SWISS DENTAL JOURNAL SSO Science and Clinical Topics

ISSN 2296-6498
swissdentaljournal.org

Clinical Topic

Criteria and prognostic factors for survival and success rates for autotransplantation of immature third molars to the area of first and second molars: a systematic review and meta-analysis

Accepted: February 26, 2025
DOI: 10.61872/sdj-2025-01-05
2025, Vol. 135

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Keywords
autotransplantation, immature third molars, survival rate, success rate, prognostic factors

Abstract

Autotransplantation of immature third molars in the area of first and second molars is an effective treatment option, offering high success rates, minimal complications, and notable improvements in occlusal function and dental aesthetics. This study aims to review and evaluate the available evidence specifically on the survival and success rates of immature autotransplanted third molars.

A comprehensive search was conducted in the Elsevier Journals (ScienceDirect), MEDLINE (PubMed), and Dentistry & Oral Sciences Source (EBSCOhost) databases up to May 2024. Risk of bias within studies was assessed with the CASP guidelines. Nine studies met the inclusion criteria for qualitative and quantitative analysis. The pooled survival rate was consistently high across studies, estimated at 91.9% (95% CI: 85.1% to 96.7%), while the success rate, though slightly lower, remained substantial at 90.2% (95% CI: 79.8 % to 97.1%).

The identified key prognostic factors include the developmental stage of the donor teeth, with better outcomes observed in those with earlier stages of root development and open apices. These developmental stages associated with enhanced success due to better potential for pulp revascularization and continued root growth. Additionally, innovative techniques, including advanced methods like computer-aided rapid prototyping (CARP) and platelet-rich plasma (PRP), were described to potentially support healing and integration. Stabilization methods during early healing methods also played a role, as excessive rigid stabilization was linked to higher rates of ankylosis and inflammatory root resorption.

Secondary objectives were to summarize prognostic factors mentioned in the literature to provide a clearer understanding of outcomes. Future research should prioritize recipient site and donor tooth characteristics, standardized success criteria, extended follow-up periods, and refined treatment protocols to enhance predictability and long-term outcomes in immature third molar autotransplantation in the area of first and second molars.

Introduction

Autotransplantation, the surgical relocation of a tooth within the same individual, has become an important treatment option in modern dentistry (1). This procedure is particularly beneficial for the area of first and second molars, which are crucial for chewing function, occlusal stability, and dental arch integrity (2,3). In cases where first and second molars require replacement due to poor prognosis, congenital absence, or orthodontic needs, immature third molar autotransplantation can be considered over implants or fixed partial dentures - especially in adolescents, where jaw growth is ongoing (1,4,5). Autotransplanted teeth offer unique advantages, including proprioception, pulp regeneration in immature roots, and cost-effectiveness compared to implants (6).

Immature roots are generally considered optimal for autotransplantation due to their higher success and survival rates, linked to better revascularization and regenerative potential (7). From an endodontic perspective, open apices facilitate pulp revascularization, reducing the risk of pulp necrosis and the need for root canal treatment (8). The presence of Hertwig's epithelial root sheath in immature teeth at the same time supports continued root development and periodontal ligament healing, enhancing long-term stability and integration (6,9). While premolars are a golden standard for autotransplantation because of their frequent extraction during orthodontic treatment (10), recent research has started to focus on third molars as well (5,11, 12, 13,14,15, 16, 17,18,19, 20,21,22). The use of mature (23, 24, 25, 26) and immature (5,12,14,15,16,17,18,19,20,27,) third molars is reported in the literature, but immature third molars, with open apices and robust periodontal ligaments, offer healing and integration advantages, although the impact of root development stage on outcomes remains unclear (28,29).

Reported success and survival rates range from 31–100% and 30.4%–100% (29) and those are key indicators of autotransplantation efficacy, with prognostic factors like root development, innovative techniques, stabilization methods during early healing, and recipient site and donor tooth characteristics playing significant roles (5,17,19,20). Although systematic reviews have explored survival and success rates for autotransplanted teeth, most include researches with premolars or incisors (26,30,31,32,33,34), molars that are transplanted not in the area of first or second molar (31), teeth with complete root formation or N/A formation (26,30,31,33, 34,35) or that research papers that are not found in open access (31), leaving a gap in research specifically addressing immature third molars.

Primarily this study aims to fill this gap by conducting a systematic review and meta-analysis exclusively on the success and survival rates of autotransplanted third molars in the area of first and second molars with incomplete root formation. A secondary objective was to summarize prognostic factors mentioned in the literature. The null hypothesis was that autotransplantation of third immature molars in the first and second molar regions is not an effective treatment method, with no significant difference in success and survival rates compared to other treatment options.

Materials and methods

Search strategy

The search strategy was based on the guidelines developed by PRISMA 2020 (Preferred Reporting Items for Systematic reviews and Meta-Analyses) (36) (Fig. 1). The author of the research paper performed an analysis of scientific literature using Elsevier Journals (ScienceDirect), MEDLINE (PubMed) and Dentistry & Oral Sciences Source (EBSCOhost) scientific databases, reviewing scientific articles from May 2004 until May 2024. The article search was conducted on 17 May 2024, Table 1 indicates the inclusion and exclusion criteria. After identifying articles, studies were subjected to a PICO analysis (37).

The PICOS criteria used for study selection was:

Population:	patients who underwent autotransplantation in the region of first or second molars.
Intervention:	autotransplantation of immature third molars.
Comparison:	none (Not applicable for outcome and survival analysis review).
Outcomes:	survival rate, success rate.

The secondary objective was addressed through a qualitative review of relevant studies, included in this systematic review. These studies have been assessed for factors such as developmental stage, donor tooth characteristics, and treatment techniques, which were then summarized and compared based on their impact on outcomes. This was done without conducting statistical analyses of these prognostic factors, as the aim was to identify key factors that had been consistently reported in the literature.

The search strategy was performed including:

(1) treatment, (2) autotransplanted tooth OR (3) region of autotransplantation (recipient site), (4) success rates OR survival rates and (5) root development.

