*Acta Odontologica Scandinavica,* 2013; 71: 1538–1546

informa
healthcare

**ORIGINAL ARTICLE**

# Autotransplantation and surgical uprighting of impacted or retained teeth: A retrospective clinical study and evaluation of patient satisfaction

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**Abstract**

***Objectives.*** This retrospective clinical study aimed to determine the success rate of autotransplanted impacted or retained teeth along with a patient satisfaction survey and to analyze the influence of relevant clinical and radiographic parameters. ***Subjects and methods.*** Fifty-seven teeth (37 canines, 10 molars, seven premolars, three incisors) in 45 patients (median 15 years) were evaluated over a mean of 1.6 years. The success criteria were pocket probing depth ≤3.5 mm, mobility grade ≤ II, Periotest ≤30 and complete alveolar bone healing. The influencing parameters were oral hygiene, smoking, periodontal screening index, occlusal/proximal contacts, horizontal position, dental age, pulp obliteration and degree of displacement. Furthermore, bone height was measured. ***Results.*** The overall success rate was 74%, along with a high patient satisfaction. The survival rate was 96% after a mean follow-up of 1.6 years. The favorable factors were proper oral hygiene, non-smoking, good general periodontal condition, proximal contacts and pulp obliteration. An increase in or maintenance of bone level was found in 96%. ***Conclusions.*** Autotransplantation of impacted or retained teeth is an appropriate treatment, if orthodontic alignment has failed, especially in growing patients.

**Key Words:** *autotransplantation, tooth impaction, patient satisfaction, surgical uprighting*

## Introduction

The alignment of impacted or retained teeth is a challenge. As the terminology regarding eruption disturbances is inconsistent, the terms used in this study are defined according to a previous review [1]. Impaction is the cessation of the eruption of a tooth due to an abnormal position of the tooth or due to a physical barrier in the eruption path. If a normally placed and developed tooth does not erupt, although there is no physical barrier in the eruption path, it is considered a primarily retained tooth. Secondary retention refers to a tooth, the eruption of which ceases after emergence without a physical barrier or abnormal position.

Maxillary canine impaction has been reported to occur in ~ 2% of the population [2]. Arch length discrepancy and crowding are considered to be the primary etiologic factors for the labial impaction of canines. For palatal impaction, variations of the lateral incisor, which serves as guidance of eruption, and genetic factors, including dental anomalies, have been proposed. In cases in which surgical exposure and orthodontic traction is not successful, autotransplantation can be the treatment of choice [3]. This choice could be due to unfavorable displacement, e.g. the position of the crown tip mesial to the mid-line of the lateral incisor or mesial angulation greater than 55° [4], as well as failure of orthodontic alignment due to immobility or because the patient refuses a conventional orthodontic therapy. Recent studies of autotransplantation of canines have reported success rates of 38–58% over more than 10 years [5,6].

In addition to canines, there are also retained or impacted molars, premolars and incisors, the orthodontic alignment of which has failed. The prevalence

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*(Received 22 October 2012; accepted 7 February 2013)*

ISSN 0001-6357 print/ISSN 1502-3850 online © 2013 Informa Healthcare
DOI: 10.3109/00016357.2013.775667

of impaction for permanent first and second molars has been reported to be up to 2.3% [7] and 0.5% for the lower second premolars [8]. Impaction of the lower premolars has been reported to be due to local factors, such as mesial drift arising from premature loss of primary molars, ectopic positioning of the developing tooth buds and pathology, such as cysts or retained or ankylosed primary molars. Regarding retention of incisors, supernumerary teeth, like mesiodentes, can inhibit physiologic eruption [9]. Similarly, traumatic intrusion can result in retention [10].

Most authors consider endodontic treatment of autotransplanted teeth with closed apices as mandatory analog of traumatically avulsed teeth with closed apices [3]. In cases of immature teeth with open apices, a wait-and-see strategy is accepted due to the considerable potential of revascularization [6], which occurs in up to 100% of these teeth [11]. In comparison, replanted teeth with open apices after avulsion display revascularization in 18–34% [10]. Here, endodontic treatment is performed only if signs of pulp necrosis or root resorption are found [6]. However, there are also authors who suggest a wait-and-see strategy even in cases of closed apices [12,13]. In the study by Ahlberg et al. [13], 30% of 33 maxillary canines with complete root formation required no endodontic treatment after an average of 6 years. In 23 teeth, endodontic treatment was performed due to root resorption or clinical symptoms ($n = 10$) or due to widening of the periodontal ligament space or periapical lesions ($n = 13$).

As an ideal outcome, an autotransplanted tooth can be present in the mouth for the patient's entire life. However, there are other reasons supporting this treatment, even if life-long survival cannot be achieved. Transplanted teeth have the capacity to preserve the alveolar ridge, especially during the growth of the jaws [10,14,15], during which dental implants are contraindicated [16]. By analogy, avulsed teeth, even those with poor prognoses, are recommended for replantation in cases of dental trauma [10].

