II and III were categorized as non-physiological according to the criteria established by Lang et al. (2003) and Savage et al. (2009) (44, 45).

A relationship between transplant success and other variables, including the surgeon and tooth type, was also observed in this review (28). Beyond the discrepancies observed in the periodontal outcomes of autologous premolar and molar transplantations, this review also showed that teeth with root lengths of one-half to three-quarters are more successful than those with alternative stages of development (32). Kafourou et al. (2017) exclusively focused

on the prognostic factors that influenced the success of tooth autotransplantation in a pediatric population of 75 patients. Although an overall success rate of 87.6% and survival rate of 94.4% were observed, the stage of root development was identified as a substantial predictor of success. This variable influences pulp and periodontal ligament healing in transplanted teeth (25).

The differences between molar and premolar autotransplantation success observed in this review are widely substantiated in the current literature. A review by Cooper et al. reported the exposure variables that influence implant stability. Implant insertion site showed the strongest association with dental implant failure. Implants in the anterior mandible resulted in a 6.43-fold lower risk of primary implant stability failure compared to other sites, whereas the maxilla had a 2.7-fold higher risk of failure than the mandible (46). Kolte et al. reported similar findings in a retrospective clinical and radiographic analysis of peri-implant tissue stability at the premolar and molar sites. However, this study suggests that there is a greater propensity for marginal bone loss at premolar implant sites than at molar implant sites (47). However, these findings warrant further investigation.

The follow-up period in autotransplant recipients is important, as major complications such as dental resorption may occur more than 24 months post-surgery (48). However, ankylosis was not widely observed in any of the included studies. The most prevalent complications were periradicular radiolucency, periodontal defects, and external root resorption.

(29). Although not the primary focus of this systematic review, a wider literature indicates a higher incidence of postoperative complications in mature transplants (49).

This systematic review focused on studies that included a minimum of five autotransplanted teeth. However, several case reports were identified in the search strategy that warrant further consideration. In addition to autologous transplantation as monotherapy, cases involving multidisciplinary approaches have been described. A 2015 case report described the 8-year follow-up of a patient who opted for autologous transplantation of tooth 48 into the alveoli of tooth 47. Subsequently, endodontic treatment and coronal rehabilitation with direct restoration were performed at a later date. Postoperative instructions were comprehensive to avoid masticatory trauma in the transplanted region. At the 8-year follow-up, the patient was asymptomatic and did not present any abnormalities in the preapical tissues around the transplanted tooth. An assessment of radiographic findings demonstrated that periapical healing was intact, and there was no external radicular resorption (40). Kumar et al. described an additional case in which a patient underwent third molar autotransplantation. At follow-up, radiographic findings indicated complete root development of the transplanted tooth with an adequately open apex and mesiodistal width of the crown for the recipient site (50).

Autologous tooth transplants are not exclusive to premolars and wisdom teeth, with a large proportion of available evidence detailing the long-term follow-up and success of primary tooth autotransplantation. Hoss et al. reported the success of 53 primary tooth autotransplantation procedures in 40 children. The overall success rate was 77% with a median survival time of 7.2-years. It was also observed that increased soft tissue and bone development in this population assisted in successful prosthetic rehabilitation (37). This research area presents opportunities for future review articles. Second, the included studies failed to report consistent quantitative data with different outcomes explored in each study. Therefore, a meta-

analysis was not performed in this systematic review, which prevented a robust assessment of the periodontal status of autologous dental transplants from being conducted.

Regarding our search strategy, we acknowledge limitations in excluding certain terms, such as “third molar” and “root resorption”, which might have potentially led to the omission of some potentially relevant studies, especially concerning key complications. This limitation could affect the breadth of our findings, and future research may benefit from incorporating broader search terms and different languages to enhance comprehensiveness.

Conclusions

Our study reports on 10 year survival rates ranging from 33.8 to 100%. This rather high variability indicates some technique sensitivity of this procedure, confounded by meticulous comprehensive treatment planning and strict case selection.