Search combinations in Elsevier Journals, MEDLINE and Dentistry & Oral Sciences Source scientific databases:

1) (autotransplantation OR autogenous transplant) AND third molar AND (survival rate OR success rate)
2) (autotransplantation OR autogenous transplant) AND (first molar OR second molar) AND (survival OR success rate)
3) (autotransplantation OR autogenous transplant) AND third molar AND (survival rate OR success rate) AND immature
4) (autotransplantation OR autogenous transplant) AND third molar AND (survival rate OR success rate) AND incomplete root formation

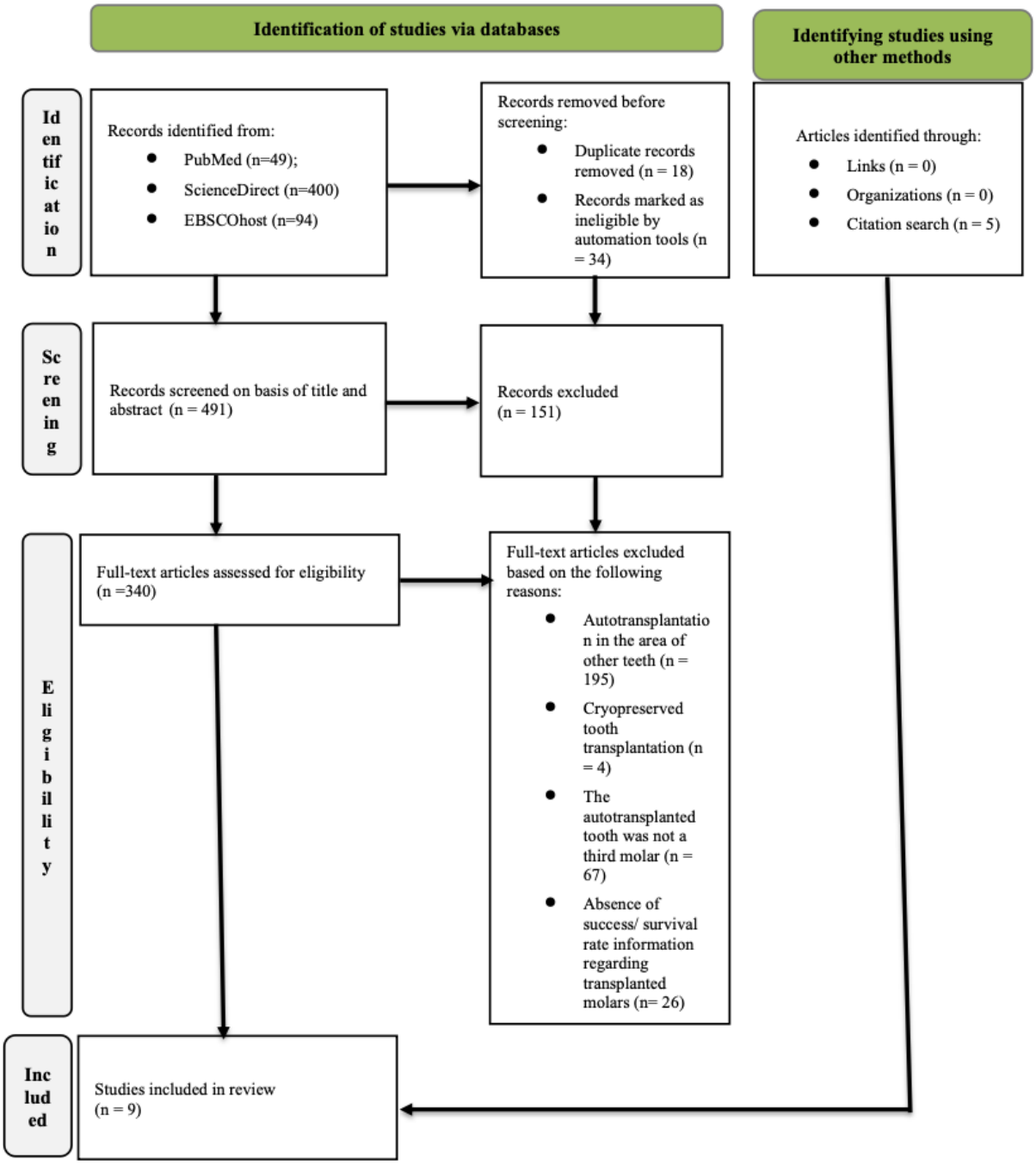

Figure 1. Selection of articles for systematic review.

Table 1. Exclusion and inclusion criteria.

Parameter	Inclusion criteria	Exclusion criteria
Intervention	- Autotransplantation in the 1st and 2nd molar region - Autotransplanted tooth - third molar - Immature autotransplanted tooth – incomplete root development/ teeth with open apexes	- Autotransplantation in non-molar sites - Cryopreserved tooth transplantation - Allogeneic transplantation - Autotransplanted tooth - First and second molar, premolars, canines, incisors
Study design	- Prospective and retrospective studies - Randomized Controlled Trial - Cross-sectional studies - Cohort studies - Case series	- Ex vivo/ In vivo experimental studies - Animal studies - Reviews - Case reports
Number of follow-up visits	- No restrictions	
Outcome	- The article should include data on donor tooth success rates and/or survival rates	
Date of publication	- Last 20 years (from May 2004 until May 2024) - The full content of the study must be available on the Internet or in the PRIMO library	
Language of publication	- English	- Other languages

Evaluation of research bias and assessment of risk of bias

To ensure study quality and reliability, the author used the Critical Appraisal Skills Programme (CASP) guidelines to assess bias risks and conflicting findings (38) (Table 1, 2 in Appendices). CASP enabled a detailed evaluation across selection, performance, detection, attrition, and reporting biases. Additionally, inconsistencies between studies were examined to build a solid, unbiased evidence base for the conclusions.

The selection and evaluation of studies was carried out by the author of this work to ensure reliability and compliance with the established criteria (Table 1, 2 in Appendices). The selected articles and the obtained data were carefully discussed with the supervisor of the scientific work to ensure a more accurate assessment. The decision on the included studies was made through joint discussion.

It was decided that the author would interpret the results from CASP guidelines as follows (39):

Low Risk of Bias: If the study adheres well to the checklist criteria, with minimal flaws that are unlikely to significantly impact the findings, it suggests a low risk of bias.