This retrospective clinical trial was performed, first, to evaluate the success rate of autotransplantation of impacted or retained teeth and, second, to analyze the influence of the relevant clinical and radiographic parameters on the outcome. Furthermore, this study evaluated descriptively how many transplanted teeth needed endodontic treatment, changes in bone height during the follow-up period and, finally, the patients' satisfaction.

## Subjects and methods

### *Participants and study setting*

In this retrospective, clinical and radiographic follow-up study, all healthy patients were included who had undergone at least one autotransplantation of an impacted or retained permanent tooth in a private practice for oral and maxillofacial surgery in the period from 2006–2009. The follow-up examinations took place in 2010. Each patient was clinically and radiologically examined once after an observation period of at least 1 year. All of the examinations were performed by one examiner experienced in autotransplantation. Informed written consent was obtained from all of the patients. The study was granted approval by the Ethics Committee of the University of Munich (No. 327-09). All of the patients who agreed to participate in this study were included.

### *Interventions*

Autotransplantation was performed according to the technique described by Andreasen et al. [8]. In our study, it may be sub-divided into conventional autotransplantation and surgical uprighting. Conventional transplantation was performed when the tooth had to be removed from the oral cavity and to be reinserted after preparation of a suitable tooth pocket. If a partially or completely retained tooth could be aligned without removing it out of the oral cavity and without the necessity of remodeling the tooth pocket, a surgical uprighting was performed. All autotransplantations were performed by one experienced maxillofacial surgeon under general anesthesia and often combined with removal of all four wisdom teeth. Further, in cases of severely displaced teeth, in particular upper canines, surgery was performed principally in general anesthesia to avoid unnecessary stress for the young patients. The location of the respective tooth was evaluated by clinical and radiographic examinations. A marginal incision and a mucoperiostal flap were made at the respective site, followed by removal of the bone covering the tooth using a surgical burr (S-11, W&H, Bürmoos, Austria) under irrigation with sterile physiologic saline. The graft was carefully extracted with a periosteal elevator and, if necessary, stored extra-orally (4 mg dexamethasone, 100 mg doxycycline, 10 ml physiologic saline). All of the teeth were positioned into a normal occlusal contact position. Repositioned soft tissue was fixed tightly to the transplanted tooth (Vicryl 4-0, Ethicon, Somerville, NJ). Depending on the clinical situation, suture splinting, semi-rigid splinting with a titanium-trauma splint (Titanium-Trauma-Splint, Medartis, Basel, Switzerland; Tetric Evo Flow, Syntac Classic, Ivoclar Vivadent, Schaan, Liechtenstein) or fixation at a present orthodontic appliance was performed for tooth stability in the pocket for 3 weeks. The first post-operative treatment was performed 1 day after surgery. After 7 days, the sutures were removed and, after 3 weeks, the splinting was removed. The further clinical and radiographic follow-ups were performed at 3, 6 and 12 months and then annually.

Endodontic treatment of the transplanted teeth was performed if any clinical or radiographic signs (periapical periodontitis or root resorptions) were detected

[6,12,13]. In cases of endodontic treatment need, the patients were referred to their dentists.

The evaluation of pre-operative radiographs included the dental age of the respective tooth according to Gat et al. [17] and, in the case of canines, the crown tip's distance from and the inclination to the occlusal plane, as well as its position [18]. Root length and bone level were assessed on radiographs taken immediately after transplantation [13,19,20].

The clinical follow-up examinations included assessment of the patient's oral hygiene [21,22], caries, smoking habits and the Periodontal Screening Index (PSI), which is based on the Community Periodontal Index for Treatment Needs (CPITN) [23], to evaluate the periodontal condition. Regarding the transplanted tooth, the pocket probing depth at six sites, from the gingival margin to the bottom of the pocket, and the mobility were measured clinically and with the Periotest device (Periotest, Med Gulden, Modautal, Germany) [24,25]. Static occlusion and inter-proximal contacts, as well as deviations from its ideal alignment, were recorded [26]. Sensitivity of the transplanted tooth was evaluated with a cryogenic spray and with electrometric pulp testing (EPT, Vitality Scanner, Sybron Endo, Orange, CA) [24]. The tenderness to percussion of the transplanted tooth was recorded [27].

For the post-operative radiographic examination, digital radiographs were obtained. The transplanted tooth was examined for its periapical status and bone healing [28] and for root resorption [10]. Further, the presence of pulp obliteration was recorded [20]. Regarding possible resorption or root development during follow-up, the root length was assessed again [27], while the crown length served as the reference [19]. The bone height was expressed as a percentage of the root length and changes over the follow-up period were calculated [13].

