



ORIGINAL ARTICLE

Mid-Term outcomes and periodontal prognostic factors Of autotransplanted third molars: A Retrospective Cohort Study

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Abstract

Background: Tooth autotransplantation is a valid method for replacing non-restorable teeth. This study aimed to assess mid-term survival and success of autotransplanted third molars and the clinical periodontal parameters and factors predicting successful periodontal attachment apparatus regeneration.

Methods: In total, 36 patients who had undergone extraction and subsequent autotransplantation of 36 third molars using virtual planning and computer-aided rapid prototyping models by an oral surgeon and endodontist were eligible. Probing pocket depth (PPD), gingival recession (REC), clinical attachment level (CAL), pulpal and periapical healing, root resorption, and radiographic bone loss (RBL) were evaluated. Additionally, a questionnaire evaluated patient-reported outcomes.

Results: The mean age of the participants was 30.2 years with a mean follow-up duration of 29.42 ± 14.56 months. The overall survival and success rates were 97.2% and 91.7%, respectively. No statistically significant differences were found in success and survival rates between open and closed apex groups or between compromised and intact buccal bone groups. No signs of pulp necrosis were found in the open apex group. Progressive replacement resorption was detected in one closed apex case. The mean PPD was 2.7 ± 0.45 mm for all transplanted teeth. REC was 0.13 mm higher in transplanted teeth than in previous hopeless teeth. CAL changes were neither clinically relevant (-0.17 ± 0.66 mm) nor statistically significant. The reported patient satisfaction was high.

Conclusions: Autotransplantation of third molars is a predictable treatment method, with a 2.5-year cumulative tooth survival and success of 97.2% and 91.7%, respectively, which were not influenced by recipient site integrity or root development.

KEYWORDS

endo-perio, gingival recession, periodontal regeneration, prognosis



1 | INTRODUCTION

Teeth extracted because of a hopeless prognosis or missing teeth can be replaced using fixed or removable prostheses and/or dental implants.^{1,2} Osseointegrated implants are considered a predictable treatment option, with long-term survival rates of over 90%.³ Dental implants lead to significant improvements in masticatory function, esthetics, and phonetics.⁴ Nevertheless, dental implants are susceptible to biological complications such as peri-implant mucositis and peri-implantitis,⁵ with an incidence ranging from 19% to 65% respectively.⁶ Some diseased dental implants may not last for the entire life span, despite receiving treatment.⁷ Hence, a constant search for valid alternative treatments is ongoing.

Autotransplantation is a widely accepted procedure for replacing non-restorable teeth.⁸ Unlike a dental implant, the successful transplanted tooth corresponds with the eruption process of the adjacent teeth and with the developmental changes.^{9,10} Therefore, it has become the first choice of treatment for tooth replacement in young patients.^{11,12}

Since Miller first reported the successful autotransplantation of the third molars in 1950,¹³ prognosis and outcome predictors have been evaluated extensively. Most authors have proposed that the predictability of this treatment option strongly depends on the survival of the periodontal ligament cells during the surgical procedure.¹⁴ Injuries to or increased extra-alveolar time of the donor tooth may damage the periodontal ligament, compromising its regenerative potential, ultimately leading to progressive root resorption.¹⁵ Lee et al. proposed the use of computer-aided rapid prototypes (CARP) during tooth autotransplantation to control these factors.¹⁶ Other authors have described the use of surgical planning software and guided surgery techniques to virtually determine the suitability of the donor tooth for the recipient tooth socket, precisely controlling the bone remodeling needed prior to the surgical appointment.¹⁷

Several authors have reported high short-term survival rates for wisdom tooth autotransplantation.^{8,18} A systematic review revealed 1- and 5-year survival rates of 98% and 90.5%, respectively.¹⁹ Although the survival rates for autotransplanted teeth, both with open and closed apices, have been widely documented, there is a lack of consensus on the exact definition of the success criteria. Most authors have included periodontal and endodontic status on their models, but the periodontal criteria remain vague or unclear.^{19,20,21} In addition, clinical studies assessing the influence of both preoperative donor tooth and recipient site conditions on periodontal healing of autotransplanted teeth are scarce.

Therefore, the aim of this study was to assess the mid-term survival and success rates of autotransplanted third molars, with special attention to periodontal status and factors that may predict the successful regeneration of the periodontal attachment apparatus.

2 | MATERIAL AND METHODS

2.1 | Study design and population

This retrospective cohort study included patients who had undergone third-molar autotransplantation by the same oral surgeon (ELT) in a private dental clinic (Barcelona, Spain) from 2015 to 2019. Ethical approval was obtained from the Ethics Committee of the Universitat Internacional de Catalunya, Spain (CIR-ECL-2020-02). Informed written consent was obtained from all patients.