High Risk of Bias: If the study has several shortcomings or methodological flaws that could potentially affect the reliability or validity of the results, it indicates a high risk of bias.

Data analysis and statistical methods

Data analysis and statistical methods were applied to analyze the study findings using a program “MedCalc” (Version 22.030). 95% confidence intervals (CI) and weight (random) (%) were calculated for studies that were included in data analysis. The inconsistency across studies was assessed using Q (Cochran’s Q), DF (degrees of freedom), significance level (p-value), I2 and 95% CI for I2. Egger's test and Begg's test was conducted (Table 3, Table 4, Table 6, Table 7) to evaluate publication bias. Visual aids such as forest plots and funnel plots (Fig. 2, Fig. 3, Fig. 4, Fig. 5) were generated to provide graphical representations of the data distribution and bias assessment.

Results

Study selection

The initial search yielded 543 articles (Fig. 1). After title and abstract screening, 340 articles were selected for full-text assessment. Only 4 articles met the inclusion criteria (5, 17,19,20). Studies involving other tooth regions (40,41), cryopreserved teeth (42,43), or complete root formation (23,24), were excluded. Studies with fewer than three qualifying cases were also omitted to ensure data robustness. A hand search of references added 5 more eligible papers (12,14,15,16,18) resulted in 9 articles for qualitative and quantitative analyses.

Quality assessment of included studies

The systematic review's quality assessment reveals that all included studies exhibit a high risk of bias (Table 1, Table 2 in Appendices). This compromises the reliability of findings and suggests potential methodological flaws across the literature. As a result, the conclusions drawn from this review should be approached with caution due to the uncertainty in the reported results and their applicability to informing decisions or policies. Future research should prioritize rigorous study designs to improve the robustness of evidence in this area.

Included studies

A total of nine studies were initially identified through database searches and “hand-searching” method (Table 3 in Appendices). The primary outcomes assessed were “survival” and “success rates” of autotransplanted third molars. Secondary outcomes included factors influencing these rates.

For this systematic review the author defined the concepts of “survival” and “success rates” based on the research paper "Tooth Autotransplantation: An Umbrella Review" (29). It was done to ensure a consistent and thorough evaluation of survival and success rates across the reviewed literature.

The definition of “survival rate” includes:

1)The presence of the tooth in its transplanted position at final follow-up visit regardless of the clinical and radiographic outcomes.

The definition of “success rate” includes:

1)Pulp revascularization following AT

2)Favorable periodontal healing with either no evidence of periapical, intra-, para- or periradicular radiolucency

3)Normal alveolar bone growth

-Absence of ankylosis

-Presence of lamina dura

Only by fulfilling all these parameters the autotransplantation can be deemed fully successful, as each parameter reflects a critical aspect of both the biological and functional integration of the transplanted tooth.

Primary outcomes

Only in two studies the criteria of survival were defined by authors (5,20). Regarding the primary outcomes of the “success”, there were mentioned:

- *pulp revascularization following AT* - vitality tests (5,14,15,16,17,18,19) and continuous root development (14,15,16,17,18,19).
- *favorable periodontal healing with either no evidence of periapical, intra-, para- or periradicular radiolucency* (5,14,15,16,17,18,20)

- *normal alveolar bone growth* - (5,12,14,15,16,17,18,20) and presence of lamina dura (5,15,18).

Table 2. Meta-analysis of overall survival rates of autotransplanted third molars.

Study	Sample size	Proportion (%)	Lower 95% CI	Upper 95% CI	Weight (random) (%)
Raabe et al. (20)	4	75	19.4	99.4	5.3
Erdem et al. (5)	12	100	73.5	100	11.4
Gonzalez-Ocasio et al. (19)	11	100	71.5	100	10.8
Nagori et al. (18)	42	85.7	71.5	94.6	23.2
Nimčenko et al. (17)	15	80	51.9	95.7	13.2
Jang et al. (16)	3	100	29.2	100	4.3
Schütz et al. (15)	34	97.1	84.7	99.9	21.1
İsa-Kara et al. (14)	11	100	71.5	100	10.8
Total (fixed effects)	132	91.5	85.6	95.6	100
Total (random effects)	132	91.9	85.1	96.7	100

Table 3. Statistical assessment of publication bias.

Publication bias	
Egger's test	
Intercept	0.3
95% CI	-2.9 to 3.4
Significance level	P = 0.8
Begg's test	
Kendall's Tau	-0.04
Significancelevel	P = 0.9

Table 4. Test for heterogeneity.

Test for heterogeniety	
Q	10.2
DF	7
Significance level	P = 0.2
I^2 (inconsistency)	31.7%
95% CI for I2	0,0 to 69,6

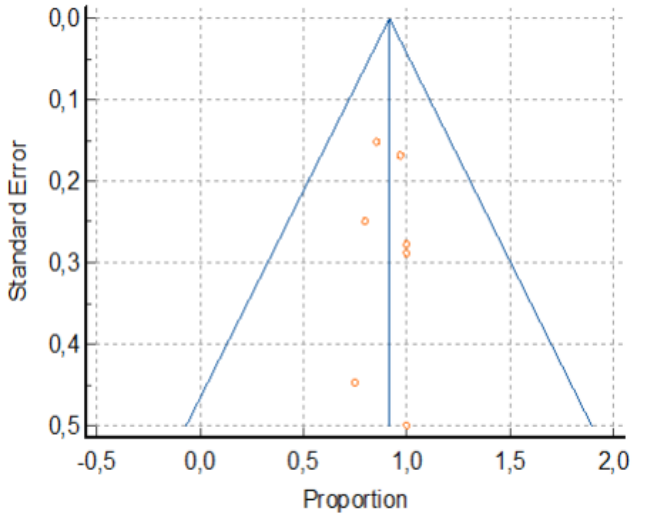

Figure 2. Funnel Plot.