To evaluate the patient's satisfaction, a questionnaire was administered, using numeric analog scales (1 = excellent; 6 = unsatisfactory). The patients rated their subjective perception of the treatment success, the aesthetic outcome, post-operative pain, current comfort and the fulfillment of their expectations. Additionally, the patients were asked how they became aware of this treatment option, how long they expected the transplant to survive, whether they would undergo another autotransplantation and whether they would recommend autotransplantation to other patients.

### *Outcomes*

The clinical success criteria were the periodontal probing depth (≤3.5 mm) and the grade of mobility (grade ≤ II or Periotest value ≤30) [24,25]. The radiographic success criterion was sound alveolar bone represented as complete periodontal trabeculation, with or without lamina dura, and a defined periodontal ligament space [28]. The clinical failure criteria were a periodontal probing depth >3.5 mm, a tooth mobility of grade III [24] or a periotest value >30 [25]. The radiographic failure criterion was incomplete alveolar bone presenting a rarefied area larger than the periodontal ligament space surrounding the transplanted tooth [28].

To analyze the influencing factors on the success rate, two groups were defined for each parameter. Patients with all three oral hygiene indices (gingiva, plaque, calculus) <1 were classified as having acceptable oral hygiene, and others were classified as having poor oral hygiene. The patients were classified as smokers or non-smokers. Patients with a PSI ≤2 were classified as good-to-moderate periodontal condition and those with a PSI >2 were classified as having a poor general periodontal condition. The teeth were divided according to the presence or absence of occlusal and proximal contacts. Additionally, the teeth's positions were differentiated according to their ideal or not ideal alignment with spaces or rotations. The developmental stages of the tooth were defined by open or closed apices, as all of the transplanted teeth showed almost complete root growth and pulp obliteration was recorded. In cases of canines, these teeth were grouped based on whether they were closer or farther from the median of the crown-tip distance, had an inclination less than or greater than 45° and were in the mesial or distal position in relation to the lateral incisor, as well as on the presence or absence of root deviations.

Tenderness to percussion, loss of sensitivity and caries resulted in the assumption of intervention need, but did not constitute failure criteria *per se*. Finally, root resorption, changes in root lengths and horizontal bone levels were assessed [13].

To increase the accuracy of the measurements, the intra-examiner reliability of the radiographic examinations was assessed. Regarding the assessment of root length and bone height changes, the measuring tolerance was calculated.

### *Statistical methods*

The data analysis was performed with SPSS software, version 18.0 (SPSS Inc., Chicago, IL). The demographic characteristics of the participants were specified descriptively. The success and failure rates overall and differentiated by tooth type are expressed as percentages of all of the included autotransplanted teeth. The success rate was calculated as follows: number of transplanted teeth meeting all clinical and radiographical success criteria at the time of examination ($n$ = 42) divided by the number of all included transplanted teeth ($n$ = 57). In contrast to the success rate, the survival rate was calculated as follows: number of present teeth at the time of examination regardless of the clinical and radiographic

Table I. Number of autotransplanted teeth sorted by tooth types and presenting anomalies.

| | Number of teeth (*n*) | | | | |
|---|---|---|---|---|---|
| | Canines | Molars | Premolars | Incisors | Total |
| Retention | 7 | 8 | 5 | 3 | 23 |
| Impaction | 30 | 2 | 2 | — | 34 |
| Total | 37 | 10 | 7 | 3 | 57 |

findings ($n$ = 55) divided by the number of all included transplanted teeth ($n$ = 57). The influence of the defined parameters on the success rate was calculated by the non-parametric two-sided Mann-Whitney U-Test ($\alpha$-level = 0.05). The intra-examiner reliability of the radiographic examinations was calculated by Cohen's unweighted kappa ($\kappa$) statistic. The number of teeth with endodontic treatment needs or pulp obliteration is given descriptively, as are the changes in bone height during the follow-up period and patient satisfaction.

## Results

In 55 patients, 74 impacted or retained teeth were autotransplanted from 2006–2009. Forty-five of these patients (female, $n$ = 26; male, $n$ = 19), with a total of 57 teeth, agreed to participate in this study. Conventional autotransplantation was performed in 32 cases and surgical uprighting in 25 cases. The mean age of the patients at the time of surgery was 17 years old (range = 9–43, median = 15 years). The number of tooth types that were autotransplanted, along with their presenting anomalies, is provided in Table I. The mean follow-up period was 1.6 years post-operatively (range = 1–4 years). Autotransplantation was performed if the referring orthodontist considered orthodontic alignment *a priori* to be impossible ($n$ = 28 teeth), if it was found intra-operatively that exposure and bonding were not possible ($n$ = 14), if preliminary orthodontic alignment failed due to immobility of the tooth ($n$ = 11) or if the patient refused orthodontic therapy and preferred surgical alignment ($n$ = 4). Therefore, orthodontic pre-treatment was performed on 11 teeth (20%). Forty-four teeth (77%) were adjusted orthodontically after transplantation. The intra-examiner reliabilities for the radiographic examination were good-to-excellent: dental age, pulp obliteration, caries, $\kappa$ = 1.0; bone healing, root length changes, $\kappa$ = 0.898; root resorptions, $\kappa$ = 0.831; bone level, $\kappa$ = 0.731.

