Clinical Oral Investigations (2022) 26:3795–3805
https://doi.org/10.1007/s00784-022-04435-8

REVIEW

Autotransplantation of teeth with incomplete root formation: systematic review and meta-analysis

Javier Sicilia-Pasos[1,5] · Naresh Kewalramani[1,5] · Juan-Francisco Peña-Cardelles[1,2] · Angel-Orión Salgado-Peralvo[3] · Cristina Madrigal-Martínez-Pereda[4] · Ángel López-Carpintero[1]

Received: 6 December 2021 / Accepted: 27 February 2022 / Published online: 8 March 2022

Abstract

Objectives To determine the survival of intentional autotransplantation of developing teeth.

Material and methods An electronic search was carried out in the MEDLINE database, Web of Science, and Cochrane Library. The criteria used are the ones described in the PRISMA Declaration. The following MeSH terms were used: ("tooth" [MeSH Terms] OR "tooth" [All Fields]) AND ("transplantation, autologous" [MeSH Terms] OR ("transplantation" [All Fields] AND "autologous" [All Fields]) OR "autologous transplantation" [All Fields] OR "autotransplantation" [All Fields]) AND ("humans" [MeSH Terms]. Randomised clinical trials and prospective and retrospective clinical studies were included.

Results The meta-analytic study of overall survival included a total of 14 studies, yielding an overall survival rate of 97.9%. In studies with 1-year follow-ups, survival was 98%. The resulting 2-year follow-up rate was 97%, while the 5- and 10-year survival rates were 95.9% and 96.9%, respectively.

Conclusions The autotransplantation technique performed in a single-phase and on teeth that have not completed their development is a predictable technique, with a described survival rate at a 2-year follow-up of more than 97%.

Clinical Relevance The technique of dental autotransplantation is considered an important resource for the resolution and rehabilitation of tooth loss in patients, especially in those who are still in a growth period. Moreover, this technique has a low complication rate and a 10-year survival rate of 96.9%. It should therefore be considered a safe and reliable procedure.

Keywords Tooth autotransplantation · Meta-analysis · Root development · Incomplete root formation · Immature impacted tooth

Introduction

Autotransplantation or autogenous tooth transplantation is defined as the transfer of a tooth from its original location to another location within the same individual to replace a missing tooth. This absence may be due to various reasons such as congenital absences, ectopically erupted teeth, extensive caries lesions, periodontal disease, trauma, or failed endodontic treatment. This treatment may include the transfer of teeth or tooth roots into post-extraction sockets

✉ Juan-Francisco Peña-Cardelles
juanfranciscopenacardelles@gmail.com

Javier Sicilia-Pasos
javiersiciliap@gmail.com

Naresh Kewalramani
k93.naresh@gmail.com

Angel-Orión Salgado-Peralvo
orionsalgado@hotmail.com

Cristina Madrigal-Martínez-Pereda
cmadrigal@odon.ucm.es

Ángel López-Carpintero
angel.carpintero@clinica.urjc.es

[1] URJC, Madrid, Spain

[2] Oral and Maxillofacial Surgery Division and Prosthodontics Division, University of Connecticut, Mansfield, CT, USA

[3] University of Seville, Seville, Spain

[4] Department of Clinical Dental Specialties, Faculty of Dentistry, Complutense University of Madrid, UCM, Madrid, Spain

[5] Faculty of Dentistry, Complutense University of Madrid, UCM, Madrid, Spain

or surgically prepared sockets. The success of the treatment will depend on the indication of the case and patient selection [1].

Although today most adult tooth loss is replaced by the placement of dental implants, there are occasions where autotransplantation may be an alternative, such as in patients in a growth period, where implants may interfere with the development of the jaws. This would not occur with a transplanted tooth, as it would adapt and allow the alveolar process to develop. On the other hand, in adult patients in whom growth has ceased, autotransplantation should be considered a viable option as third molars are in root development in many young adult patients, and revascularisation could even be achieved if they were used as donor teeth for transplantation. [2]

The key to the success of autotransplantation in patients in the growth period and development stages is the absence of ankylosis, which could serve as the first factor for good treatment predictability, as well as pulp revascularisation. Other criteria for success are the absence of root resorption, a healthy state of the soft and hard tissues around the transplanted tooth, and a crown-to-root ratio of less than one [3]. Ong et al. [4] established other criteria for success, such as treatment of medically stable patients, donor tooth with normal morphology and matching the recipient socket, atraumatic tooth extraction technique, minimal extraoral time of the donor tooth, tooth transplanted into an existing socket rather than a created socket, avoiding post-transplant trauma, and maintaining excellent oral hygiene.

Tooth autotransplantation is a technique that has continued to be developed to the present day, being valid and with results in clinical studies that support its use in daily practice [2]. Numerous reviews confirm the success of this technique in patients with completed tooth development; however, the number of reviews in the scientific literature that focus their research exclusively on teeth that have not completed their root development is not so high. Furthermore, it should be borne in mind that the technique used in this type of tooth is very favourable due to the possibility of revascularisation and therefore preserves pulp vitality.

The present study aims to determine the survival of autotransplanted teeth with a developing apex using the immediate surgical technique by means of a systematic review with meta-analysis.

Material and methods

An electronic search was carried out in the MEDLINE database (through *PubMed*), Web of Science (WoS), and Cochrane Library using the following MeSH (*Medical Subjects Headings*) terminology: ("tooth"[MeSH Terms] OR "tooth"[All Fields]) AND ("transplantation, autologous"[MeSH Terms] OR ("transplantation"[All Fields] AND "autologous"[All Fields]) OR "autologous transplantation"[All Fields] OR "autotransplantation"[All Fields])) AND ("2010/04/03"[PDat]: "2021/03/30"[PDat] AND "humans"[MeSH Terms].

The criteria used are the ones described in the PRISMA (*Preferred Reporting Items for Systematic Reviews and Meta-analysis*) Declaration [5]. The main objective was to answer the following "PICO" (P = *patient/problem/population*; I = *intervention*; C = *comparison*; O = *outcome*) question (Table 1):

In patients with edentulism or patients with the need for exodontia of one or more teeth (P), does autotransplantation of a tooth that has not completed root development, with immediate surgical technique (I), has a survival and success rate at two or more years post-treatment (O)?