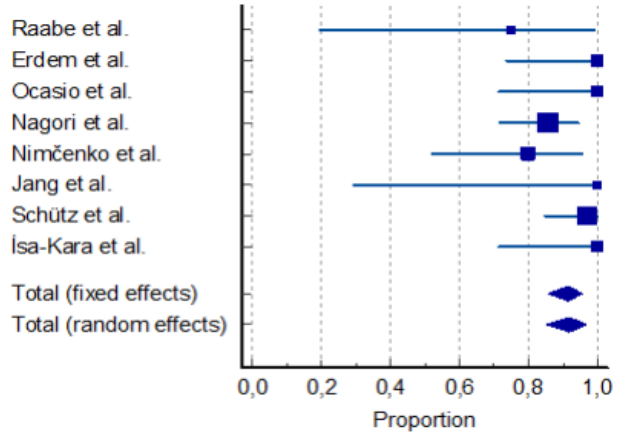

Figure 3. Forest Plot.

The survival rate was consistently high across most studies - 91.9% (95% CI: 85.1% to 96.7%, Table 2). The heterogeneity test revealed a Q value of 10.2457 (p = 0.2, Table 4), indicating moderate heterogeneity (I^2 = 31.7%, 95% CI for I^2: 0.0% to 69.6%, Table 4), which suggests that there is some variability among the study results, but this variability is not statistically significant (p > 0.05).

Table 5. Meta-analysis of overall success rates of autotransplanted third molars.

Study	Sample size	Proportion (%)	Lower 95% CI	Upper 95% CI	Weight (random) (%)
Raabe et al. (20)	4	25	0.6	80.6	7.5
Erdem et al. (5)	12	100	73.5	100	12.6
Gonzalez-Ocasio et al. (19)	11	100	71.5	100	12.2
Nagori et al. (18)	42	85.7	71.5	94.6	18.1
Nimčenko et al. (17)	15	80	51.9	95.7	13.7
Jang et al. (16)	3	100	29.2	100	6.4
Schütz et al. (15)	34	97.1	84.7	99.9	17.3
İsa-Kara et al. (14)	11	100	71.5	100	12.2
Total (fixed effects)	132	90.7	84.6	94.9	100
Total (random effects)	132	90.2	79.8	97.1	100

Table 6. Publication bias.

Publication bias	
Egger's test	
Intercept	-0.7
95% CI	-4.8 to 3.5
Significance level	P = 0.7
Begg's test	
Kendall's Tau	-0.3
Significance level	P = 0.4

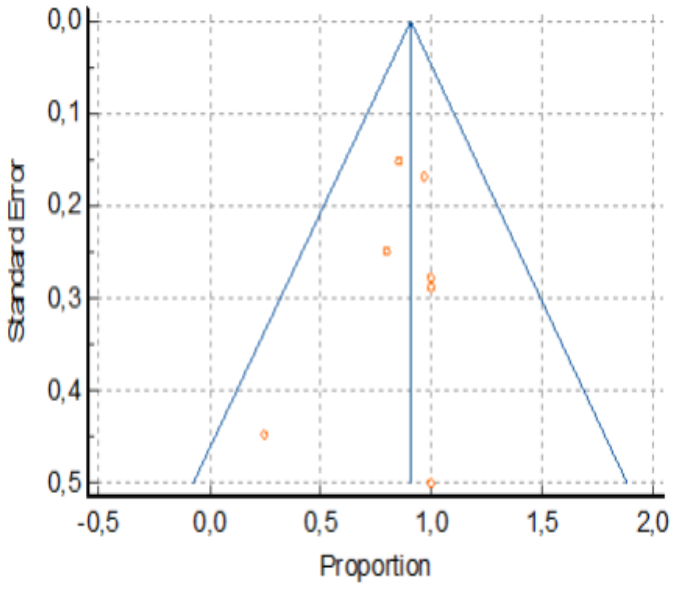

Figure 4. Funnel Plot.

Table 7. Test for heterogeneity.

Test for heterogeneity	
Q	18.4
DF	7
Significance level	P = 0.01
I^2 (inconsistency)	61.9%
95% CI for I2	17.8 to 82.4

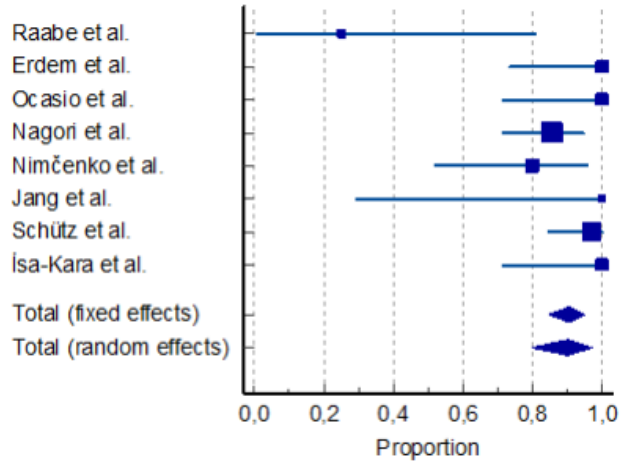

Figure 5. Forest Plot.

Success, as defined by favorable clinical and radiographic outcomes, was generally lower than the survival rate across the studies yielding 90.2 % (95% CI: 79.8 % to 97.1 %, Table 5). Heterogeneity was significant (Q = 18.4, p = 0.01, Table 7), with an I^2 value of 61.9% (95% CI for I^2: 17.8 % to 82.4 %, Table 7), suggesting moderate inconsistency among the studies.

It wasn't possible to draw any data about survival and success rate from one article (12), therefore this article wasn't included in meta-analysis. Nevertheless, it was mentioned that only two infections resulted in the loss of transplants, with 42 out of 44 transplants being successful (37 teeth were with open apex and 7 with closed).