2.2 | Eligibility criteria

Nonsmoker patients who had undergone third-molar extraction and subsequent third-molar autotransplantation using both virtual planning and a CARP model were screened using the relevant codes in the clinical database system. The case history charts were reviewed, and patients with insufficient preoperative endodontic and periodontal records, those who had undergone tooth autotransplantation without the use of virtual planning and a CARP model, cases that suffered intra-operative complications at the recipient site such as buccal plate damage and patients with <1 year of follow-up were excluded from this study.

2.3 | Digital planning protocol

Cone-beam computed tomography (CBCT) images were obtained for all patients, which were exported in the Digital Imaging and Communications in Medicine format to a surgical planning software*, for virtual treatment planning. Donor teeth were virtually segmented using the same software, and the images were saved in the stereolithographic format using the method described by Shahbazian et al. to create a CARP model.¹⁹ Similar to the digital treatment planning for dental implants, the CARP model was virtually moved to the recipient site to determine the suitability of the donor tooth, based on the anatomic landmarks of the recipient site. Finally, the CARP model file was sent to a dental laboratory for 3D-printing using a bio-compatible resin.

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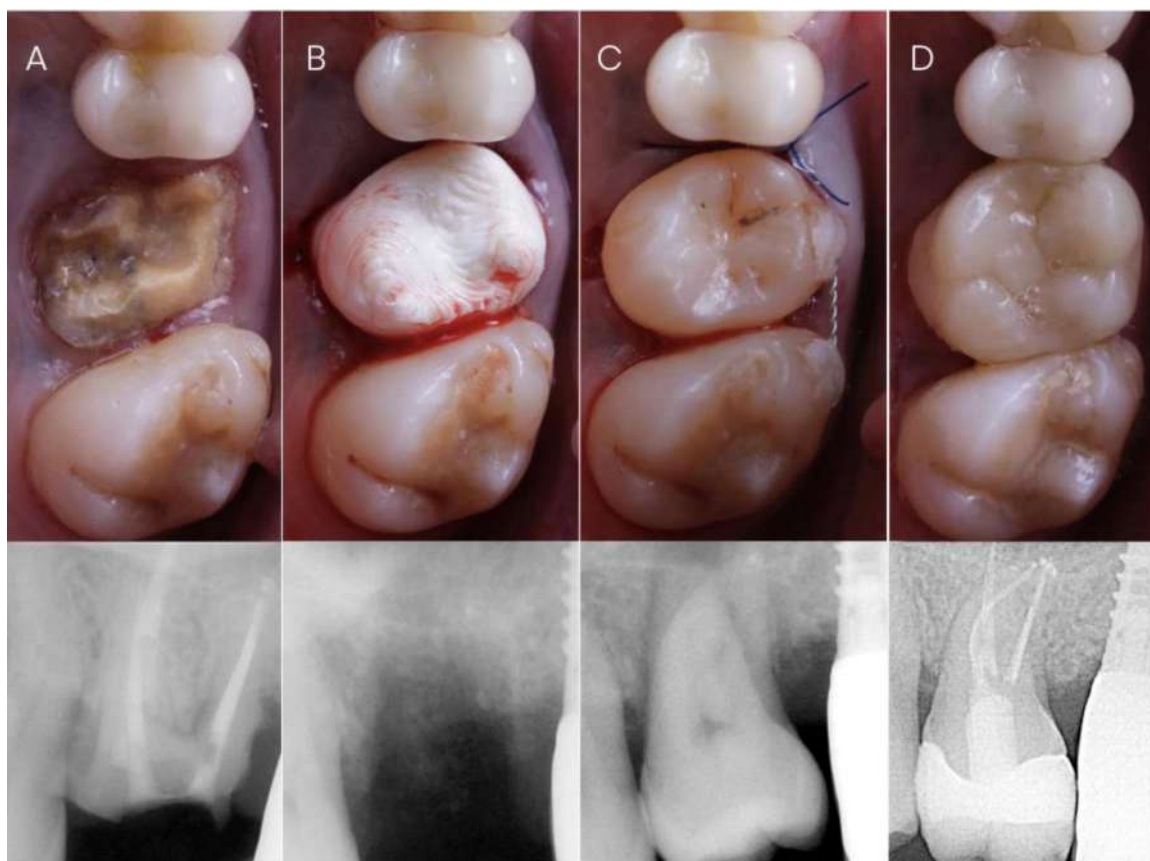


FIGURE 1 A representative case of autotransplantation. (A) Preoperative condition. (B) Intraoperative trial of the computer-aided rapid prototyping model after surgical modification of the recipient socket. (C) Immediate postoperative condition showing the splinted donor tooth. (D) 18-month control

2.4 | Surgical procedure

The surgical procedure in all patients was performed by an experienced oral surgeon in tooth autotransplantation (ELT) and an endodontist (ML), using the same surgical, endodontic, and restorative protocols (Figure 1). The periodontal status of the entire dentition was ensured to be stable before surgical planning.