In addition, the need or not to perform root canal treatment on the autotransplanted teeth was evaluated.

Meta-analysis

A meta-analysis was carried out to determine the overall, 1-year, 2-year, 5-year, and 10-year survival of autotransplanted teeth with an open apex. In this case, it is a prevalence study since there are not two techniques to compare with each other, but the survival of the autotransplanted teeth has been investigated. The software used for its calculation was Stata® release 15 (College Station, TX: StataCorp LLC). To obtain the meta-analysis of the survival data, the fixed effects method was used due to the homogeneity obtained between the studies, through Cochran's Q statistic.

Table 1 Components of the PICO question

P *(population)*	Patients with edentulism, or the need for exodontia of one or more teeth that have not completed their dental development
I *(intervention)*	Tooth autotransplantation with immediate surgical technique
C (comparison)	There is no comparison. Tooth survival is evaluated at 1 year, 2 years, 5 years, and 10 years
O *(outcome)*	Survival of autotransplanted teeth and success of autotransplanted teeth at two or more years post-treatment
PICO question	*In patients with edentulism or the need for exodontia of one or more teeth that have not completed root development, does autotransplantation with immediate surgical technique show survival and success at two or more years post-treatment?*

Inclusion criteria

(a) Randomised clinical trials (RCTs), (b) prospective and retrospective clinical studies, (c) human studies, (d) articles published in English and Spanish, (e) studies in patients who have not completed their tooth development, (f) studies in patients presenting edentulism of one or more teeth or need for exodontia of any tooth, (g) studies with a minimum sample of 10 cases of autotransplantation, (h) publications with a follow-up time greater than or equal to 2 years, and (i) grey literature.

Exclusion criteria

(a) Animal studies, (b) ex vivo studies, (c) in vitro studies, (d) studies on patients who have completed tooth development, and (f) studies in which cryopreservation of the tooth has been performed.

Risk of bias

The risk of bias in the included studies was independently evaluated by two authors (JSP, NK). In both the extraction of the data and the evaluation of the risk of bias, the disagreements between the two authors were resolved through the intervention of a third author (CMMP).

In addition, to make a common analysis of the risk of bias for all studies, the critical appraisal tool of the Joanna Briggs Institute [6] was used (Table 2). This assessment aims to determine whether the studies that met the planned inclusion criteria are of as high a methodological quality as possible. In addition, this assessment will interpret the possible risks of bias in the selected studies. To determine the methodological quality of each study, a score was assigned according to whether they met the criteria for high, medium, or low methodological quality. Thus, if they answered yes to more than 7 items, they were considered to be of high methodological quality, between 5 and 7 of medium methodological quality and less than 5 of low methodological quality.

Results

Search strategy and study selection:

The electronic databases were searched using the term "tooth autotransplantation." A total of 337 results of human studies were obtained by establishing the time range between 2010 and 2021, and after analysing the titles of these studies, 14 were discarded as they were duplicated. Of the remaining 323, 147 were excluded because they dealt with topics different from the purpose of the study. We then screened for studies that were not available in full text, having to discard 30 of them to obtain a total of 146 articles to analyse. After reading the titles and abstracts of these 146 articles, 77 were discarded for having a sample of fewer than 10 cases, 7 for having carried out cryopreservation of the teeth, 6 for being in vitro or cadaver studies, 30 for carrying out the studies on teeth with complete root development, and 9 for not specifying the degree of root development of the teeth included in the study. Finally, a total of 17 articles were included for the present review, 11 being observational, 5 clinical trials, and 1 RCT (Fig. 1).

Clinical studies

A total of 17 studies published between 2010 and 2021 met the inclusion criteria for the analysis of the clinical outcomes obtained. Of these, 11 were observational studies [7–18], 5 non-randomised clinical trials [20–24], and one RCT [1]. Regarding the methodological quality of these studies, after analysis using the Joanna Briggs Institute's critical appraisal tool, 7 articles were found to be of high methodological quality and the other 10 articles were of medium methodological quality.

In these studies, a total of 610 teeth with incomplete root development were transplanted; however, the total number of patients in whom these autotransplantations were performed could only be obtained from 5 articles for a total of 165 patients (Table 3).

The stage of root development was evaluated using the Moorrees et al. classification [8] with the following values:

Stage 1: initial to one quarter root formation
Stage 2: one half root formation
Stage 3: three-quarters of root formation
Stage 4: complete root formation with open apical foramen
Stage 5: complete root formation with half-open apical foramen
Stage 6: complete root formation with closed apical foramen

The donor teeth were canines, premolars, and molars, both maxillary and mandibular, and the recipient sites were fundamentally the anterior area, as well as the molar and premolar areas.

In total, 26 autotransplanted teeth required a root canal treatment.

RCT

Only one RCT [1] was found with a sample of 13 autotransplanted teeth, of which, one received subsequent root canal treatment. The described success rate was 92%, and the survival rate 100%. The analysis of this study using the Joanna

Table 2 Assessment of risk of bias through the critical appraisal tool of the Joanna Briggs Institute [9] (Y., yes; N., no; NA., not applicable; U., unknown)