Secondary outcomes

The following clinical parameters were assessed across the studies to evaluate the success of autotransplantation (AT):

- Absence of pain. Reported as a success criterion in multiple studies (16, 17,19,20).
- Post-operative mobility. Most studies assessed physiological mobility of an AT tooth as a sign of periodontal healing (5,14,15,16,17,18,19,20). Limited studies are available on acceptable mobility thresholds and long-term monitoring (5, 12, 17, 18).
- Probing depths were mentioned in studies (5,15,16,17,19,20). Inconsistent thresholds were found for pathology, with some studies considering >3-4 mm as concerning (5, 15, 19, 20).
- Absence of signs of inflammation. Used as a parameter in (5,14,15,17,20), though there is a lack of standardized evaluation timeframe.
- Absence of pain to percussion. Noted parameters in several studies (5,15,16,17,18,20), but no comparison was made between stabilization methods.
- Percussion sounds. Specifically analyzed in (14,15) primarily to detect ankylosis. However, percussion itself is not a highly objective parameter for assessing ankylosis (44).
- Periodontal plaque and bleeding on probing (BOP). Evaluated in two studies (5,15). There is limited research on their impact on healing.
- Changes in tooth color. Observed in two studies (14,18). Tooth color changes can be indicative of underlying issues such as inflammation, infection, and may reflect the effectiveness of treatment (45). Further research on correlation with success is needed.
- Occlusion. Considered in many studies (5,12,15,16,17,19). Proper occlusion is crucial for maintaining functional stability of the teeth and surrounding structures (46), but under-researched for its role in success.
- Progression of pulp canal obliteration (5,15,16,20). It may suggest healing and pulp revascularization (47), but requires more research to link with long-term success.

Adherence to follow-up protocols was also noted as an additional factor (20).

Prognostic factors

Factors that influence the success and long-term outcome of transplanting an immature molar were:

- Stabilization methods during early healing of autotransplanted tooth using adhesive techniques, sutures, or fixed orthodontic appliances where present (5,12,14,15,16,17,18,20). The use of these methods, sutures, or fixed orthodontic appliances can stabilize the autotransplanted third molar and is critical for its proper healing and integration (14).
- Stage of root development (5,12,14,15,16,17,18,20). More mature roots correlated with better outcomes (5,12,14,15,16,17,18,19,20).
- Innovative techniques used (CARP or PRP) (5,12,18,19). CARP and PRP may enhance healing, especially for less experienced surgeons (26).

- Recipient site (socket) preparation (5,12,14,15,17,18). Essential for optimal healing (12,14,17).
- Recipient site and donor tooth characteristics (17). Bone density at the recipient site affects integration (48).
- Patient age (5,18,19). Younger patients generally have better outcomes (5,18,19).
- Oral hygiene (14). Key to preventing complications (14).
- Case selection (5). Important for favorable outcomes (5).
- Complex root anatomy (5, 18). Complex root structures can negatively impact success (15,20).

Discussions and conclusion

Main Findings

This systematic review reveals that autotransplanted third molars exhibit a high survival rate of 91.9% (heterogeneity test $p>0.05$), suggesting that this procedure is effective in maintaining transplanted teeth in the first or second molar regions. While the survival rate is strong, the success rate with moderate heterogeneity (heterogeneity test $p<0.05$). Therefore the null hypothesis is only partially supported.

Survival and Success Criteria

The variability in success criteria between studies limits direct comparisons. A similar observation was noted also by the author Barber et al. (9), who stated that definitions of success may vary. Analyzed studies converge on a core set of criteria that include clinical health (absence of pain, signs of inflammation, and abnormal mobility are consistently highlighted), healthy probing depths (generally less than or equal to 3 mm) and radiographic criteria (the absence of root resorption and the maintenance of normal periodontal ligament space are commonly required for a transplant to be considered successful) (29).

However, each study also emphasizes different elements, from pulp vitality (9) to occlusal function, which complicates generalization (5,9, 14,15,17,18,19,20). While one study (20) focuses on physiologic mobility specific to root length and includes specific radiographic outcomes like progressing pulp canal obliteration, Gonzalez-Ocasio et al. (19) defines success including the transplant's asymptomatic status and avoidance of endodontic therapy. Erdem (5) in the study includes functionality at occlusion. Nagori et al. (18) and Schütz et al. (15) both emphasize tooth functionality and periodontal health, but Schütz et al. (15) includes additional criteria related to pulp vitality. Nimčenko et al. (17) sets time-specific benchmarks for clinical and radiographic criteria, including detailed healing timelines. İsa-Kara et al. (14) includes continued root growth and non-ankylosis as part of the success criteria, adding a developmental perspective to the evaluation. Barber et al. (9) identified transplant survival, reasons for failure, pulp health, resorption, and evidence of infection (suppuration) as the most important clinical outcomes in evaluating transplant success. Jang et al. (16) and Reich (12) didn't mention the clear "success" definition.

Only two studies (5, 20) defined “survival” clearly, and none utilized Kaplan-Meier curves, underscoring the need for standardized reporting.

Key Prognostic Factors

Stage of Tooth Development: Studies (5,12,14,16,17,19,20) focus on donor teeth that are classified as immature with partial root development (Moorrees classification R ¼ to ¾) (49). No clear correlation was found between root length and success rates, suggesting that root length may not significantly affect outcomes, but more research is needed (15, 17, 18, 50). Some studies propose that a fully developed root with an open apex (>1 mm) may offer the best potential for success and pulp regeneration (17).

Innovative Techniques: Advanced techniques such as PRP (Platelet-Rich Plasma) (Gonzalez-Ocasio (19) and CARP (Computer-Aided Rapid Prototyping) (5,16,22,43) have shown promise in improving outcomes. CARP, through 3D-printed templates reduces extraoral time and minimizes damage to the periodontal ligament (PDL), a critical factor in autotransplantation success (50). However, its direct impact on long-term biological outcomes remains uncertain, while other factors, such as root morphology and site preparation, still play significant roles (22, 51)

Stabilization methods during early healing: Numerous splinting techniques have been suggested for postoperative transplant stabilization, including stabilization methods with orthodontic appliances, ligature wires, acid-etch composites, and sutures (13,52,53). The stabilization time is usually between 1 and 4-6 weeks (13). However, excessive stabilization time for the transplanted tooth was found to inhibit periodontal regeneration, leading to numerous occurrences of ankylosis, periodontal inflammation, and inflammatory root resorption (13,54). Furthermore, rigid splinting has been observed to have adverse effects on the revascularization of the pulp (14).

The consensus on the ideal stabilization method and duration remains debated. More well-designed controlled clinical studies are required to investigate the effect of splinting regimen on periodontal and pulp healing (29).

Recipient Site and Donor Tooth Characteristics: Some studies provide detailed information on the recipient site and donor tooth, aiding prognosis tracking (5,15,16,17). However, a lack of detail in other studies limits the ability to draw clear conclusions regarding their impact on surgical success.