However, the periodontal status after ATT of the premolars and molars can nevertheless be considered as promising under the premise of adequate treatment conditions. Literature indicates that this procedure may be more viable in premolars than in molars, with a higher success rate and fewer complications observed in these patients. The clinical and radiological outcomes were consistent with those of traditional dental implants. Therefore, we recommend that autotransplantation should be considered in cases where dental implants are indicated, as the patient’s bone and soft tissue would remain in a favorable condition for subsequent treatment if autologous transplantation fails unless osteolysis due to inflammatory processes, like root resorptions, the bone and soft tissue do not remain in a favorable condition for subsequent treatment. Future research is warranted to identify factors associated with periodontal complications in autologous transplant recipients.

Zusammenfassung

Einleitung: Die Zahnautotransplantation (ATT) hat eine lange Geschichte und bietet eine Alternative zu herkömmlichen Zahnimplantaten. Trotz der vergleichbaren Langzeitprognose und der funktionellen Vorteile, wie dem Erhalt des parodontalen Ligaments und kontinuierlichem Knochenwachstum, ist die Methode in der allgemeinen Praxis noch nicht weit verbreitet. Diese systematische Übersichtsarbeit zielt darauf ab, klinische und radiologische Ergebnisse nach der Transplantation von Prämolaren und Weisheitszähnen zu untersuchen, mit besonderem Fokus auf den parodontalen Status.

Materialien und Methoden: Eine systematische Literaturrecherche wurde in den Datenbanken PubMed, Cochrane Register of Controlled Trials (CENTRAL), Scopus und EMBASE bis zum 5. April 2024 durchgeführt. Eingeschlossen wurden Studien mit menschlichen Teilnehmern, einer Mindeststichprobengröße von fünf autotransplantierten Zähnen, Prämolaren oder Molaren, veröffentlicht auf Englisch und mit einer Nachbeobachtungszeit von mindestens einem Jahr. Die Suchstrategie umfasste Begriffe wie "Zahntransplantation", "parodontaler Status" und spezifische Komplikationen wie "Ankylose" und "Wurzelresorption". Die Datenextraktion und Qualitätsbewertung erfolgten gemäß den PRISMA-Richtlinien und dem GRADE-Tool.

Ergebnisse: Von den 466 relevanten Studien wurden 25 für die endgültige Analyse ausgewählt. Diese umfassten klinische und radiologische Ergebnisse von 3732 Zähnen, darunter 569 Prämolaren und 350 Molaren, mit einer durchschnittlichen Nachbeobachtungsdauer von 6,1 Jahren. Die 10-Jahres-Überlebensrate der autolog transplantierten Zähne variierte stark von 33,8% bis 100%. Die durchschnittlichen Komplikationsraten betragen 8,9% für Wurzelresorption und 14,0% für Ankylose. Weitere Komplikationen wie radioluzente Bereiche und parodontale Defekte traten seltener auf, jeweils weniger als 10%. Prämolaren zeigten im Vergleich zu Molaren bessere klinische und radiologische Ergebnisse.

Diskussion: Die Ergebnisse dieser systematischen Übersichtsarbeit zeigen, dass die Überlebensrate und der parodontale Status nach ATT von Prämolaren und Molaren vergleichbar mit traditionellen Zahnimplantaten sind. Die Überlebensrate war bei Prämolaren höher als bei Molaren, möglicherweise aufgrund der schwierigeren atraumatischen Extraktion von Molaren, was zu einem höheren Risiko für Ankylose und Infektionen führen kann. Ein erfolgreicher Transplantationserfolg wird durch Faktoren wie das Stadium der Wurzelbildung, die Integrität des parodontalen Ligaments, die chirurgische Technik und die Qualität der Empfänger-alveole beeinflusst. Diese Faktoren tragen zur parodontalen Heilung bei, die durch Parameter wie Taschentiefenreduktion, Gingiva-Attachment-Gewinn und Knochenregeneration gemessen wird.