The overall success rate was 74% (42/57 teeth) and the failure rate was 26% (15/57 teeth). The success rate for canines was 73%, for molars it was 70%, for pre-molars it was 71% and for incisors it was 100%. For a detailed description and data, see Tables II and III. The success rate for autotransplanted teeth was 75% and for surgically uprighted teeth 72%. One canine and one molar were lost before the 1-year follow-up due to mobility and incomplete bone healing, respectively. The survival rate was, thus, 96% after a mean follow-up of 1.6 years.

Oral hygiene showed a statistically significant influence on the success rate ($p$ = 0.047), as did smoking ($p$ = 0.027), PSI ($p$ = 0.002), the presence of proximal contacts ($p$ < 0.0001) and pulp obliteration ($p$ = 0.020). However, there was no significant influence on success of dental age ($p$ = 0.770), the presence of static occlusion ($p$ = 0.289), horizontal position ($p$ = 0.097) or degree of displacement (inclination, $p$ = 0.933; mesiodistal position of the crown-tip, $p$ = 0.921; distance to occlusal plane, $p$ = 0.800).

Twenty-eight of the 55 presently examined transplants (51%) showed signs of root resorption. Twenty-seven teeth (49%) showed no such signs. Thirty teeth (55%) showed signs of endodontic treatment need due to root resorptions or lack of sensitivity associated with tenderness to percussion. Twenty-five teeth (45%) showed no clinical and/or radiographic signs indicating endodontic treatment. Thirty-six teeth (63%) were transplanted with open apices and 21 teeth (37%) with closed apices. The success rate for immature teeth was 75% and for mature teeth it was 71%. Overall, 30 teeth (55%) developed pulp obliterations. The rate of pulp obliteration in the success group (62%) was distinctly higher than in the failure group (27%).

Along with the measurements for the reliability of the examiner regarding the assessment of root length changes, a mean measuring tolerance of −0.24 mm ± 0.72 mm was calculated. Therefore, only root length changes less than −0.96 mm and greater than +0.48 mm were considered to be real root length changes. These calculations refer to those 55 teeth that were *in situ* at the time of examination. Accordingly, 16 teeth (29%) increased their root length (range = 0.5–6 mm). Eleven teeth (20%) showed root shortenings (range = −1.9 to −4 mm) and 28 teeth (51%) were within the measuring

Table II. Success and failure rates, as well as absolute numbers of autotransplantations differentiated according to tooth types.

| | Canines | Molars | Premolars | Incisors | Total |
|---|---|---|---|---|---|
| Success rate, *n* (%) | 27 (73%) | 7 (70%) | 5 (71%) | 3 (100%) | 42 (74%) |
| Failure rate, *n* (%) | 10 (27%) | 3 (30%) | 2 (29%) | 0 (0%) | 15 (26%) |
| Total number of teeth, *n* | 37 | 10 | 7 | 3 | 57 |

Table III. Reasons for transplant failure. One tooth can have several reasons.

| | Number of teeth (*n*) | | | | |
|---|---|---|---|---|---|
| | Canines | Molars | Premolars | Incisors | Total |
| Pocket probing depth >3.5 mm | 6 | 2 | — | — | 8 |
| Mobility grade III | 2 | — | — | — | 2 |
| Incomplete bone healing | 8 | 1 | 2 | — | 11 |

tolerance (range = −0.8–0.4 mm). In relation to the respective root length, bone height was assessed post-operatively and at the time of follow-up. The accuracy of the examiner's bone height measurements was assessed by duplicate measurements. The standard deviations were ± 5.6% for the post-operative measurements and ± 3.4% at the time of follow-up. The mean bone level changed from 67% post-operatively (range = 20–100%) to 86% (range = 19–100%) at the time of follow-up, i.e., immediately after autotransplantation, 67% of the root length was covered with bone, which increased to 86% at the time of follow-up. Thirty-seven teeth (67%) showed growth of bone level, while two teeth (4%) showed loss of bone height. Sixteen teeth (29%) fell within 1 SD. The bone height changes with regard to success and failure are given in Table IV.

Asking the patients about their subjective perceptions of the success of the operations, an average assessment (school grades: 1 = excellent to 6 = unsatisfactory) of 1.6 was given. The aesthetic outcome was scored 1.8, post-operative pain was scored 2.3, current comfort was scored 1.2 and the fulfillment of expectations was scored 1.6. Forty patients (89%) reported that they would undergo another autotransplantation if indicated and 41 patients (91%) would recommend the procedure. Thirty-one patients (69%) became aware of the possibility of this treatment by their orthodontist, eight (18%) by the surgeon himself, three (7%) by their dentists and another three by their own research. Nineteen patients (42%) expected the transplant to survive for the rest of their lives, 10 patients (22%) expected a survival time of 10–15 years and 16 patients (36%) did not make a prediction.