Follow-up Period

Short follow-up periods may overestimate success due to delayed complications like root resorption and ankylosis (31). The minimum recommended follow-up period for autotransplanted teeth, including the completion of root development, is generally cited as one year (55). However, there is a noticeable lack of precise data regarding immature third molars in particular. This may explain why some of the articles analyzed by the author lack a minimal common follow-up period (12,15). Longer-term follow-ups (across multiple time points: 1, 3, 5, and 10 years) are necessary to gain a complete understanding of autotransplantation success.

Search Strategy and Study Limitations

This review faced challenges due to diverse study designs and definitions. Several studies did not clearly report success rates for immature molars in the area of first and second molars (27), and the definition of 'success' varied significantly across others (5,14,15,17,18,19,20), making it challenging to directly compare results between studies. Additionally, a substantial number of studies included mature teeth, were structured as case reports or did not include autotransplanted molars. This variability emphasizes the need for standardized methods and more robust, controlled studies to enhance evidence quality.

The variability in individual study protocols and the limited sample sizes across studies have resulted in a lack of reliable, consistent information, making it difficult to draw definitive conclusions. These inconsistencies highlight the need for standardized protocols and larger sample sizes to improve the reliability and generalizability of findings in this field.

Challenges and Risks of Autotransplantation of Immature Third Molars

Autotransplantation of immature third molars offers benefits like alveolar bone preservation, but it also involves risks (56, 57, 58). Failure due to infection can complicate future treatment, as bone grafting may be needed before dental implant placement (57). Ankylosis, where the tooth fuses to the bone, can preserve bone volume, potentially aiding future implant procedures (59, 60).

Compared to premolars, the use of immature third molars is less well-documented and poses unique challenges (6, 61, 62, 63, 64, 65, 66). Extracting deeply impacted third molars can cause damage to surrounding structures (63, 64). The underdeveloped roots of immature molars complicate healing, affecting both periodontal and endodontic recovery (6, 65). Achieving proper occlusion and mobility is also more difficult due to their size and developmental stage (6, 66). These factors highlight the importance of careful donor tooth selection and consideration of potential risks.

Future directions

Future research should focus on standardizing success criteria and treatment protocols, increasing sample sizes, evaluating stabilization methods to prevent complications, conducting long-term survival studies with Kaplan-Meier analysis, and investigating the impact of donor tooth development on success rates. These improvements will enhance consistency and the overall value of autotransplantation as a treatment option.

Conclusion

Autotransplantation of immature third molars in the area of first and second molars is a viable treatment option with high survival and success rates, though variability in criteria, techniques, and follow-up limits definitive conclusions.

Zusammenfassung

Einleitung

Die Autotransplantation unreifer Weisheitszähne ist eine praktikable Behandlungsoption zum Ersetzen fehlender Zähne und bietet Potenzial für eine Pulparevaskularisierung und parodontale Heilung. Trotz des klinischen Potenzials besteht kein Konsens über Überlebens- und Erfolgskriterien sowie die Prognosefaktoren, die die Ergebnisse beeinflussen. Ziel dieser systematischen Überprüfung und Metaanalyse ist es, Überlebens- und Erfolgsraten zu bewerten und Schlüsselfaktoren zu identifizieren, die die Prognose der Autotransplantation unreifer Weisheitszähne beeinflussen.

Materialien und Methoden

Eine systematische Überprüfung und Metaanalyse wurden gemäß den PRISMA-Richtlinien durchgeführt. Recherchen in den Datenbanken PubMed, ScienceDirect und EBSCOhost bis Mai 2024 ergaben neun Studien, die die Einschlusskriterien erfüllten. Diese Studien konzentrierten sich auf die Überlebens- und Erfolgsraten von autotransplantierten unreifen Weisheitszähnen. Die statistische Analyse wurde mit der Software MedCalc durchgeführt, wobei zur Berechnung der gepoolten Raten ein Zufallseffektmodell angewendet wurde.

Resultate

Die zusammengefasste Überlebensrate der autotransplantierten unreifen Weisheitszähne betrug 91,87 % (95 % KI: 85,06 %–96,74 %), während die Erfolgsrate 90,16 % (95 % KI: 79,81 %–97,07 %) betrug. Wichtige Prognosefaktoren, die die Ergebnisse beeinflussten, waren das Entwicklungsstadium des Spenderzahns (Moorrees R ¼ bis Rc), die Anwendung innovativer Techniken wie plättchenreiches Plasma (PRP) und kontrollierte Ankylose-Wurzelkonservierung (CARP) sowie optimierte Fixierungsstrategien. Umgekehrt war eine übermäßige Fixierung mit Komplikationen wie Ankylose und Wurzelresorption verbunden.

Diskussionen

Diese Studie zeigt, dass die Autotransplantation unreifer Weisheitszähne hohe Überlebens- und Erfolgsraten erzielt, was sie zu einer vielversprechenden Option für die Zahnrehabilitation macht. Die Variabilität der Studienkriterien, Nachsorgeprotokolle und Erfolgsdefinitionen begrenzt jedoch die Standardisierung. Weitere Forschung sollte darauf abzielen, einheitliche Erfolgskriterien festzulegen, die langfristigen Auswirkungen der Wurzelentwicklungsstadien zu untersuchen und Fixierungstechniken zu optimieren, um die klinischen Ergebnisse zu verbessern. Durch die Beseitigung dieser Lücken können Kliniker erfolgreiche Ergebnisse bei der Autotransplantation unreifer Weisheitszähne besser vorhersagen und erzielen.

Résumé

Introduction

L'autotransplantation de troisièmes molaires immatures est une option thérapeutique viable pour remplacer les dents manquantes, offrant un potentiel de revascularisation pulpaire et de guérison parodontale. Malgré ses promesses cliniques, il n'existe pas de consensus sur les critères de survie et de réussite, ainsi que sur les facteurs pronostiques qui influencent les résultats. Cette revue systématique et méta-analyse vise à évaluer les taux de survie et de réussite et à identifier les facteurs clés affectant le pronostic de l'autotransplantation de troisièmes molaires immatures.