Die Unterschiede in den Ergebnissen zwischen Prämolaren- und Molaren-Transplantationen unterstreichen die Notwendigkeit weiterer Forschung, um spezifische Risikofaktoren für parodontale Komplikationen zu identifizieren. Trotz der Variabilität in den Ergebnissen und der eingeschränkten Verfügbarkeit konsistenter quantitativer Daten unterstützt die vorhandene Literatur die Empfehlung, ATT als vielversprechende Alternative bei Zahnverlust in Betracht zu ziehen.

Schlussfolgerungen: Die systematische Übersichtsarbeit zeigt eine hohe Überlebensrate und einen vielversprechenden parodontalen Status nach ATT von Prämolaren und Molaren. Diese Methode sollte als Alternative zu Zahnimplantaten in Betracht gezogen werden, insbesondere da bei einem Fehlschlagen der Transplantation der Knochen und das Weichgewebe des Patienten in einem günstigen Zustand für weitere Behandlungen bleiben. Weitere Forschung ist erforderlich, um Faktoren zu identifizieren, die mit parodontalen Komplikationen bei autologen Transplantationen verbunden sind.

Résumé

Introduction: La transplantation dentaire autologue (TDA) a une longue histoire et offre une alternative aux implants dentaires conventionnels. Malgré le pronostic à long terme comparable et les avantages fonctionnels, tels que la préservation du ligament parodontal et la croissance osseuse continue, cette méthode n'est pas encore largement répandue dans la pratique générale. Cette revue systématique vise à examiner les résultats cliniques et radiologiques après la transplantation de prémolaires et de dents de sagesse, en se concentrant particulièrement sur l'état parodontal.

Matériels et Méthodes: Une recherche systématique de la littérature a été effectuée dans les bases de données PubMed, Cochrane Register of Controlled Trials (CENTRAL), Scopus et

EMBASE jusqu'au 5 avril 2024. Les études incluses comprenaient des participants humains, avec un échantillon d'au moins cinq dents autotransplantées, des prémolaires ou des molaires, publiées en anglais et avec une période de suivi d'au moins un an. La stratégie de recherche incluait des termes tels que "transplantation dentaire", "état parodontal" et des complications spécifiques comme "ankylose" et "résorption radiculaire". L'extraction des données et l'évaluation de la qualité ont été réalisées conformément aux directives PRISMA et à l'outil GRADE.

Résultats: Sur les 466 études pertinentes, 25 ont été sélectionnées pour l'analyse finale. Celles-ci comprenaient des résultats cliniques et radiologiques de 3732 dents, dont 569 prémolaires et 350 molaires, avec une durée moyenne de suivi de 6,1 ans. Le taux de survie à 10 ans des dents autotransplantées variait fortement de 33,8 % à 100 %. Les taux moyens de complications étaient de 8,9 % pour la résorption radiculaire et de 14,0 % pour l'ankylose. D'autres complications, telles que les zones radiotranslucides et les défauts parodontaux, étaient moins fréquentes, chacune représentant moins de 10 %. Les prémolaires ont montré de meilleurs résultats cliniques et radiologiques par rapport aux molaires.

Discussion: Les résultats de cette revue systématique montrent que le taux de survie et l'état parodontal après TDA de prémolaires et de molaires sont comparables à ceux des implants dentaires traditionnels. Le taux de survie était plus élevé pour les prémolaires que pour les molaires, probablement en raison de l'extraction atraumatique plus difficile des molaires, ce qui peut augmenter le risque d'ankylose et d'infections. Le succès de la transplantation est influencé par des facteurs tels que le stade de formation des racines, l'intégrité du ligament parodontal, la technique chirurgicale et la qualité de l'alvéole réceptrice. Ces facteurs contribuent à la guérison parodontale, mesurée par des paramètres tels que la réduction de la profondeur des poches, le gain d'attachement gingival et la régénération osseuse.

Les différences dans les résultats entre les transplantations de prémolaires et de molaires soulignent la nécessité de recherches supplémentaires pour identifier les facteurs de risque spécifiques des complications parodontales. Malgré la variabilité des résultats et la disponibilité limitée de données quantitatives cohérentes, la littérature existante soutient la recommandation de considérer la TDA comme une alternative prometteuse en cas de perte dentaire.