Table IV. Number of teeth with growth or loss of bone height in relation to success and failure.

| | Number of teeth (*n*) | | | |
|---|---|---|---|---|
| | Growth of bone height | Loss of bone height | Within the SD | Total |
| Success | 31 | — | 11 | 42 |
| Failure | 6 | 2 | 5 | 13 |
| Total | 37 | 2 | 16 | 55 |

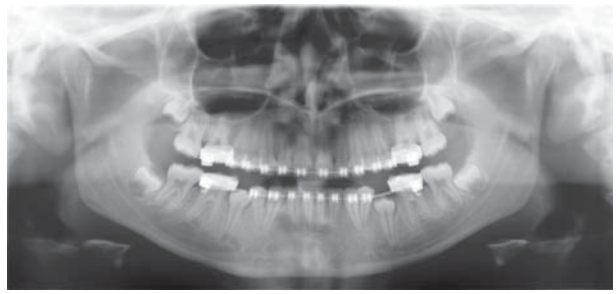

Figure 1. Initial radiologic finding of a retained lower left second premolar.

Figures 1,2,3 show the autotransplantation of a retained lower premolar, Figures 4,5,6 that of an impacted lower molar. Figures 7,8,9 show the autotransplantation of a severely displaced upper canine.

## Discussion

The success rate found in this study (74%) is higher than that found in other studies. This difference might be due mainly to patient age and the observation period [6]. In a recent trial examining 73 canines in 59 patients (mean age = 20.7 years old), a success rate of 58% after a mean follow-up time of 11 years was found [6]. Whereas we were able to follow-up 81% of the patients with autotransplantations, Gonnissen et al. [6] followed up 71%. In another recent study, a success rate of 38% after an average of 14.5 years was found. However, out of 191 treated patients, only 26% (49 patients) were followed up (mean age = 21.8. years), which might have impaired the validity of the results. The relatively young patient age in our study (mean age = 17 years old, median = 15 years old), as well as the relatively short observation period (mean = 1.6 years), might have contributed to the high success rate found. Nonetheless, our observation period is of relevance as it covers a considerable length of time in growing patients. As

Figure 2. Radiological finding immediately after autotransplantation of the retained lower left second premolar.

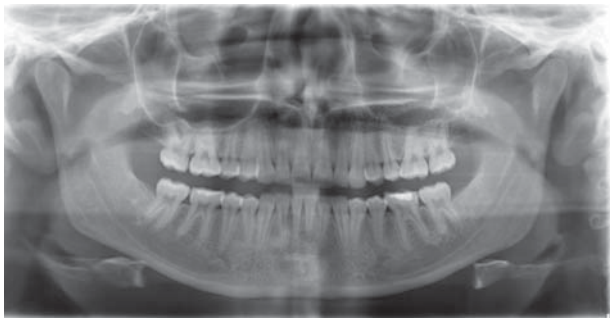

Figure 3. Radiological finding 3 years after successful autotransplantation of the lower left second premolar. The pulp chamber is partially obliterated.

in many studies, the survival rates of the transplants are given instead of success rates, so a comparison of previous studies with ours is difficult. In the present study the survival rate was 96%. To state, the survival rate only gives the number of autotransplanted teeth present in the mouth at the time of examination, regardless of the clinical or radiographic findings. In contrast, the success rate describes the number of teeth deemed as successful according to pre-defined criteria. In the literature, survival rates from 75–83% are given [5,6].

The failure criteria in this study were a pathologic periodontal condition, high tooth mobility and incomplete alveolar bone healing. These criteria were similar to those used in other studies evaluating the success rates of autotransplantation of teeth [5,6,29]. Out of our 55 examined teeth, 28 (51%) showed root resorptions, whereas 27 teeth (49%) showed no signs of root resorption. To clarify, these findings are limited by the analysis of panoramic radiographs, in which root resorption and root shapes are less precise for evaluation, compared to dental films [30]. In comparison, a current study found signs of root resorption in 38% of the examined teeth after a mean observation period of 11 years [6]. Another possible cause of root resorption of transplanted teeth that should be taken into account is orthodontic treatment [31]. In our cohort, 11 teeth (20%) underwent orthodontic pre-treatment and 44 teeth (77%) underwent adjustment after transplantation. However, no

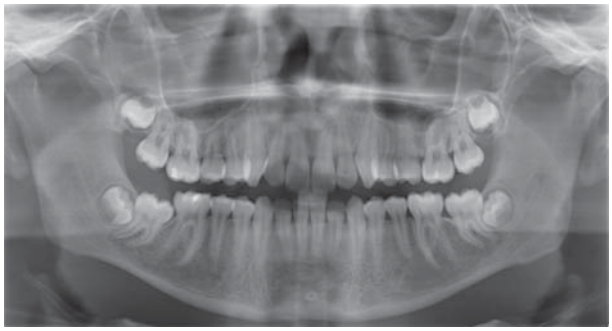

Figure 4. Initial state of an impacted lower right second molar and four impacted wisdom teeth.