Gonnissen et al.[7] (2010)	Y	Y	N	Y	Y	Y	Y	Y	Y	NA
Yan et al.[19] (2010)	Y	U	Y	N	U	Y	Y	N	Y	U
Isa-Kara et al.[9]. (2011)	N	Y	N	Y	N	Y	Y	NA	Y	Y
Marques–Ferreira et al.[1] (2011)	Y	Y	N	N	Y	Y	Y	NA	Y	Y
Vilhjálmsson et al. [11] (2011)	Y	Y	Y	Y	Y	Y	Y	N	U	N
Plakwicz et al.[20]. (2013)	Y	U	N	Y	Y	Y	Y	Y	Y	U
Schütz et al.[12]. (2013)	Y	U	Y	Y	Y	Y	Y	Y	Y	U
Nagori et al.[21]. (2014)	Y	Y	Y	Y	Y	Y	Y	Y	Y	U
Gilijamse et al.[13] (2016)	Y	U	Y	Y	Y	Y	Y	Y	U	U
Mertens et al.[15]. (2016)	Y	U	N	Y	Y	Y	Y	N	Y	U
Stange et al.[16]. (2016)	Y	Y	N	Y	Y	Y	Y	Y	U	U
Kafourou et al. [17]. (2017)	Y	Y	Y	Y	Y	Y	Y	N	NA	U
Michl et al.[22]. (2017)	Y	Y	N	Y	Y	Y	Y	Y	Y	Y
Strbac et al.[18]. (2017)	Y	Y	Y	Y	Y	Y	Y	Y	U	U
Jakobsen et al.[23]. (2018)	Y	Y	Y	Y	Y	Y	Y	Y	N	Y
Van Westerveld et al.[10] (2019)	Y	U	Y	Y	Y	Y	Y	Y	U	U
Yang et al.[14]. (2019)	Y	Y	Y	Y	Y	Y	Y	Y	Y	U
	1. Was the sample representative of the target population?	2. Were study participants recruited in an appropriate way?	3. Was the sample size adequate?	4. Were the study subjects and the setting described in detail?	5. Was the data analysis conducted with sufficient coverage of the identified sample?	6. Were objective, standard criteria used for the measurement of the condition?	7. Was the condition measured reliably?	8. Was the appropriate statistical analysis?	9. Are all important confounding factors and subgroups differences identified and accounted for?	10. Were subpopulations identified using objective criteria?

Briggs Institute tool found it to be an RCT with medium methodological quality, as it answered yes to 7 of the 10 items analysed.

Meta-analysis

The possibility of meta-analysis of the variable "treatment success" had to be discarded due to the lack of common criteria for defining autotransplant success. Not having been studied in all publications, in the same way, statistical analysis for this variable was not possible.

In the overall survival group, a total of 14 studies were included [1, 9–13, 15, 16, 18–23] with a survival rate of 97.9% at a confidence interval of 96.2–99.6% (Fig. 2). In studies where recalls were done at 1 year, survival is 98%, with a 95% confidence interval of 96.1–99.9% (Fig. 3). The resulting percentage for studies that followed up at 2 years was 97% at a confidence interval of 94.4–95.5% (Fig. 4). In both the 5- and 10-year reevaluation publications, the survival rates were also high at 95.9% (Fig. 5) and 96.9% (Fig. 6), respectively.

Discussion

Survival and success criteria

In this systematic review on autotransplantation of teeth with immature apex, the success and survival of this technique have been studied by basing the review on studies published in the last 11 years, which have been subjected to strict inclusion and exclusion criteria. The survival rates reported by the present meta-analysis in the first, second, fifth, and tenth year are higher than 95%, so autotransplantation should be considered as a predictable long-term technique; however, a great heterogeneity has been observed among the criteria used to consider autotransplantation a "success." In this regard, Gonnissen et al. [7] considered the treatment to be successful when the transplanted tooth remained asymptomatic, even though it may have had root canal treatment. If the tooth showed progressive root resorption, pathological periodontal pockets, alveolar bone loss, or apical inflammation, the transplantation was defined as "unsuccessful," even if the tooth remained asymptomatic.

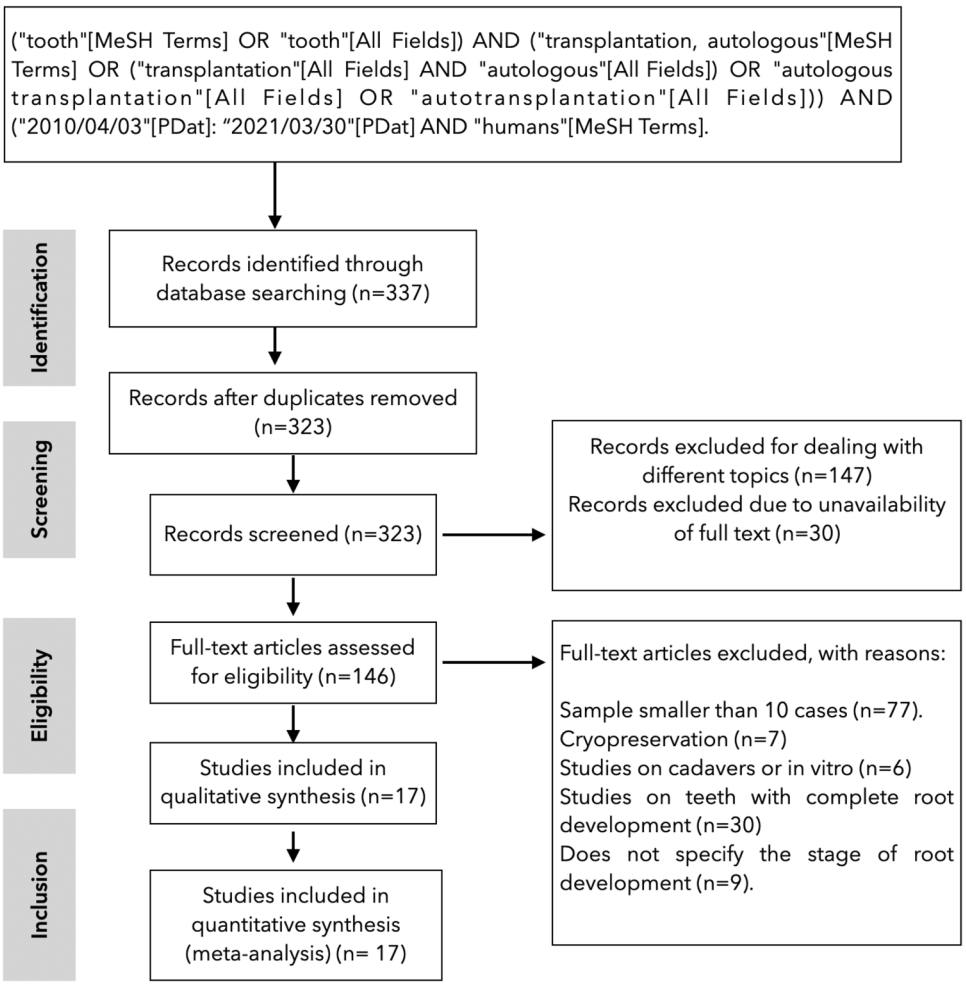
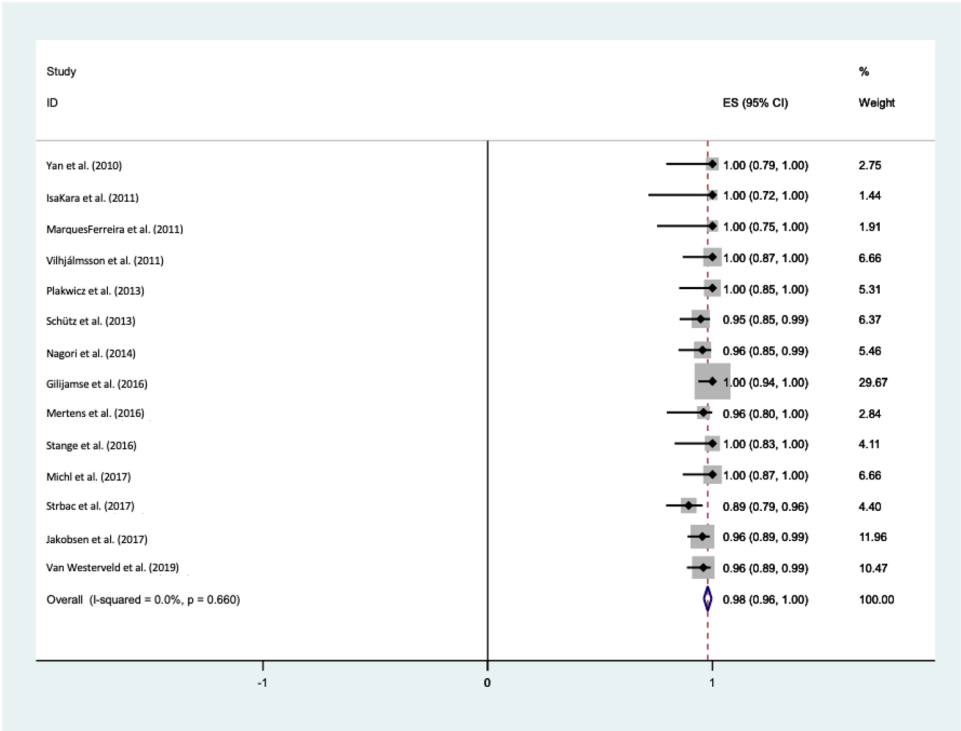