Conclusions: La revue systématique montre un taux de survie élevé et un état parodontal prometteur après la TDA de prémolaires et de molaires. Cette méthode devrait être envisagée comme une alternative aux implants dentaires, en particulier car, en cas d'échec de la transplantation, l'os et les tissus mous du patient restent dans un état favorable pour des traitements ultérieurs. Des recherches supplémentaires sont nécessaires pour identifier les facteurs associés aux complications parodontales dans les transplantations autologues.

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Table 1. PEO framework for the formulation of the research question.

Participants	Patients who have undergone an ATT
Exposure	Autologous tooth transplantation, tooth auto-transplantation, premolar transplantation, wisdom tooth transplantation
Outcomes	Periodontal status, probing depths, recessions, degree of loosening, ankylosis, bone level, stability or loss

Table 2. The level and quality of evidence criteria according to the GRADE recommendations.

Level of Evidence	Rationale
<i>High quality of evidence</i>	We are confident that the true effect lies close to that of the estimate effect.
<i>Moderate quality of evidence</i>	We are moderately confident that the true effect lies close to that of the estimate effect; however, we expect that there are notable differences.
<i>Low quality of evidence</i>	We have limited confidence that the true effect lies close to that of the estimate effect and suspect that substantial differences are apparent between the two.
<i>Very low quality of evidence</i>	We have very little confidence that the true effect lies close to that of the estimate effect and are confident that substantial differences exist between the two.

Table 3. Study characteristics of included literature.

Author (year) (reference)	Study design	Number of teeth	Tooth type	Mean follow-up (years)
Watanabe et al. (2009) (15)	Retrospective	33	n/a	9.2
Tang et al. (2017) (16)	Retrospective	26	26 molars	2
Suwanapong et al. (2021) (17)	Retrospective	50	1 premolar, 49 molars	1
Stange et al. (2016) (18)	Retrospective	12	12 premolars	16.2
Schütz et al. (2013) (19)	Retrospective	56	n/a	2.2
Plakwicz et al. (2013) (20)	Prospective	23	23 premolars	2.9
Plakwicz et al. (2014) (21)	Case control	9	9 premolars	5
Mertens et al. (2016) (22)	Retrospective	25	n/a	14.3
Mendoza et al. (2012) (23)	Retrospective	12	12 premolars	14
Kokai et al. (2015) (24)	Retrospective	100	n/a	5.8
Kafourou et al. (2017) (25)	Retrospective	89	n/a	2.6
Erdem et al. (2021) (26)	Retrospective	12	n/a	1.5
Carvalho et al. (2014) (27)	Retrospective	33	n/a	7
Ronchetti et al. (2015) (28)	Retrospective	75	56 premolars, 19 molars	3.95
Boschini et al. (2020) (29)	Retrospective	21	13 premolars, 8 molars	11.9
Kvint et al. (2010) (30)	Retrospective	269	43 premolars, 93 molars	4.8
Plakwicz et al. (2014) (31)	Case control	9	9 premolars	5

Table 4. Periodontal status, 10-year survival rate and complications reported in the included literature (periodontal parameters are highlighted in red).