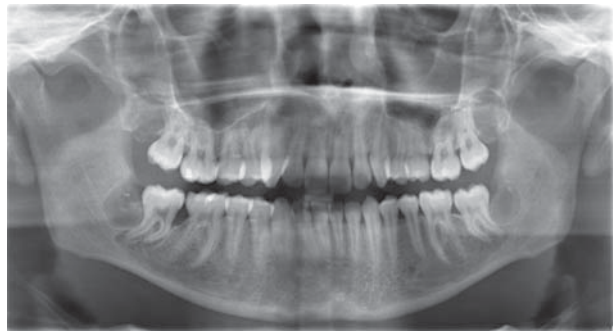

Figure 5. X-ray control after extraction of four impacted wisdom teeth and autotransplantation of the impacted lower right second molar.

significant influence on root resorption or on the success rate was found.

We found a statistically significant influence of oral hygiene and smoking on the success rate. This finding is supported analogously by a study concerning dental implants, in which it was found that smokers showed greater bleeding indices, mean pocket probing depths, degrees of mucosal inflammation and bone reductions [32]. The presence of proximal contacts had a highly significant influence on the success rate. Inadequate contacts have been reported as causing food impaction, periodontal disease and tooth movement [33], which can impair the healing of transplanted teeth. However, no statistically significant influence of static occlusion was found. As a consequence, the recommendation of positioning autotransplanted teeth in infra-occlusion could be questioned [6,29,34], as occlusal load is deemed necessary for development and function of the periodontal ligament and the alveolar bone remodeling. Further, the degree of initial displacement had no statistically significant influence on the success rate. Although not significant, teeth with open apices showed a slightly better success rate (75%) than teeth with closed apices (71%). Additionally, although not significant, a recent study found a success rate of 71% for immature canines and 61% for teeth with closed apices [6]. An older study, evaluating a larger sample ($n = 278$) with all types of teeth, found a

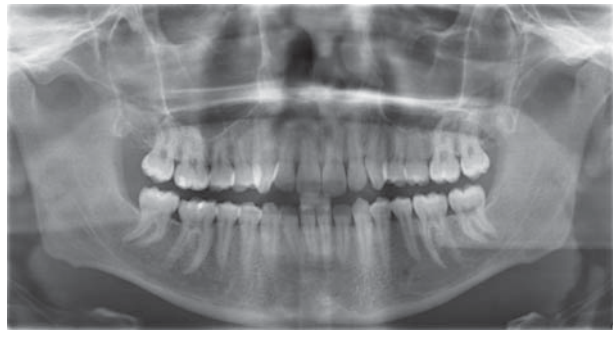

Figure 6. Follow-up 2 years after autotransplantation of the impacted lower right second molar. Complete alveolar healing pulp obliteration can be found.

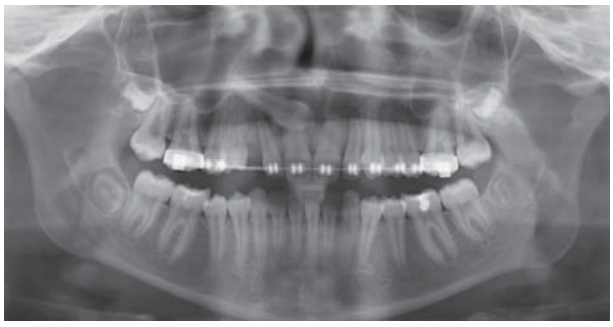

Figure 7. Initial radiographic state of a displaced upper right canine.

significant difference in favor of open apices, with a success rate of 94% vs 84% for closed apices [34]. A recent systematic review investigating 6064 cases over a mean period of 10 years reported a significantly higher survival rate of 87% for immature teeth compared with 80% for teeth with closed apices [35]. Interestingly, in all these studies the outcome between mature and immature teeth differs only by ~ 10%, suggesting that autotransplantation of mature teeth with a closed apex is by far better as to be expected from the current clinical view.

Endodontic treatment of transplanted teeth has been performed according to clinical and radiographic findings [6,12,13]. Out of our 55 examined teeth, 45% exhibited no clinical or radiographic signs of endodontic treatment need. Thirty teeth (55%) developed endodontic treatment need. In an older study that evaluated 33 mature canines over 6 years, endodontic treatment was performed in 23 teeth

Figure 8. Radiological control immediately after autotransplantation of the displaced upper right canine.