Fig. 1 PRISMA® flow diagram of the search processes and results

Table 3 Included studies (RTC, randomised clinical trial; max, maxillary; mand, mandibular; I, incisor; C, canine; M, molar; PM, premolar)

Authors (year)	Study type	Sample size	Autotransplanted teeth	Root development stage	Root canal treatment	Donor tooth	Receptor bed	Success rate (%)	Survival rate (%)
Gonnissen et al.[7] (2010)	Retrospective observational	-	17	2, 3, 4	-	C (max, mand) M (mand)	C (max)	70.6	-
Yan et al.[19] (2010)	Clinical trial	-	16	5	2	3 M	M	87.5	100.0
Isa-Kara et al. [9]. (2011)	Retrospective observational	-	11	2–5	0	3 M	M	100.0	100.0
Marques–Ferreira et al. [1] (2011)	RCT								
Vilhjálmsson et al.[11] (2011)	Retrospective observational	-	26	0–5	0	-	I, C	84.6	100.0
Plakwicz et al.[20]. (2013)	Prospective Clinical trial	19	23	2–5	0	PM (max, mand)	I, PM	91.3	100.0
Schütz et al. [12]. (2013)	Retrospective observational	46	57	2–4	1	3 M (max, mand)	M, PM	94.7	94.7
Nagori et al. [21]. (2014)	Prospective Clinical trial	-	45	2–5	-	3 M (max, mand)	M (max, mand)	86.7	-
Gilijamse et al.[13] (2016)	Retrospective observational	-	57	3–4	-	-	-	-	100.0
Mertens et al. [15]. (2016)	Retrospective observational	30	25	3	0	3 M (mand) 2PM (mand)	2PM, 1 M, 2 M	61.1	96.0
Stange et al. [16]. (2016)	Retrospective observational	19	20	-	0	PM	I (max)	93.3	100.0
Kafourou et al.[17]. (2017)	Retrospective observational	-	45	-	11	-	-	-	-
Michl et al. [22]. (2017)	Prospective Clinical trial	-	26	3–5	-	PM	-	-	-
Strbac et al. [18]. (2017)	Retrospective cohort study	-	66	2, 3	4	M	PM, M	-	89.4
Jakobsen et al.[23]. (2018)	Non-randomised clinical trial	-	89	2, 3	0	PM	-	-	-
Van Westerveld et al. [10] (2019)	Retrospective observational	51	74	-	7	PM, M	-	-	95.4
Yang et al. [14]. (2019)	Retrospective observational	-	13	5	-	-	-	-	-

Most authors consider the presence of external or internal root resorption as a sign of autotransplantation failure. However, other authors such as Yan et al. [19] did not take this criterion as a criterion for success, measuring other variables such as the stability of the tooth in the alveolar bed, without the presence of symptomatology, correct masticatory efficiency, and that radiographically no periapical radiolucent images were observed and the appearance of the lamina dura