All procedures were performed under local anesthesia. The recipient site tooth was extracted using the "flapless" method. The recipient site socket was prepared using a tungsten carbide round bur attached to a surgical contra-angle handpiece under copious saline irrigation. The suitability of the CARP model for the recipient site was determined. Once a passive fit of the CARP model was verified, the donor tooth was atraumatically extracted using an extraction forceps, with minimal use of elevators, to reduce the possibility of damage to the periodontal ligament. If the donor tooth was impacted, a flap was elevated and sufficient osteotomy was performed prior to its extraction.

The final position and occlusion of the transplanted tooth were checked clinically and radiographically. The

donor tooth was splinted to the adjacent teeth using a semi-rigid wire, and sutures were placed, if required, to facilitate healing by primary intention.

Postoperatively, 500-mg amoxicillin every 8 hours for 7 days and 600-mg ibuprofen every 8 hours for 3 days were prescribed to all patients. A soft diet was recommended for 2 weeks. The sutures and the splint were removed after 15 days. The endodontist (ML) completed the endodontic treatment within 1 month from the surgery in teeth with closed apices. Restorative treatment, if needed, was performed 2 to 6 months after the surgical procedure.

2.5 | Data collection

The electronic database of patients' records was reviewed by a single examiner (JMP). The following baseline (T1) records were retrieved from the clinical history database:

- Sociodemographic data including age and sex.
- Donor tooth type and root developmental stage classified as open or closed apex.



- Location, periapical status, and buccal alveolar bone condition of the recipient site classified as dehiscence (when a defect of ≥ 3 mm was evident) or intact buccal bone, based on preoperative CBCT images.
- Periodontal records including both probing pocket depth (PPD) and gingival recession (REC). Clinical attachment level (CAL) was calculated indirectly.

Once the patient was determined an eligible candidate, a follow-up appointment (T2) was scheduled, in which patients underwent thorough periodontal and endodontic examinations by obtaining parallel digital periapical radiographs[†] of the recipient sites. The following data were collected:

- Donor tooth mobility.
- PPD and REC measured at six sites. CAL was calculated indirectly.
- Pulpal and periapical healing, defined as normal or compromised, after clinical and radiographic examinations.
- Evidence of root resorption.
- Radiographic bone loss (RBL) estimated as a percentage.
- Response to a questionnaire that comprised eight questions adapted from Czychrowska et al. based on a 10-cm visual analog scale to evaluate patient-reported outcome measurements.¹²

2.6 | Definition of survival and success criteria

Survival was defined as the presence of an autotransplanted tooth with no clear indication for its removal at the most-recent follow-up appointment.

Autotransplanted teeth were determined as successful when the following clinical and radiographic conditions were fulfilled:

1. Normal function and physiologic mobility without pain or discomfort with palpation and percussion.
2. Stable periodontal attachment apparatus, defined by PPD ≤ 4 mm and CAL ≤ 5 mm.
3. Normal radiographic appearance of the periodontal ligament space around the transplanted tooth with absence of any progressive root resorption, periapical radiolucency, or RBL $\geq 50\%$.

2.7 | Statistical analysis

Data from all patients were entered into a spreadsheet and verified for entry errors. Categorical variables were

described as means of absolute and relative frequencies. The primary outcome of the study was CAL changes at the recipient site. A descriptive analysis segmented by groups was performed for two different groups: buccal bone condition (dehiscence or intact buccal bone) and root development (open or closed apex). Inferential analysis included all statistical tests required to assess intergroup and intra-group differences in addition to the association between preoperative variables and postoperative CAL changes. Mann-Whitney, Chi-square, and Fisher's tests of independence were used to assess the homogeneity of variables. Wilcoxon's test was used to compare the changes in clinical parameters from T1 to T2. Significance level was set at 5% ($\alpha = 0.05$). Multiple regression analysis was performed to predict the average CAL changes from baseline (extraction of teeth with hopeless prognosis) to the follow-up visit (autotransplanted teeth) based on age, root development stage, buccal alveolar bone condition, and CAL at the preoperative recipient site.