Figure 9. Radiological follow-up 3 years after autotransplantation of the displaced upper right canine. No signs of resorption and a complete alveolar bone healing can be recorded.

(70%) [13]. In a recent study, endodontic treatment of autotransplanted canines was performed generally on patients who were older than 20 years old [6]. Younger patients' teeth or teeth with open apices were root-filled only if clinical or radiographic indications were found. According to this criterion, endodontic treatment was needed in 40% of the sample. Another recent study that examined 38 autotransplanted mature teeth in 32 patients (observation period of 6 years) found that the survival and success rates were also influenced by the quality of the root fillings and the authors recommended autotransplantation before the root development was completed [36].

Pulp obliteration was found in 54% of our examined teeth. Interestingly, teeth with obliteration showed a statistically higher success rate than teeth without obliteration. Therefore, the influence of pulp obliteration on the success rate was statistically significant. In accordance, Gonnissen et al. [6] found pulp obliteration in 49% of their cases. As described in an extensive review of pulp canal obliteration, the pulp of asymptomatic teeth with pulp obliteration showed no histological signs of inflammation [37]. Complete radiographic obliteration of the pulp space does not necessarily imply an absence of pulp tissue. To clarify, up to 75% of teeth with pulp canal obliteration have been reported to be asymptomatic and have not required endodontic treatment. From this review, it has been suggested that endodontic treatment should only be performed if the following symptoms arise: (1) pulp necrosis, indicated by periapical pathology; and (2) clinical symptoms, accompanied by a negative response to sensitivity testing. A negative response to sensitivity testing alone is not considered

to indicate pulp necrosis. Teeth with pulp obliteration are often reported to be root-filled unnecessarily [37]. It has been recommended that teeth with pulp obliteration be managed conservatively by periodic clinical and radiographic examination. Pulp obliteration is a vital sign of the transplant and, therefore, does not demand root canal treatment.

The average bone height changed from 67% to 86% of the root length. A loss of bone height was detected only in two teeth and an increase was detected in 37 cases. In 16 of the investigated teeth, the change in bone height was within the measuring tolerance. This reported bone level change might have been due mainly to the surgical procedure, as the possible post-operative orthodontic treatment was only a fine adjustment. Although there were more teeth with bone growth in the success group (74%), growth of bone could also be detected in 46% of the failure group. Accordingly, an older study found no reduction in bone height over a period of 6 years [13]. The bone level in that study varied between 70–78% of the root length. In a recent study covering an observation time of 14.5 years, normal bone levels were found in 94% of the cases [5]. Significant loss of bone was found in only 6%, although the success rate in this study was as low as 38%. Insofar, autogenous tooth transplantation exerts a unique induction of bone growth, which is highly appreciated, in particular in growing patients.

## Conclusion

Within the limitations of this retrospective clinical trial, the results suggest that autotransplantation of impacted or retained teeth is a useful and psychosocially positive method, especially in adolescent patients in whom alternative treatments, such as dental implants, are not yet indicated. Due to its potential to increase or at least to maintain the bone level, autotransplantation facilitates a later dental implant supply.

***Declaration of interest:*** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

## References


[1] Raghoebar GM, Boering G, Vissink A, Stegenga B. Eruption disturbances of permanent molars: a review. J Oral Pathol Med 1991;20:159–66.

[2] Bedoya MM, Park JH. A review of the diagnosis and management of impacted maxillary canines. J Am Dent Assoc 2009;140:1485–93.

[3] Arikan F, Nizam N, Sonmez S. 5-year longitudinal study of survival rate and periodontal parameter changes at sites of maxillary canine autotransplantation. J Periodontol 2008;79:595–602.

[4] Ericson S, Kurol J. Early treatment of palatally erupting maxillary canines by extraction of the primary canines. Eur J Orthod 1988;10:283–95.

[5] Patel S, Fanshawe T, Bister D, Cobourne MT. Survival and success of maxillary canine autotransplantation: a retrospective investigation. Eur J Orthod 2011;33:298–304.

[6] Gonnissen H, Politis C, Schepers S, Lambrichts I, Vrielinck L, Sun Y, et al. Long-term success and survival rates of autogenously transplanted canines. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010;110:570–8.

[7] Bondemark L, Tsiopa J. Prevalence of ectopic eruption, impaction, retention and agenesis of the permanent second molars. Angle Orthod 2007;77:773–8.

[8] Andreasen JO, Petersen JK, Laskin DM. Textbook and color atlas of tooth impactions. Copenhagen, Denmark: Munksgaard; 1997.

[9] Stellzig A, Basdra EK, Komposch G. Mesiodentes: incidence, morphology, etiology. J Orofac Orthop 1997;58:144–53.

[10] Andreasen JO, Andreasen FM, Andersson L. Textbook and color atlas of traumatic injuries to the teeth. 4th ed. Copenhagen, Denmark: Munksgaard; 2007.