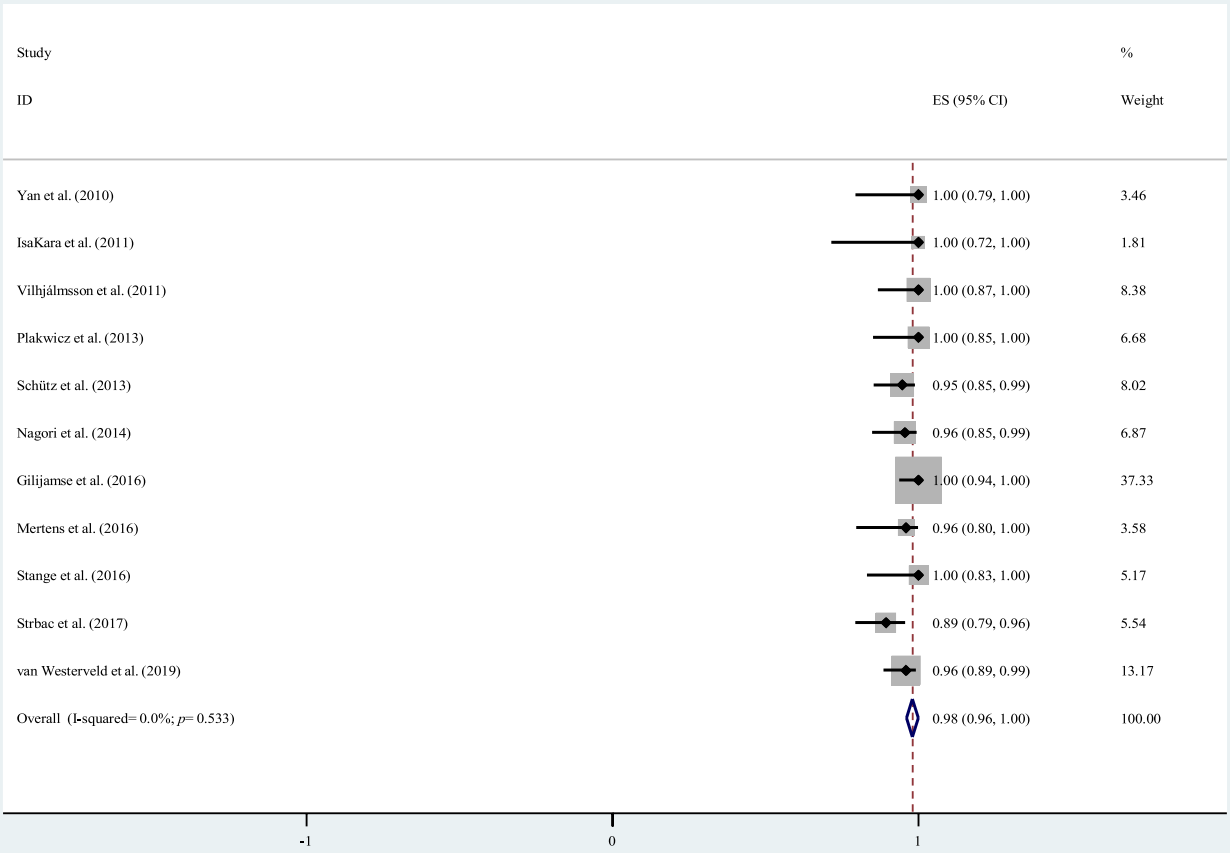


Fig. 2 Meta-analysis of overall survival data

Fig. 3 Meta-analysis of 1-year survival data

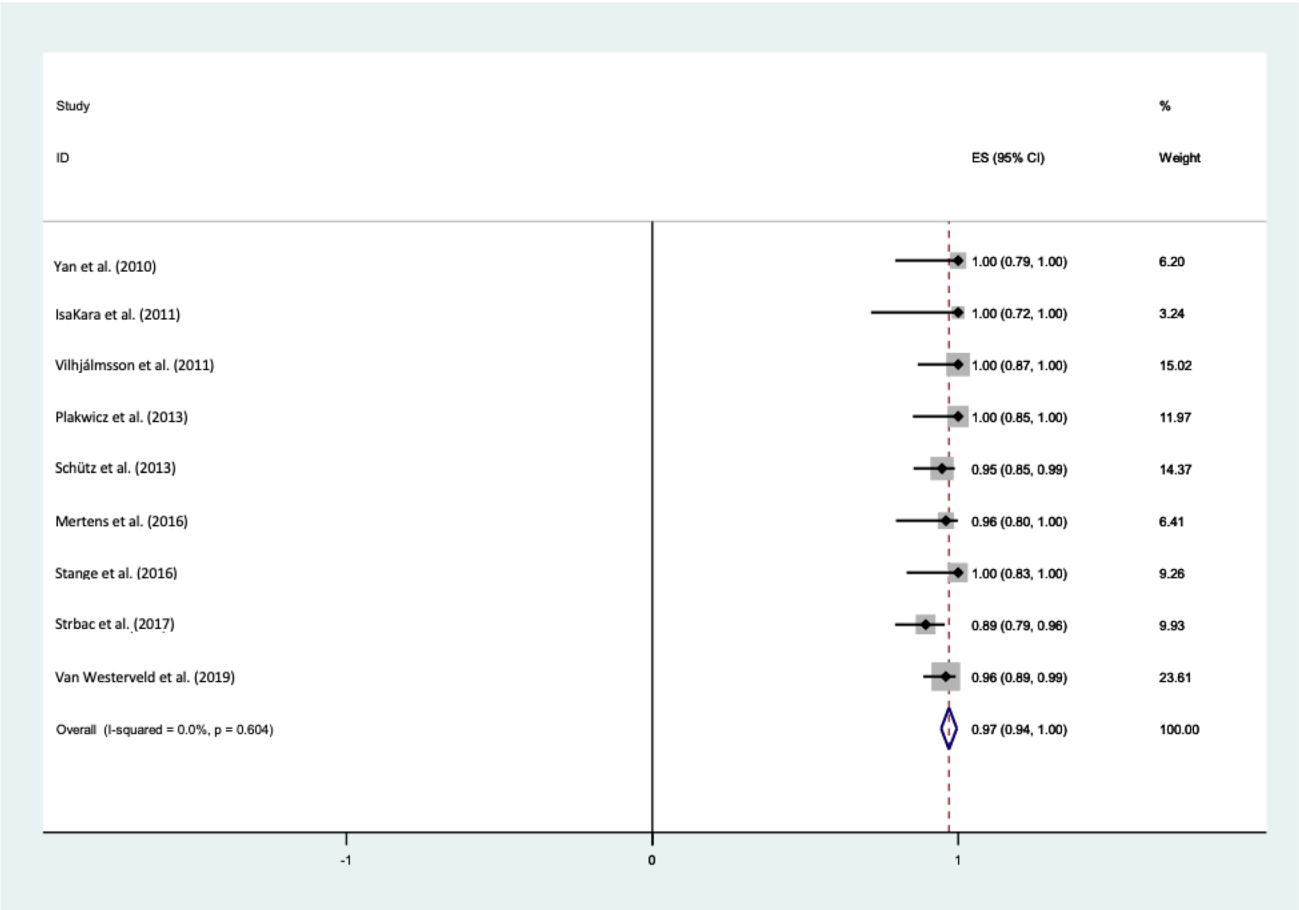


Fig. 4 Meta-analysis of 2-year survival data

radiographically appeared adequate. Other authors such as Yang et al. [14], Plackwicz et al. [20], and Schütz et al. [12] stated correct healing of the periodontal soft tissues and a healthy appearance during the various check-ups as criteria for success. Kafourou et al. [17], Mertens et al. [15], and Van Westerveld et al. [10] reported the continuation of root development in teeth with immature apex, while Vilhjálmsson et al. [11], Gilijamse et al. [13], and Michl et al. [22] evaluated the absence of radiographic apical pathology. Other factors considered relevant for treatment success have also been described in the scientific literature, such as the absence of non-physiological mobility, absence of discomfort for the patient, acceptable aesthetics, and the presence of periodontal pockets no deeper than 3 mm [7, 9, 16].