3 | RESULTS

3.1 | Patient demographics

A total of 36 autotransplanted teeth in 36 patients (12 male and 24 female) with a mean age of 30.2 years (range 14 to 61 years) were included in this study. The most frequent reason for extraction of the recipient site tooth was endodontic or restorative hopeless prognosis.

The mean follow-up duration, defined as the period from the day of the surgical procedure to the day of the most-recent visit or failure, was 29.42 ± 14.56 months. The most common donor teeth were maxillary third molars (66.6%), whereas the mandibular third molars were selected in the remaining third of the cases. Twenty-six donor teeth were fully erupted at the time of the surgical procedure whereas 10 were non erupted. Although most procedures were performed simultaneously with recipient site tooth extraction, two recipient sites were edentulous at the time of the surgical procedure. In addition, seven of the 34 extraction sockets had a compromised buccal bone wall, and of them, 72% exhibited a periapical lesion (Table 1).

3.2 | Survival and success

The overall survival and success rates were 97.2% and 91.7%, respectively, as determined by the evaluated clinical variables and radiographic signs.

One case of open apex failed in the early healing period. It had exhibited signs of poor periodontal integration that resulted in increased mobility and considerable patient

[†] Kodak RVG 6100; Carestream Health, Rochester, NY

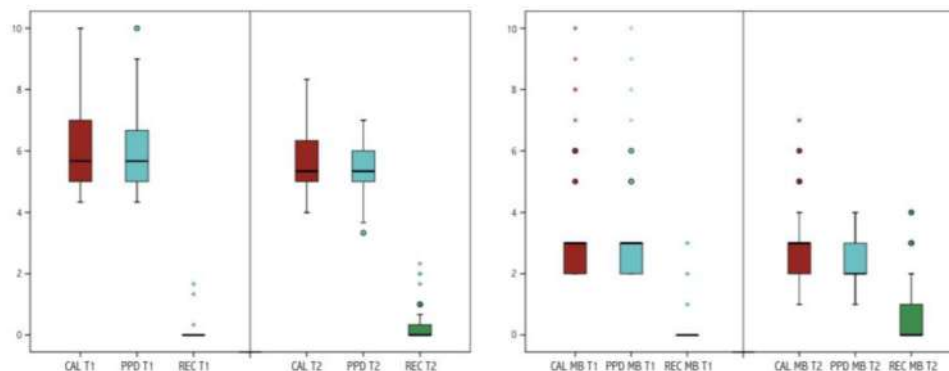


FIGURE 2 Periodontal outcomes at baseline and at the follow-up visit. (A) All sites. (B) Midbuccal sites

TABLE 1 Baseline patient characteristics and clinical parameters

Follow-up	29.42 ± 14.56 months
Sex (M/F)	12/24
Age	30.2 ± 12.6 years
Donor tooth (maxillary/mandibular)	24/12
Recipient site (maxilla/mandible)	17/19
Apical lesion (±)	26/10
Dehiscence (±)	29/7
Root development (open apex/closed apex)	12/24

discomfort. Two additional cases were categorized as failures despite their survival; one tooth with an open apex, because of the presence of a 5-mm residual periodontal pocket concurrent with a C:R <1 and one tooth with a closed apex because of progressive root replacement resorption and presenting a 5-mm residual PPD.

3.3 | Endodontic outcomes

No signs of pulp necrosis were evident in teeth with open apices, whereas all teeth with closed apices had undergone prophylactic endodontic treatment according to the established protocol. Progressive replacement resorption was detected in one tooth with a closed apex. Inflammatory root resorption was not observed in any tooth.

3.4 | Periodontal outcomes

The mean PPD was 2.7 ± 0.45 mm in all transplanted teeth. A statistically significant improvement ($P = 0.044$) was found in the mean PPD between the extracted hopeless teeth (3.02 ± 0.73 mm) and the transplanted teeth.

A 0.13-mm increase in REC was also statistically significant ($P = 0.011$). As a result of the decrease in PPD and increase in REC, mean CAL changes were neither clinically relevant (-0.17 ± 0.66 mm) nor statistically significant ($P = 0.386$) between T1 and T2 (Figure 2).

3.5 | Effect of root development

Table 2a describes the clinical characteristics of the teeth in the open and closed apex groups. The survival and success rates for teeth in the open apex group were 90.9% and 81.8%, respectively, whereas those for teeth in the closed apex group were 100% and 96%, respectively. Differences between groups were not statistically significant ($P > 0.05$).