Author (year) (reference)	10-year survival rate (%)	Complications (%)	Other outcomes *
Watanabe et al. (2009) (15)	86.8	Ankylosis: 18.2%, Resorption: 3.0%	PPD (mm): 1.2-2.5 REC (mm): 0.5 PP: 6.1%
Tang et al. (2017) (16)	100	n/a	PI: 0 BI: 0 PPD (mm): 1.0 – 3.0 TM: 0
Suwanapong et al. (2021) (17)	n/a	n/a	n/a
Stange et al. (2016) (18)	100	n/a	BI: 66.6 PPD (mm): 1.0-3.0 REC (mm): 1.0-3.0 PP: 8.3% Obliteration: 100%
Schütz et al. (2013) (19)	94.7	n/a	Obliteration: 21.4%
Plakwicz et al. (2013) (20)	91.3	Ankylosis: 4.3%	PPD (mm): 1.33-3.33, Obliteration: 95.7%
Plakwicz et al. (2014) (21)	100	n/a	PPD (mm): 1.55-2.27, Obliteration: 11.1%
Mertens et al. (2016) (22)	61.1	Ankylosis: 27.8%, Resorption: 22.2%	PI: 0.67 BI: 0.33 PPD (mm): 2.24 REC (mm): 0.06 PP 16.7%
Mendoza et al. (2012) (23)	80	Resorption: 16.6%	Obliteration: 100%
Kokai et al. (2015) (24)	71	Ankylosis: 15.0% Resorption: 10.0%	n/a
Kafourou et al. (2017) (25)	85.4	Ankylosis: 13.5% Resorption: 11.2%	n/a
Erdem et al. (2021) (26)	100	n/a	n/a
Carvalho et al. (2014) (27)	n/a	Ankylosis: 39.0%	Obliteration: 9.0%
Ronchetti et al. (2015) (28)	81.6 (premolars) 33.8 (molars)	n/a	No significant association between success and root development (p=.13) or use of enamel matrix proteins (p=.10), apex width (p=.59 or recipient area (p=.48)
Boschini et al. (2020) (29)	95	Root resorption (4.8), Radiolucency (9.5), Periodontal defect (4.8), Acute infection (4.8)	Full rehabilitation of chewing function at 2-months
Kvint et al. (2010) (30)	81	n/a	n/a
Plakwicz et al. (2014) (31)	100	n/a	Wider zone of keratinized gingiva, increased probing depths (0.04 to 0.49mm), pulp canal obliteration, slightly higher crown-to-root-ratio
Denys et al. (2013) (32)	72.2	Ankylosis (10.2) Resorption (20.4)	n/a
Yoshino et al. (2011) (33)	70.5	Attachment loss (9.1), Root resorption (4.4), Caries (0.65), Root fracture (0.49)	n/a
Yoshino et al. (2013) (34)	63 (males) 79 (females)	Attachment loss (4.5), Root resorption (8.9), Ankylosis (5.0)	Gender differences were observed in complications. Loss of transplanted
Albaloochy et al. (2023) (35)	80	Ankylosis: 12.5% Resorption: 2.7%	BI: 19.4, REC (mm): 2.7 Obliteration: 38.4%
Barendregt et al. (2023) (36)	95.5	Ankylosis: 4.1% Resorption: 2.7%	PP: 1.6%
Hoss et al. (2021) (37)	77	n/a	PI: 14 BI: 10, PPD (mm): 2.2 TM: 1.5 Obliteration: 23%
Lucas-Taule et al. (2021) (38)	91.7	Resorption: 2.8%	PPD (mm): 2.7
Maddalone et al. (2022) (39)	90.3	Ankylosis: 4.9% Resorption: 6.6%	n/a

Table 5. Risk of bias of literature included in the systematic review.

Author (year) (reference)	Inconsistency	Indirectness	Imprecision	Publication Bias
Watanabe et al. (2009) (15)				
Tang et al. (2017) (16)				
Suwanapong et al. (2021) (17)				
Stange et al. (2016) (18)				
Schütz et al. (2013) (19)				
Plakwicz et al. (2013) (20)				
Plakwicz et al. (2014) (21)				
Mertens et al. (2016) (22)				
Mendoza et al. (2012) (23)				
Kokai et al. (2015) (24)				
Kafourou et al. (2017) (25)				
Erdem et al. (2021) (26)				
Carvalho et al. (2014) (27)				
Ronchetti et al. (2015) (28)				
Boschini et al. (2020) (29)				
Kvint et al. (2010) (30)				
Plakwicz et al. (2014) (31)				
Denys et al. (2013) (32)				
Yoshino et al. (2011) (33)				
Yoshino et al. (2013) (34)				
Albalooshy et al. (2023) (35)				
Barendregt et al. (2023) (36)				
Hoss et al. (2021) (37)				
Lucas-Taule et al. (2021) (38)				
Maddalone et al. (2022) (39)				