Pulp considerations

Pulp vitality is considered to be one of the main criteria for successful autotransplantation. In the study conducted by Northway et al. [24], a positive response to pulp vitality testing was obtained at 2- and 4-month follow-up. This response is usually followed by a sign of pulp obliteration, which is corroborated in all teeth with immature apex treated in the study by Czochrowska et al. [25]. Furthermore, in the investigation by Vilhjálmsson et al. [11], the presence of radiographic pulp obliteration was considered a criterion for success. Nagori et al. [21] also demonstrated that all transplanted open apex teeth showed a positive response after electrical pulp vitality testing. Other authors such as Gonnissen et al. [7] or Vilhjálmsson et al. [11] considered the technique to be successful even if the tooth had to undergo root canal treatment, provided that this had been carried out correctly and without subsequent complications.

Post-extraction sockets vs artificially created sockets

Mertens et al. [15] stated that the prognosis for survival and success of teeth transplanted into post-extraction sockets was higher than in those transplanted into artificially created sockets, probably due to the presence of periodontal ligament cells, which was corroborated by Gilijamse et al.

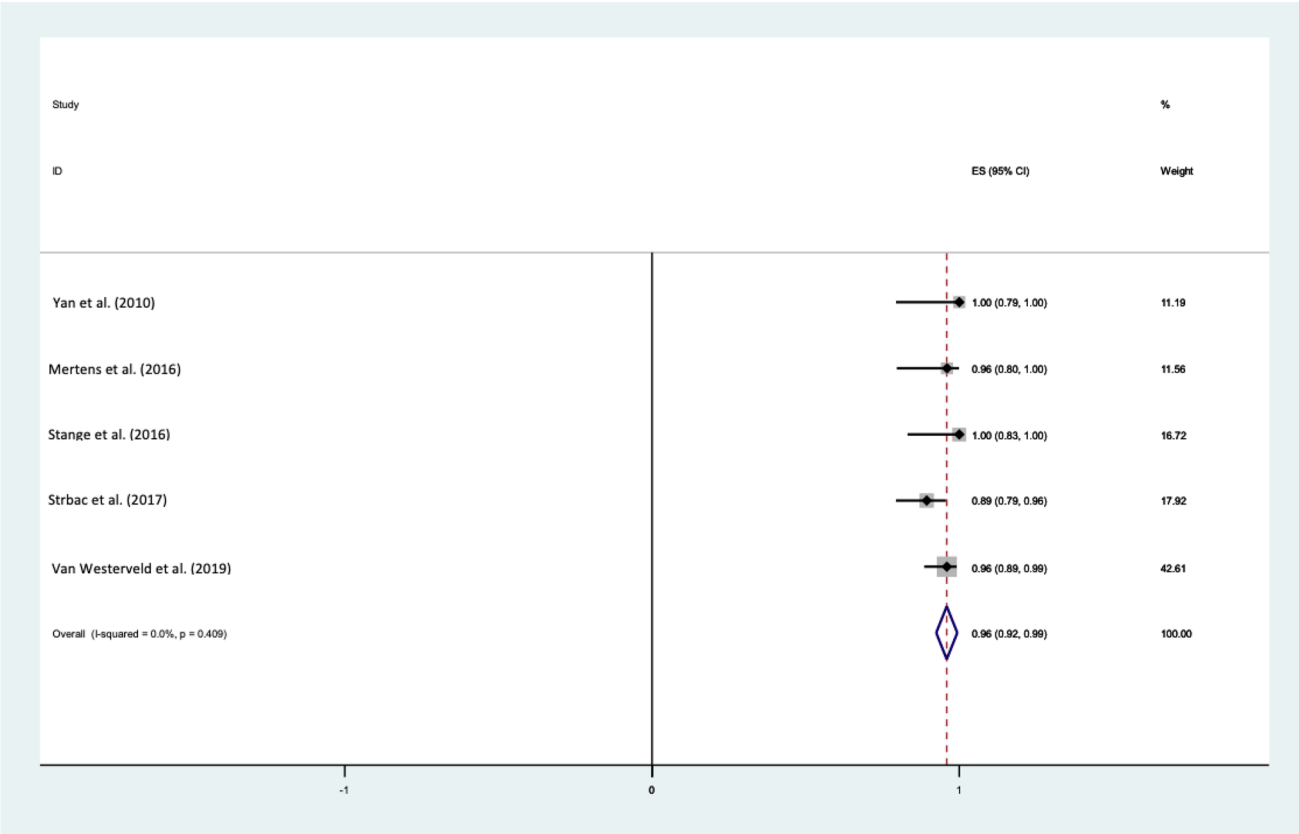


Fig. 5 Meta-analysis of 5-year survival data

[13]. On the other hand, Plakwicz et al. [20] observed that only one of the teeth transplanted into an artificially created socket did not form a conventional hard plate.

Donor teeth and recipient sites

Molars, mainly the third molar, have been the most commonly used teeth, followed by premolars, usually extracted for orthodontic indication so that in many cases these autotransplanted teeth are subjected to further orthodontic treatment. In most cases, these teeth were transferred to the molar and premolar areas, although there are also cases of transplantation to the incisal area. On the other hand, the main recipient sites chosen are the molar area, due to a higher incidence of caries, and the incisal area, as this is where trauma occurs most frequently and can lead to the loss of the upper central incisors.