When assessing the periodontal outcomes, the two groups were initially balanced for PPD, REC, and CAL. At control visits, no statistically significant differences were found between the groups for any assessed variable. A similar outcome was evident when the midbuccal sites were considered independently. No difference was noted in any collected clinical parameter between the two groups, except for the CAL value at T2, which tended to be higher for the teeth with closed apices (3.29 ± 1.57 mm) than for the teeth with open apices (2.22 ± 0.71 mm) ($P = 0.1$). In addition, a tendency ($P = 0.076$) for higher prevalence of increased RBL (>25%) at T2 was evident, being higher in the open apex group (20%) than in the closed apex group (0%).

3.6 | Effect of recipient site buccal bone condition

Table 2b illustrates the clinical characteristics of the intact buccal bone and dehiscence groups. No statistically significant differences were evident in the success and survival rates between the compromised and intact buccal bone groups ($P > 0.05$).

**TABLE 2** Outcome segmented by groups. (A) Donor tooth root development stage. (B) Recipient site buccal bone condition

Root development stage (A)				
	T1	T2	P	Δ
PPD				
Open apex	3,22 ± 0,81	2,69 ± 0,37	0,141	-0,44 ± 0,78
Closed apex	2,94 ± 0,7	2,71 ± 0,48	0,163	-0,23 ± 0,66
P	0304	0827		0546
Midbuccal PPD				
Open apex	3,6 ± 2,55	2,22 ± 0,83	0,196	-1,44 ± 2,83
Closed apex	3,29 ± 2,03	2,46 ± 0,88	0,127	-0,83 ± 1,69
P	0696	0619		0827
REC				
Open apex	0 ± 0	0 ± 0	1	0 ± 0
Closed apex	0,07 ± 0,21	0,25 ± 0,39	0,011*	0,17 ± 0,29
P	0589	0133		0133
Midbuccal REC				
Open apex	0 ± 0	0 ± 0	1	0 ± 0
Closed apex	0,25 ± 0,74	0,87 ± 1,29	0,017*	0,61 ± 1,03
P	0589	0133		0198
CAL				
Open apex	3,22 ± 0,81	2,69 ± 0,37	0,141	-0,44 ± 0,78
Closed apex	3,01 ± 0,75	2,94 ± 0,62	0,913	-0,06 ± 0,59
P	0445	0392		0238
Midbuccal CAL				
Open apex	3,6 ± 2,55	2,22 ± 0,83	0,196	-1,44 ± 2,83
Closed apex	3,54 ± 2,28	3,29 ± 1,57	0,35	-0,25 ± 1,26
P	0,78	0102		0437
Midbuccal CAL >3 mm				
Open apex	25 %	0 %	–	
Closed apex	20 %	25 %	1	
P	0754	0156		
RBL >25%				
Open apex	20 %			
Closed apex	0 %			
P	0076			
Survival				
Open apex	90,9 %			
Closed apex	100 %			
P	0306			
Success				
Open apex	81,8 %			
Closed apex	96,0 %			
P	0216			
Recipient site buccal condition (B)				
	T1	T2	P	Δ
PPD				
Dehiscence -	2,75 ± 0,45	2,65 ± 0,37	0,821	-0,06 ± 0,51
Dehiscence +	4,05 ± 0,75	2,90 ± 0,67	0,018*	-1,14 ± 0,63
P	<0001*	0,156		<0.001*

(Continues)



TABLE 2 (Continued)

Recipient site buccal condition (B)				
Midbuccal PPD				
Dehiscence -	2,41 ± 0,5	2,27 ± 0,67	0499	-0,12 ± 0,91
Dehiscence +	7,14 ± 1,95	2,86 ± 1,35	0018*	-4,29 ± 1,6
<i>P</i>	<0001*	0169		<0.001*
REC				
Dehiscence -	0,02 ± 0,13	0,11 ± 0,29	0066	0,09 ± 0,23
Dehiscence +	0,14 ± 0,31	0,40 ± 0,46	0068	0,26 ± 0,32
<i>P</i>	0335	0102		0123
Midbuccal REC				
Dehiscence -	0,07 ± 0,38	0,36 ± 0,86	0102	0,28 ± 0,79
Dehiscence +	0,57 ± 1,13	1,57 ± 1,62	0066	1 ± 1,15
<i>P</i>	0335	0083		0092
CAL				
Dehiscence -	2,78 ± 0,47	2,76 ± 0,41	0,431	0,03 ± 0,46
Dehiscence +	4,19 ± 0,62	3,31 ± 0,81	0043*	-0,88 ± 0,8
<i>P</i>	<0001*	0099		<0.005*
Midbuccal CAL				
Dehiscence -	2,48 ± 0,7	2,62 ± 0,9	0,378	0,15 ± 0,88
Dehiscence +	7,71 ± 1,5	3,31 ± 0,85	0018*	-3,29 ± 2,06
<i>P</i>	<0001*	0,03*		<0.001*
Midbuccal CAL >3 mm				
Dehiscence -	3,7 %	7,7 %	1	
Dehiscence +	100 %	57,1 %	–	
<i>P</i>	<0001*	0011*		
RBL >25%				
Dehiscence -	3,6 %			
Dehiscence +	14,3 %			
<i>P</i>	0365*			
Survival				
Dehiscence -	96,6 %			
Dehiscence +	100 %			
<i>P</i>	1			
Success				
Dehiscence -	93,1 %			
Dehiscence +	85,7 %			
<i>P</i>	0488			