Matériels et méthodes

Une revue systématique et une méta-analyse ont été menées conformément aux directives PRISMA. Les recherches dans les bases de données PubMed, ScienceDirect et EBSCOhost jusqu'en mai 2024 ont permis de trouver neuf études répondant aux critères d'inclusion. Ces études se sont concentrées sur les taux de survie et de réussite des troisièmes molaires immatures autotransplantées. L'analyse statistique a été réalisée à l'aide du logiciel MedCalc, en appliquant un modèle à effets aléatoires pour calculer les taux regroupés.

Résultats

Le taux de survie global des troisièmes molaires immatures autotransplantées était de 91,87 % (IC à 95 % : 85,06 %–96,74 %), tandis que le taux de réussite était de 90,16 % (IC à 95 % : 79,81 %–97,07 %). Les principaux facteurs pronostiques influençant les résultats comprenaient le stade de développement de la dent donneuse (Moorrees R ¼ à Rc), l'application de techniques innovantes telles que le plasma riche en plaquettes (PRP) et la préservation contrôlée des racines ankylosées (CARP), et des stratégies de fixation optimisées. À l'inverse, une fixation excessive était associée à des complications telles que l'ankylose et la résorption radiculaire.

Discussions

Cette étude démontre que l'autotransplantation de troisièmes molaires immatures permet d'obtenir des taux de survie et de réussite élevés, ce qui en fait une option prometteuse pour la réhabilitation dentaire. Cependant, la variabilité des critères d'étude, des protocoles de suivi et des définitions de réussite limite la standardisation. Des recherches plus poussées devraient viser à établir des critères de réussite uniformes, à explorer l'impact à long terme des stades de développement radiculaire et à optimiser les techniques de fixation pour améliorer les résultats cliniques. En comblant ces lacunes, les cliniciens peuvent mieux prédire et obtenir des résultats positifs dans l'autotransplantation de troisièmes molaires immatures.

Acknowledgements

The authors express their deep gratitude to Prof. Sergio E. Uribe (RSU) and Prof. Shaju Jacob Pulikkotil (RSU) for critical comments on the article and suggestions for its improvement. The authors are also grateful to M. biol. Māra Grēve (RSU) and Mg. Inga Znotiņa (RSU) for assistance in preparing statistical data and methodology for this systematic review.

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Appendices

Table 1. CASP checklist for cohort and studies with n/a study design.

	Section A: Are the results of the study valid?							Section B: What are the results?			Section C: Will the results help locally?	
	Q1	Q2		Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11
Title	Did the study address a clearly focused issue?	Was the cohort recruited in an acceptable way?	**Is it worth continuing?**	Was the exposure accurately measured to minimise bias?	Was the outcome accurately measured to minimise bias?	a) Have the authors identified all important confounding factors? b) Have they taken account of the confounding factors in the design and/or analysis?	a) Was the follow up of subjects complete enough?* b) Was the follow up of subjects long enough?	What are the results of this study?	How precise are the results?	Do you believe the results?	Can the results be applied to the local population?	Do the results of this study fit with other available evidence?
	Answer	Answer		Answer	Answer	Answer	Answer	Description	Description	Answer	Answer	Answer
Raabe, 2021 (20)	Yes	Yes	**Yes**	Yes	Yes	a) Yes b) Yes	b) No	1) Survival rate of 92.9% 2) Success rate was 62.5%. Unmodified immature teeth - 69.6% success rate, mature teeth with root-end resection had 44.4%. 3) Complications – invasive cervical resorption, apico-marginal lesion	The reliability is limited by the small sample size and potential biases inherent in a retrospective study design.	No	No	Yes
Erdem, 2021 (5)	Yes	Yes	**Yes**	Yes	Yes	a) Yes b) Yes	b) No	1) Success rate – 100%. Survival rate -100%. 2) No root resorption or ankylosis was	The author provided a robust dataset for evaluating the outcomes of the autotransplantation procedure.	No	No	Yes

								observed in any teeth.				
Schütz, 2013 (15)	Yes	Yes	**Yes**	Yes	Yes	a) Yes b) No	b) No	1) Success rate – 95%. Survival rate – 95%. 2) No complications	While the study's precision is supported by clear methodologies, the moderate sample size and retrospective nature suggest caution in generalizing the results.	No	No	Yes
Isa-Kara, 2011 (14)	Yes	Yes	**Yes**	Yes	Yes	a) Yes b) No	b) Yes	1) 88.8% success rate. 2) Failures included one due to root inflammation, two due to root resorption, and two with ankylosis.	The precision of the treatment effect estimate is limited by the small sample size and lack of detailed statistical analysis.	No	No	Yes
Nagori, 2014 (18)	Yes	Yes	**Yes**	Yes	Yes	a) Yes b) Yes	b) No	1) Success rate - 86% Survival rate – 86%. 2) All failures within first 6 months (due to root resorption).	The study gives a comprehensive overview, the rigor of data collection, and the statistical analyses conducted.	Yes	No	Yes
Reich, 2008 (12)	Yes	Yes	**Yes**	Yes	Yes	a) Yes b) Yes	b) No	1) Success rate – 86% 2) Failures occurred within 6 months. Ankylosis, root resorption, malocclusion in the transplanted teeth.	The study provides precise and reliable data on the success and failure rates of autogenous third molar transplantation, with significant findings regarding the factors affecting the outcomes	No	No	Yes

* It is challenging to determine whether the follow-up of subjects was enough, as there is no clear evidence indicating which follow-up period is optimal for assessing the success of autotransplanted molars.

Table 2. CASP checklist for case series studies.