Degree of root development

The degree of root development is one of the most important considerations when deciding on the indication for autotransplantation and thus determining the prognosis of the tooth. In this regard, the most successful teeth reported were found with 75% or more of the root formed, but without complete apex closure [14, 22]. Another important factor is the condition of the periodontal ligament at the time of autotransplantation [7]. Jakobsen et al. [23] assessed the damage to the periodontal ligament during the procedure and found that three of the treated teeth had suffered some type of lesion. Of these, only one achieved adequate root development, so it is considered that the damage to the ligament will make it difficult for the tooth to continue root formation in teeth with immature apexes.

Method of fixation

There is also no consensus on the most effective method of fixation of the transplanted tooth. For some authors, rigid fixation for a long period, longer than 4–6 weeks [9], might be counterproductive because it may promote ankylosis. In addition, rigid suturing may limit root growth, as well as hinder pulp revascularisation [26, 27]. Another factor supporting the use of non-rigid fixation is the occlusal stimulation of the transplanted tooth, which will promote regeneration and healing of the bone and periodontal ligament [13]. The only situation in which rigid fixation would be justified is in teeth that do not have good primary stability once placed in the

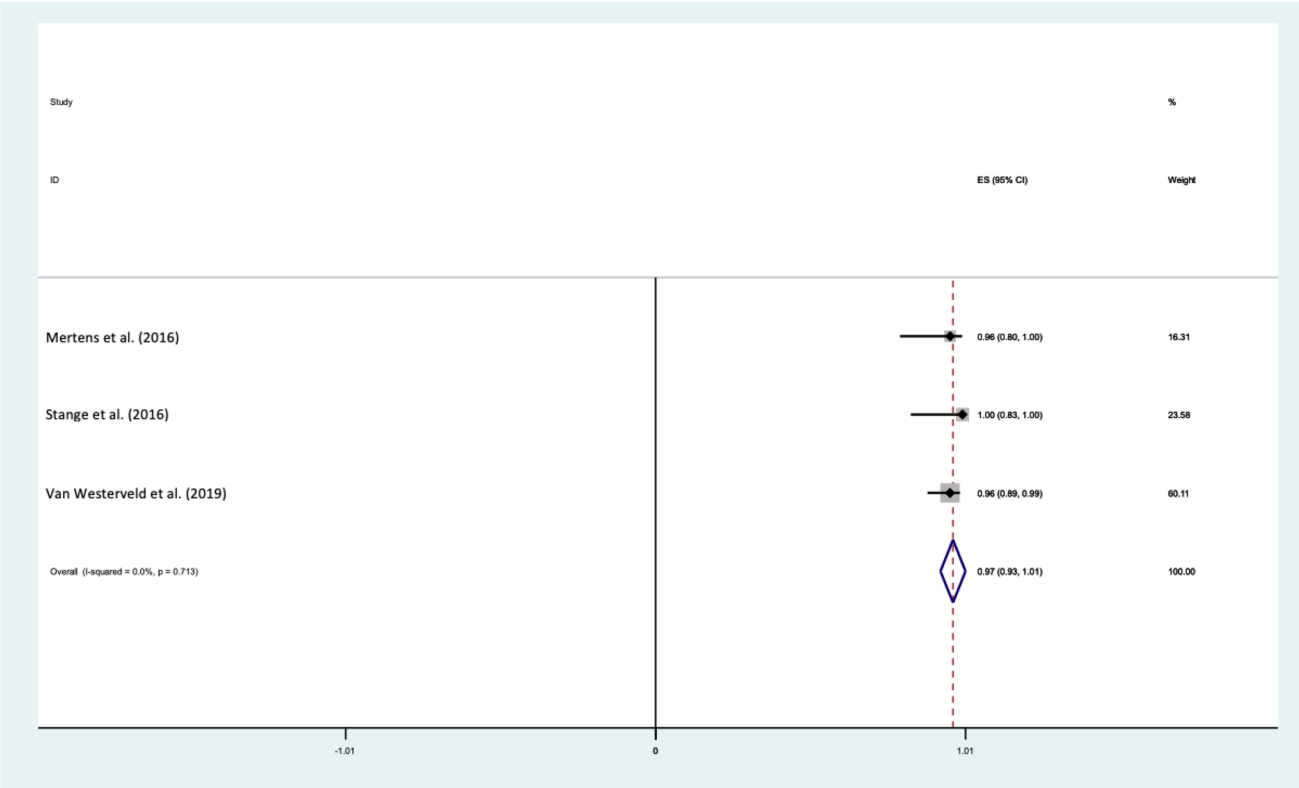


Fig. 6 Meta-analysis of 10-year survival data

socket, and even then, it should not be performed for long periods. Isa-Kara et al. [9] performed fixation of transplanted teeth using a thermoplastic retainer, which is now considered to be a durable, easy to sanitise, economical, and simple to produce fixation method. Moreover, more than 80% of their patients were satisfied with this type of retention.

Limitations

Due to the lack of uniformity of the success criteria described, there is no equivalence between the different studies, which makes it difficult to compare them. It is, therefore, necessary to establish common success criteria. Future lines of research should be directed towards RCTs on teeth with incomplete root development with larger sample sizes.

Conclusions

With the limitations of this study, it can be affirmed that the technique of autotransplantation performed in a single phase and with teeth that have not completed their development is a predictable technique, with a survival rate described at two years of follow-up of over 97%. This technique is especially recommendable in patients in the growth period and development stages; however, it is necessary to establish a clear surgical protocol in these cases, as well as a unification of the success criteria to be able to evaluate the effectiveness of the technique, as well as the necessary follow-up time.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00784-022-04435-8.

Declarations

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent For this type of study, formal consent is not required as the information is anonymised, and the submission does not include images that may identify the person.

Conflict of interest The authors declare no competing interests.