Abbreviations: PPD, probing pocket depth; REC, gingival recession; CAL, clinical attachment level; RBL, radiographic bone loss; T1, at baseline; T2, at follow-up appointment.

When only measurements at the midbuccal sites were considered, the average PPD and CAL were significantly higher ($P < 0.001$) in the dehiscence buccal bone group than in the intact buccal bone group at baseline (T1). Further, significant improvements ($P = 0.018$) were noted in PPD (-4.29 ± 1.6 mm) and CAL (-3.29 ± 2.06 mm) in the compromised buccal bone group when intragroup (T1-T2) changes were compared. Changes in both PPD and CAL within the intact buccal bone group were non-

significant. This resulted in a significant intergroup difference for T1-T2 changes in PPD and CAL ($P < 0.001$). Therefore, at T2, no differences between the groups were noted in PPD ($P > 0.05$), and a small clinical difference could be detected between the groups in CAL (0.69 mm, $P = 0.03$). When mean values from the six sites were analyzed, a similar trend was observed for mean values of both PPD and CAL, despite the weaker differences.

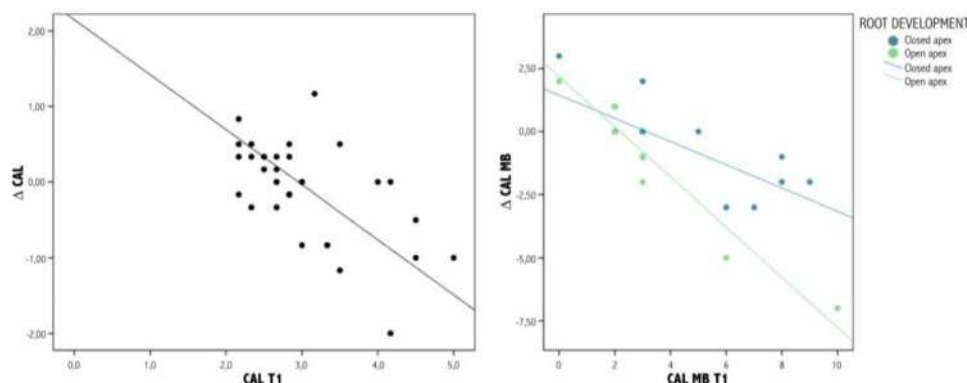


FIGURE 3 Association between the initial clinical attachment level (CAL, T1) and changes in the CAL (T1-T2) for **(A)** All sites and **(B)** Midbuccal sites

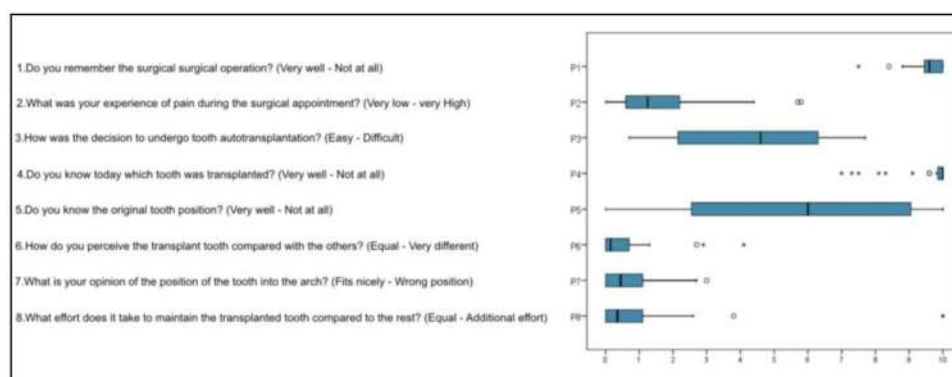


FIGURE 4 Answers to the questionnaire used to evaluate patient satisfaction and opinions at the follow-up appointment

3.7 | Predictors for CAL changes

The mean CAL gain was 0.626 mm for each mm of preoperative CAL, when CAL gain was considered as the dependent variable (Figure 3A). A significant regression equation was found with $R^2 = 0.56$.