[11] Kristerson L. Autotransplantation of human premolars. A clinical and radiographic study of 100 teeth. Int J Oral Surg 1985;14:200–13.

[12] Pogrel MA. Evaluation of over 400 autogenous tooth transplants. J Oral Maxillofac Surg 1987;45:205–11.

[13] Ahlberg K, Bystedt H, Eliasson S, Odenrick L. Long-term evaluation of autotransplanted maxillary canines with completed root formation. Acta Odontol Scand 1983;41:23–31.

[14] Hjortdal O, Bragelien J. Induction of jaw bone formation by tooth autotransplantation. Norske Tannlaegeforenings Tidende 1978;88:319–22.

[15] Czochrowska EM, Stenvik A, Bjercke B, Zachrisson BU. Outcome of tooth transplantation: survival and success rates 17–41 years post treatment. Am J Orthod Dentofacial Orthop 2002;121:110–19.

[16] Schwartz-Arad D, Levin L, Ashkenazi M. Treatment options of untreatable traumatized anterior maxillary teeth for future use of dental implantation. Implant Dent 2004;13:120–8.

[17] Gat H, Sarnat H, Bjorvath K, Dayan D. Dental age evaluation. A new six-developmental-stage method. Clin Prev Dent 1984;6:18–22.

[18] Grande T, Stolze A, Goldbecher H, Kahl-Nieke B. The displaced maxillary canine - a retrospective study. J Orofac Orthop 2006;67:441–9.

[19] Linge L, Linge BO. Patient characteristics and treatment variables associated with apical root resorption during orthodontic treatment. Am J Orthod Dentofacial Orthop 1991;99:35–43.

[20] Bauss O, Röhling J, Rahman A, Kiliaridis S. The effect of pulp obliteration on pulpal vitality of orthodontically intruded traumatized teeth. J Endod 2008;34:417–20.

[21] Löe H, Silness J. Periodontal disease in pregnancy I. Prevalence and severity. Acta Odontol Scand 1963;21:533–51.

[22] Silness J, Löe H. Periodontal disease in pregnancy II. Correlation between oral hygiene and periodontal condition. Acta Odontol Scand 1964;22:121–35.

[23] Ainamo J, Barmes D, Beagrie G, Cutress T, Martin J, Sardo--Infirri J. Development of the World Health Organization (WHO) community periodontal index of treatment needs (CPITN). Int Dent J 1982;32:281–91.

[24] Andreasen JO, Paulsen HU, Yu Z, Ahlquist R, Bayer T, Schwartz O. A long-term study of 370 autotransplanted premolars. Parts I-IV. Eur J Orthod 1990;12:3–50.

[25] Mackie I, Ghrebi S, Worthington H. Measurement of tooth mobility in children using the periotest. Endod Dent Traumatol 1996;12:120–3.

[26] Becker A, Kohavi D, Zilberman Y. Periodontal status following the alignment of palatally impacted canine teeth. Am J Orthod 1983;84:332–6.

[27] Bauss O, Zonios I, Rahman A. Root development of immature third molars transplanted to surgically created sockets. J Oral Maxillofac Surg 2008;66:1200–11.

[28] Waikakul A, Kasetsuwan J, Punwutikorn J. Response of autotransplanted teeth to electric pulp testing. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2002;94:249–55.
[29] Kvint S, Lindsten R, Magnussen A, Nilsson P, Bjerklin K. Autotransplantation of teeth in 215 patients. Angle Orthod 2010;80:446–51.
[30] Sameshima GT, Asgarifar KO. Assessment of root resorption and root shape: periapical vs. panoramic films. Angle Orthod 2001;71:185–9.
[31] Wan Hassan WN, Stephenson PA, Waddington RJ, Sloan AJ. An *ex vivo* culture model for orthodontically induced root resorption. J Dent 2012;40:406–15.
[32] Haas R, Haimböck W, Mailath G, Watzek G. The relationship of smoking on peri-implant tissue: a retrospective study. J Prosthet Dent 1996;76:592–6.
[33] Hancock EB, Mayo CV, Schwab RR, Wirthlin MR. Influence of interdental contacts on periodontal status. J Periodontol 1980;51:445–9.
[34] Lundberg T, Isaksson S. A clinical follow-up study of 278 autotransplanted teeth. Br J Oral Maxillofac Surg 1996;34:181–5.
[35] Nolte D, Hinrichs K, Lange S. Autogenous tooth transplantation: a topical evidence based systematic review [in German]. German Dent J 2011;66:279–94.
[36] Watanabe Y, Mohri T, Takeyama M, Yamaki M, Okiji T, Saito C, et al. Long-term observation of autotransplanted teeth with complete root formation in orthodontic patients. Am J Orthod Dentofacial Orthop 2010;138:720–6.
[37] McCabe PS, Dummer PM. Pulp canal obliteration: an endodontic diagnosis and treatment challenge. Int Endod J 2012;45:177–97.