	Section A: Are the results of the trial valid?							Section B: What are the results?			Section C: Will the results help locally?	
	Q1	Q2		Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11
	Did the study address a clearly focused issue?	Did the authors use an appropriate method to answer their question?	**Is it worth continuing?**	Were the cases recruited in an acceptable way?	Were the controls selected in an acceptable way?	Was the exposure accurately measured to minimize bias?	a) Aside from the experimental intervention, were the groups treated equally? b) Have the authors taken account of the potential confounding factors in the design and/or in their analysis?	How large was the treatment effect?	How precise was the estimate of the treatment effect?	Do you believe the results?	Can the results be applied to the local population?	Do the results of this study fit with other available evidence?
The name of an article	Answer	Answer		Answer	Answer	Answer	Answer	Description	Description	Answer	Answer	Answer
Gonzalez-Ocasio, 2017 (19)	Yes	Yes	**Yes**	Yes	Can't Tell	Yes	a) Can't Tell b) Yes	The AT is an effective treatment, but there is an absence of a CG and small sample size.	The precision is limited by the small sample size and lack of detailed statistical analysis.	No	No	Yes
Nimčenko, 2013 (17)	Yes	Yes	**Yes**	Yes	Can't Tell	Yes	a) Can't Tell b) Yes	Further details such as comparative data with CG or pre- and post-treatment assessments with numerical outcomes would be necessary.	The study lacks precise statistical analysis.	No	No	Yes
Jang, 2013 (16)	Yes	Yes	**Yes**	Yes	Can't Tell	Yes	a) Can't Tell b) Yes	The small sample size of 4 cases limits	Answered in the	No	No	Yes

								definitive conclusions.	previous ques-tion.			

Table 3. Articles included in the review.

	Authors	Year	Study design	Sample Size[1]	Age Range	Root development stage	Autotransplantation region	Follow-up Duration (years)	Success Rate (%)	Survival Rate (%)	Post-transplantation assessment criteria	Complications	Assessment according to CASP guidelines
1	Raabe et al. (20)	2021	A retrospective study	4 teeth	8 to 28 years[2]	*Moorrees* (49) R ¼, R 2/4 and R 3/4	d38 -> d36 d48 -> d46 d48 -> d47 d28 -> d46	1.7 12.5 3.4 n/a	25%	75%	Clinically – no pain, mobility, probing depths, no signs of inflammation, no pain to percussion Radiographically – intact periodontal space, no sign of any type radiolucency, progressing pulp obliteration	Invasive cervical resorption (n=1), apico-marginal lesion (n=1)	High Risk of Bias
2	Erdem et al. (5)	2020	A retrospective study	12 teeth	15 to 21 years	*Moorrees* (49) Root development of ¾ of the expected final root length	d38 -> d37 (n=1) d48 -> d47 (n=4) d38 -> d37 (n=3) d48 -> d46 (n=2) d18 -> d46 (n=1) d38 -> d46 (n=1)	1.5-3	100%	100%	Clinically - mobility, peridontal plaque, BOP, percussion sensitivity, periodontal pocket, vitality, occlussion Radiographically - root resorption, ankylosis, presence of lamina dura, healing of periapical lesion	Minimal complications - edema and postoperative pain	High Risk of Bias
3	Gonzalez-Ocasio & Stevens ((19)	2017	A case series	11 teeth	10-17 years	1/3 to 2/3 of root formation	- lower teeth to mandibula (n=7) - upper teeth to maxilla (n=3) - upper tooth to mandibula (n=1)	1	100%	100%	Occlusion, mobility, periodontal probing depths, vitality tests, periapical radiographs (tooth root gain)	Absence of postoperative complications	High Risk of Bias
4	Nagori et al. (18)	2014	N/A	42 teeth	15-25 years [2]	*Moorrees* *(49)* R ½, R ¾ and Rc (root length complete with open apex)	-A maxillary third molar -> mandibular molar region (n=2) -A mandibular third molar -> maxillary tooth region (n=1)	1	86%	86%	Any signs of infection or tenderness on percussion, periodontal probing, mobility, root resorption, periodontal probing, mobility, pulp sensitivity	Root resorption in 7 cases, 1 of infection (6/8 teeth were immature)	High Risk of Bias
5	Nimčenko et al. (17)	2013	A case series	15 teeth	15-20 years	*Moorrees* *(49)* R ½ to ¾ of root formed	d28 -> d26 (n=2) d28 -> d36 (n=2) d18 -> d46 (n=1) d38 -> d36 (n=4) d48 -> d46 (n=6)	0.75	80%	80%	Mobility, discomfort, function, periodontal probing, sensitivity test to cold, radiographic healing, continous root formation, resorption	2 lost transplants - surgical failure 1 lost transplant - persisting infection/fistula	High Risk of Bias
6	Jang et al. (16)	2013	A case series	3 teeth	15-21 years[2]	*Moorrees* (49) R ¼ to R ¾	d18 -> d17 (n=3)	2-7	100%	100%	Pulp vitality, root development, absence of complications (root resorption or ankylosis), and functionality	No significant complications	High Risk of Bias
7	Schütz et al. (15)	2013	A retrospective study	34 teeth	14-21 years[2]	*Demirjian* *(50)* R growth stage E (50% root growth) Root growth F (75% root	- d18 and d28 to maxillary molar region (n=20) - d38 and d48 to mandibular molar region (n=14)	2.2	97%	97%	Occlusion, percussion pain, probing measurements (periodontal health), physiological tooth mobility, radiological findings of the pulp and root	Transplant tooth 48 with root growth stage G to region 36 with a non-repairable molar -> failure	High Risk of Bias

						growth, open apex) Root growth G (vertical root growth almost complete, apical foramen still open)							
8	İsa-Kara et al. (14)	2011	A retrospective study	11 teeth	16-39 years[2]	Open apex teeth with at least half root development	N/A	2.6 – 3.9	100%	100%	color, mobility, position, ankylosis signs, the form of gingival tissue, periodontal attachments and root surfaces, a presence of any inflammation pulpal changes or progressive external or internal root resorption and continued development of root growth	Transplants with an open apex were successful; ankylosis, resorption and periapical inflammation were not observed in teeth with open apex.	High Risk of Bias
9	Reich (12)	2008	N/A	37 teeth	11-25 years[2]	The requirement was 1/3 root development. The ideal root length was considered to be 2/3 root formation based on the study of Andreasen et al. (55)	N/A	1.6	N/A	N/A	ankylosis, root resorption, malocclusion in the transplanted teeth	Two infections resulting in the loss of 2 transplants occurred (not mentioned, were those transplants with open apex or not). The remaining 42 transplants were asymptomatic and functional, with no need for endodontic therapy post-transplantation.	High Risk of Bias

[1] Number of teeth with immature root development.

[2] This range applies to **all** included teeth in the studies that were analyzed.