A significant regression equation was also found with a CAL gain at midbuccal sites; the CAL gain was 0.647 mm for each mm of preoperative CAL, when studied independently. Teeth with open apices showed a greater CAL gain of 0.945 mm than teeth with closed apices (Figure 3B).

3.8 | Patient-reported outcomes

All patients reported that they remembered the surgical procedure vaguely (Q1) and as a non-painful experience (Q2). Decision making for tooth autotransplantation was neither easy nor difficult, and considerable discrepancies were found between patient answers (Q3). All patients believed to know the extracted recipient site tooth but were

doubtful when asked about the position of the initial donor tooth (Q4,5). The perception of the transplanted teeth was good and homogeneous, when asked to compare with the rest of their teeth and about their position in the dental arch (Q6,7). Most participants declared that no particular measures were taken to maintain the transplanted teeth (Q8) (Figure 4).

4 | DISCUSSION

4.1 | Survival

A recent systematic review has shown that tooth autotransplantation is a predictable mode of treatment with a 5-year cumulative survival rate of 90.5%,¹⁹ which is consistent with the 97.2% survival obtained after 29 months of follow-up in this study. Further, long-term studies have also reported a high survival rate of autotransplanted teeth.¹² The treatment outcome has gradually improved over time, aided by the increased understanding of pivotal factors



that govern the healing for autotransplanted teeth. In this regard, the CARP model minimizes the trauma exerted on the periodontal ligament of the donor tooth by reducing the extra-alveolar time.^{22,23} Despite the low quality of existing evidence, this approach has resulted in higher and more homogeneous survival rates²¹ than conventional techniques.⁸

4.2 | Success

The success rate of autotransplanted teeth in this study was 91.7%, which agrees with the 14.6% failure rate estimated in a recent systematic review that included teeth with both open and closed apices.⁸

Despite the extensive evidence on tooth autotransplantation, there is a lack of consensus in defining the criteria for success. Unspecific success criteria have been encountered, particularly with periodontal variables. Vague definitions without clear specifications lead to difficulties in reproducibility and comparison. Moreover, CAL is seldom considered, despite being the primary criterion for the diagnosis of periodontal disease. Therefore, the success criteria proposed in this study included stable periodontal apparatus (PPD ≤ 4 mm and CAL ≤ 5 mm) in addition to normal function and absence of progressive root resorption.

In this study, two of three cases were considered as failures despite their survival and lack of patient discomfort. Both teeth exhibited isolated sites with 5-mm PPDs and one exhibited a compromised C:R. In this regard, multiple residual periodontal pockets with depths of 5 mm or higher have been associated with a long-term higher risk of periodontal disease progression and tooth loss in periodontally susceptible individuals.²⁴ However, the implication of a single residual periodontal pocket in a young and periodontally healthy patient is unclear. Further, an increased C:R ratio has been associated with a worsened tooth prognosis in periodontally affected patients.²⁵ However, the periodontal attachment area of a root is greater in the cervical region than that in the apical- and middle-third regions.²⁶ Therefore, despite similar C:R ratios, considerable discrepancies in tooth stability exist between periodontally compromised teeth and teeth without fully developed roots or resected apices.²⁷

Owing to disagreement and ambiguity, heterogeneity in success rates is not exclusively related to disparate clinical outcomes but also to the specific definitions applied for evaluation. Hereby, the importance of consensus on the success criteria for autotransplanted teeth, beyond tooth loss, would be advantageous to facilitate research standardization and interpretation.

4.3 | Periodontal outcomes

Periodontal assessment of autotransplanted teeth has been traditionally smudged owing to the non-specific success criteria. Statistical analysis has been reported beyond qualitative evaluation.²⁸ To the best of our knowledge, this is the first study to analyze the differences in preoperative recipient site and postoperative periodontal condition of transplanted teeth. A previous longitudinal prospective study has reported an average PPD of 2.4 mm and CAL of 2.5 mm, 1 year after autotransplantation. These results are in agreement with those of this study. Further, for teeth retained even after 5 years (90.3%), the CAL changes were limited because only 4% surfaces displayed a CAL loss of 3 mm or higher.²⁸

In this study, only two transplanted teeth were categorized as having RBL between 25% and 50%, though both exhibited a partially developed root at the time of the surgical procedure. Therefore, caution should be exercised while interpreting this result. Andreasen et al. reported that only 14% teeth with open apices complete root formation.²⁹ Because RBL is a relative measuring unit, the biologic width in incompletely formed roots may explain this finding.