References

1. Marques-Ferreira M, Rabaça-Botelho M-F, Carvalho L et al (2011) Autogenous tooth transplantation: evaluation of pulp tissue regeneration. Med Oral Patol Oral Cir Bucal 16:e984–e989. https://doi.org/10.4317/medoral.16926

2. Rohof ECM, Kerdijk W, Jansma J et al (2018) Autotransplantation of teeth with incomplete root formation: a systematic review and meta-analysis. Clin Oral Investig 22:1613–1624. https://doi.org/10.1007/s00784-018-2408-z
3. Kugelberg R, Tegsjö U, Malmgren O (1994) Autotransplantation of 45 teeth to the upper incisor region in adolescents. Swed Dent J 18:165–172
4. Ong D, Itskovich Y, Dance G (2016) Autotransplantation: a viable treatment option for adolescent patients with significantly compromised teeth. Aust Dent J 61:396–407. https://doi.org/10.1111/adj.12420
5. Moher D, Liberati A, Tetzlaff J, Altman DG (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med 6:e1000097. https://doi.org/10.1371/journal.pmed.1000097
6. Munn Z, Moola S, Lisy K, Riitano D, Tufanaru C (2015) Methodological guidance for systematic reviews of observational epidemiological studies reporting prevalence and incidence data. Int J Evid Based Healthc 13(3):147–215
7. Gonnissen H, Politis C, Schepers S et al (2010) Long-term success and survival rates of autogenously transplanted canines. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 110:570–578. https://doi.org/10.1016/j.tripleo.2010.02.039
8. Moorrees C, Fanning E, Eej H (1963) Age variation of formation stages for ten permanent teeth. J Dent Res 42:1490–1502. https://doi.org/10.1177/00220345630420062701
9. Isa-Kara M, Sari F, Emre-Coşkun M et al (2011) Stabilization of autotransplanted teeth using thermoplastic retainers. Med Oral Patol Oral Cir Bucal 16:e369–e375. https://doi.org/10.4317/medoral.16.e369
10. van Westerveld KJH, Verweij JP, Toxopeus EE et al (2019) Long-term outcomes 1–20 years after autotransplantation of teeth: clinical and radiographic evaluation of 66 premolars and 8 molars. Br J Oral Maxillofac Surg 57:666–671. https://doi.org/10.1016/j.bjoms.2019.06.006
11. Vilhjálmsson VH, Knudsen GC, Grung B, Bårdsen A (2011) Dental auto-transplantation to anterior maxillary sites. Dent Traumatol 27:23–29. https://doi.org/10.1111/j.1600-9657.2010.00952.x
12. Schütz S, Beck I, Kühl S, Filippi A (2013) Results after wisdom tooth transplantation. A retrospective study Schweiz Monatsschr Zahnmed 123:303–313
13. Gilijamse M, Baart JA, Wolff J et al (2016) Tooth autotransplantation in the anterior maxilla and mandible: retrospective results in young patients. Oral Surg Oral Med Oral Pathol Oral Radiol 122:e187–e192. https://doi.org/10.1016/j.oooo.2016.06.013
14. Yang S, Jung B-Y, Pang N-S (2019) Outcomes of autotransplanted teeth and prognostic factors: a 10-year retrospective study. Clin Oral Investig 23:87–98. https://doi.org/10.1007/s00784-018-2412-3
15. Mertens B, Boukari A, Tenenbaum H (2016) Long-term follow up of post-surgical tooth autotransplantation: a retrospective study. J Investig Clin Dent 7:207–214. https://doi.org/10.1111/jicd.12126
16. Stange KM, Lindsten R, Bjerklin K (2016) Autotransplantation of premolars to the maxillary incisor region: a long-term follow-up of 12–22 years. Eur J Orthod 38:508–515. https://doi.org/10.1093/ejo/cjv078
17. Kafourou V, Tong HJ, Day P et al (2017) Outcomes and prognostic factors that influence the success of tooth autotransplantation in children and adolescents. Dent Traumatol 33:393–399. https://doi.org/10.1111/edt.12353
18. Strbac GD, Giannis K, Mittlböck M et al (2017) Survival rate of autotransplanted teeth after 5 years - A retrospective cohort study. J Craniomaxillofac Surg 45:1143–1149. https://doi.org/10.1016/j.jcms.2017.03.023
19. Yan Q, Li B, Long X (2010) Immediate autotransplantation of mandibular third molar in China. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 110:436–440. https://doi.org/10.1016/j.tripleo.2010.02.026
20. Plakwicz P, Wojtowicz A, Czochrowska EM (2013) Survival and success rates of autotransplanted premolars: a prospective study of the protocol for developing teeth. Am J Orthod Dentofac Orthop 144:229–237. https://doi.org/10.1016/j.ajodo.2013.03.019
21. Nagori SA, Bhutia O, Roychoudhury A, Pandey RM (2014) Immediate autotransplantation of third molars: an experience of 57 cases. Oral Surg Oral Med Oral Pathol Oral Radiol 118:400–407. https://doi.org/10.1016/j.oooo.2014.05.011
22. Michl I, Nolte D, Tschammler C et al (2017) Premolar autotransplantation in juvenile dentition: quantitative assessment of vertical bone and soft tissue growth. Oral Surg Oral Med Oral Pathol Oral Radiol 124:e1–e12. https://doi.org/10.1016/j.oooo.2017.02.002
23. Jakobsen C, Stokbro K, Kier-Swiatecka E et al (2018) Autotransplantation of premolars: does surgeon experience matter? Int J Oral Maxillofac Surg 47:1604–1608. https://doi.org/10.1016/j.ijom.2018.08.003
24. Northway W (2002) Autogenic dental transplants. Am J Orthod Dentofac Orthop 121:592–593. https://doi.org/10.1067/mod.2002.124795
25. Czochrowska EM, Stenvik A, Bjercke B, Zachrisson BU (2002) Outcome of tooth transplantation: survival and success rates 17–41 years posttreatment. Am J Orthod Dentofac Orthop 121:110–9; quiz 193. https://doi.org/10.1067/mod.2002.119979
26. Nayak BN, Wiltshire WA, Ganss B et al (2008) Healing of periodontal tissues following transplantation of cells in a rat orthodontic tooth movement model. Angle Orthod 78:826–831. https://doi.org/10.2319/082807-396.1
27. Bauss O, Schwestka-Polly R, Schilke R, Kiliaridis S (2005) Effect of different splinting methods and fixation periods on root development of autotransplanted immature third molars. J Oral Maxillofac Surg 63:304–310. https://doi.org/10.1016/j.joms.2004.06.056
28. Peters LB, Wesselink PR, van Winkelhoff AJ (2002) Combinations of bacterial species in endodontic infections. Int Endod J 35:698–702. https://doi.org/10.1046/j.1365-2591.2002.00550.x