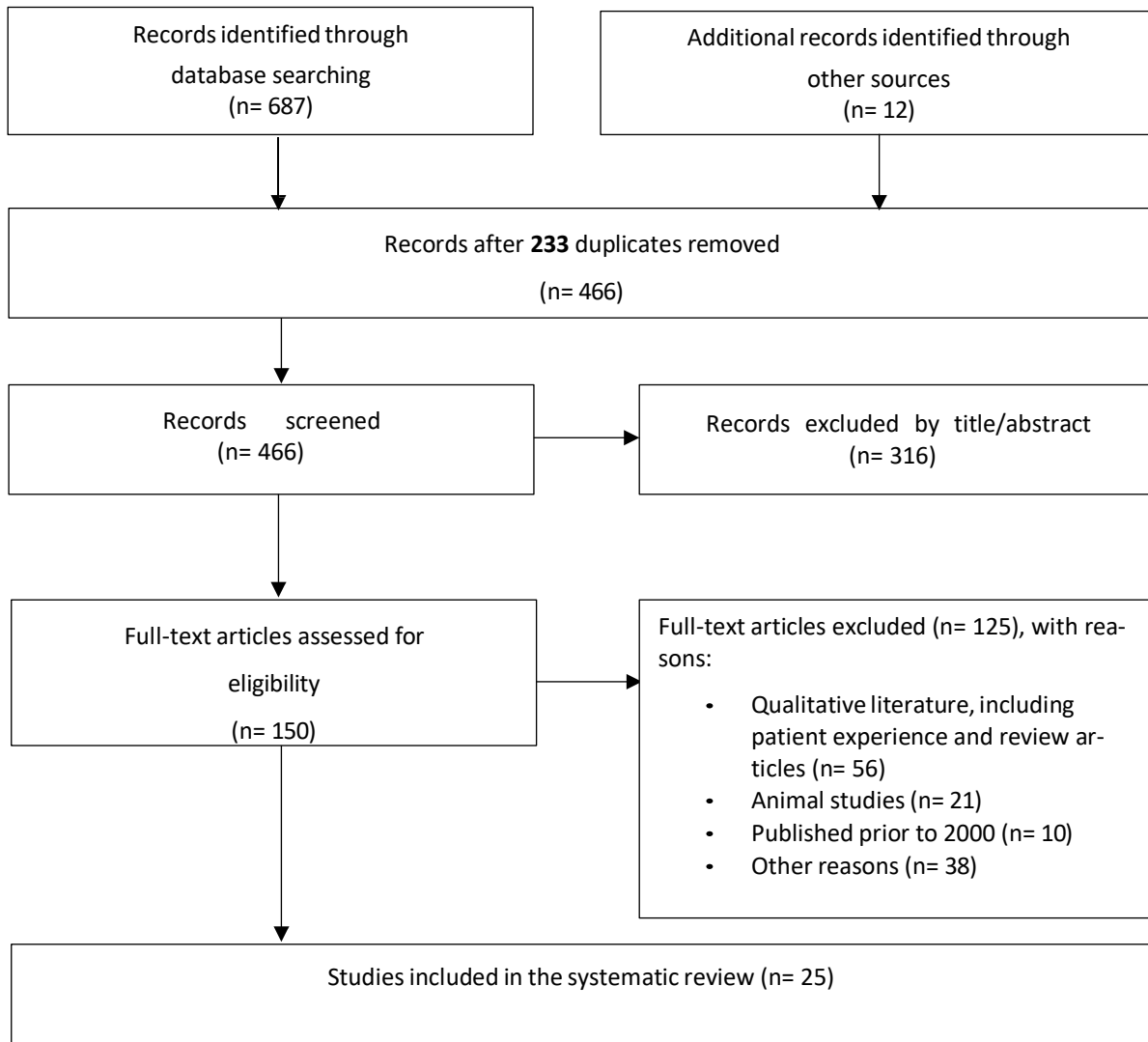


Figure 1. PRISMA flow diagram for the study selection process for this systematic review.