Several variables such as age,^{30,31,32} tobacco smoking,³³ plaque control,³³ donor tooth type,^{15,31,32} eruptive stage,^{11,31,34,35} periodontal condition,^{30,32} root development stage,^{31,34,36} extra-alveolar time,¹⁴ recipient site integrity,³⁴ adjacent bone defect,³⁵ and fixation method^{19,32,37} have been related to the prognosis of autotransplanted teeth, but not specifically to periodontal healing. These associations affect the regenerative potential of the periodontal attachment of donor teeth. In this retrospective study, the eligibility criteria controlled most of these variables, allowing an unbiased analysis of age, recipient site integrity, and developmental stage of the donor tooth as prognostic factors.

Concerning the recipient site integrity, despite significant initial disparities in CAL between periodontally compromised and non-compromised groups, no clinically relevant differences were evident at the follow-up appointment among the groups. This can be explained by the considerable changes in CAL at the recipient sites with dehiscences. Previous animal experimental studies have shown the possibility of periodontal reattachment in reimplanted teeth, even in sockets without buccal bone.³⁸ Some authors have described simultaneous regenerative approaches for the management of this clinical challenge.^{39,40} However, according to the results of this study, benefits of the previously introduced reconstructive therapies are questionable. Nevertheless, long-term functional stability of re-established clinical attachment in compromised sockets is



uncertain. The absence of the complete regeneration of a buccal bone plate could act as a predisposing factor for future gingival recession under the occurrence of additional contributory factors.⁴¹

As evident through both intergroup and multiple regression analysis, teeth with open apices tend to heal with a shallower CAL. Their regenerative potential is best expressed in initially compromised sites, where the additional CAL gain at the midbuccal site is almost 1 mm, compared to teeth with closed apices. Because the Herwig's epithelial rest sheet (HERS) cells are essential for the differentiation of dental follicle cells to form periodontal structures,^{42,43} a possible justification for this difference between groups might be the elevated levels of amelogenins produced by HERS cells on developing root surfaces.⁴⁴

Despite the influence of these factors on periodontal healing, their clinical significance is limited. Neither root development nor recipient site integrity seemed to exert any influence on the mid-term success or survival rate of autotransplanted teeth.

4.4 | Patient-reported outcomes

As per the response to the self-assessed satisfaction questionnaire, patients felt that their transplanted teeth were similar to any other teeth in their mouth, despite remembering their original locations. We noticed a lack of prospective trials on posterior teeth when we attempted to compare our results with those of previous studies. Only one study included a patient-centered assessment for autotransplanted teeth, including third molars. After a 1.6-year follow-up, the results were in accordance with those of this study, because 89% patients consented to undergo the procedure again.³¹

4.5 | Strengths and limitations

This study has some limitations, including the relatively small number of patients, lack of blinding the investigators, and retrospective nature of the study that led to a random exclusion of potential cases. Further, buccal bone condition classification was based solely on preoperative CBCT images instead of direct intrasurgical measurements. Nevertheless, the limitations were partially compensated by strict inclusion criteria and a private practice setting with single specialist clinicians; thus, providing external validity. Further, to the best of our knowledge, this is the first longitudinal study to assess the influence of preoperative conditions of the donor tooth and

the recipient site on the periodontal healing of autotransplanted teeth.

5 | CONCLUSION

Autotransplantation of third molars is a predictable mode of treatment for the replacement of extracted teeth with hopeless prognosis and missing teeth in young patients with a 29.42 ± 14.56 -month cumulative tooth survival rate of 97.2%. Further, neither success nor survival was influenced by recipient site integrity or root development. This might be explained by the favorable periodontal healing encountered in compromised sockets, especially in partially formed donor teeth. Nevertheless, further research is advised to determine the long-term stability of these results.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest related with this study.

AUTHOR CONTRIBUTIONS

Ernest Lucas-Taule: Drafting of the article, Data collection, critical revision, and approval of the submitted and final versions. Marc Llaquet: Data collection, drafting of the article, and approval of the submitted and final versions. Jesus Munoz-Penalver: Data collection, approval of the submitted and final versions. Jose Nart: Data collection, approval of the submitted and final versions. Federico Hernandez-Alfaro: Data collection, approval of the submitted and final versions. Jordi Gargallo-Albiol: Critical revision, approval of the submitted and final versions.

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