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# Dental auto-transplantation to anterior maxillary sites

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**Abstract** – *Aim*: To investigate the indications for, and the outcome of auto-transplantation of teeth to the anterior maxillary region. *Material and methods*: From 1978 to 1994, 41 teeth in 31 subjects were transplanted to anterior maxillary sites at the Department of Oral Surgery, Stavanger University Hospital, Norway. All transplantations were performed by one oral surgeon (B.G.). Relevant information was collected from patients' files, including radiographs of the tooth graft, the recipient site and follow-up radiographs. *Results*: The mean observation period was 55.1 months (range 1–158 months). The age of the patients at the time of the auto-transplantation ranged from 10 to 30 years (mean 14.8 year). The most common indications for auto-transplantation were aplasia (41.5%), sequelae of trauma (36.6%) and impacted or ectopic teeth (17.1%). Eight teeth were judged to be failures; five had been extracted because of severe root resorptions and periodontal infection and three were judged as failures owing to severe ongoing root resorption but remained in the alveolus. *Conclusion*: Trauma is as common indication as aplasia for transplantation. From a biological point of view, dental auto-transplantation to the anterior maxillary region has a high success rate. Hence, auto-transplantation is an important treatment option for missing or lost maxillary anterior teeth where preservation of the alveolar bone is important during growth and development in adolescents. The major reason for failure was various types of root resorptions, some of which were detected late.

Substituting missing maxillary incisors is a clinical challenge, especially in younger individuals. The ideal substitute has to meet the patient's aesthetic expectations and have functionality similar to that of the neighbouring teeth. Furthermore, the ideal substitute must preserve the alveolar bone level and stimulate continuous skeletal bone growth with a predictable success rate. Implant treatment is contra-indicated until skeletal growth has ceased, the most relevant treatment strategies for these adolescents are orthodontic closure or auto-transplantation of an available and suitable tooth. Auto-transplantation has a well-documented survival rate (1–10) and good patient acceptability, even in the anterior region (2, 3, 5, 11).

The main reasons for anterior maxillary tooth loss are trauma (12–14), or aplasia, usually confirmed at early age (15–17). Other indications for auto-transplantation are impacted or ectopic teeth (2, 18).

Most studies of auto-transplantation report survival rate and not success rate. Survival rate includes teeth with poor or uncertain prognosis, whereas success rate describes the outcome in detail. In this context, success rate is a more appropriate measure, as it takes into consideration the status of the tooth and its supporting tissues.

The purpose of this study was to retrospectively investigate the indications for and the success rate of dental auto-transplantation to maxillary anterior sites and to identify risk factors related to non-success.

## Material and methods

### Study area

The county of Rogaland is situated in the south west part of Norway. Government statistics indicate a population of 305 490 in 1981, 337 906 in 1991 and 373 210 in 2000 (19), making up 7.5%, 8.0% and 8.3% of the Norwegian population. The number of 13- to 17-year-old adolescents in Rogaland was 24 734 in 1999 (9% of the national population).

### Material

During the 22-year period from 1978 to 1999, all patients from the county of Rogaland were referred for dental auto-transplantation to the Department of oral Surgery, Stavanger. One surgeon at the department (B.G.) evaluated all patients and undertook all transplantations working under local anaesthesia. The surgical procedures were carried out in accordance with the guidelines of Slagsvold and Bjercke (1). In 1988, the technique was slightly modified and adjusted to the guidelines later described by Andreasen et al. (20). Preoperative radiographs of both the tooth graft in original site and recipient site had been registered by the oral surgeon. Clinical examination involved checking the mobility and position of the transplant (occlusal contact of infra position), examination of the periodontium and

percussion test had been registered. Follow ups of transplanted teeth were carried out by the same oral surgeon. Transplanted teeth had been followed up at regular intervals and follow-ups visits included clinical and radiographical examination. The following data were registered from records and radiographs retrospectively: indication for transplantation, transplantation and recipient site sex, age of patients, referring dentist (general dentist or orthodontist) and relevant pre per and postoperative factors like the shape of the new alveolus, type of fixation – and time, extra alveolar storage of the tooth graft (saline or back to original socket), anatomical deviations about the transplant and the use of antibiotics and chlorhexidine after surgery. Radiographic evaluation included pulp canal obliteration, the periradicular area, the stage of root development and whether further root development or root resorption had occurred. All radiographs were examined and interpreted by two calibrated endodontists (A.B. and G.C.K.). In cases of disagreement, cases were discussed and a consensus was made. Values for inter-examiner agreement ranged from 0.84 to 1.00 for the relevant variables.

Success, based on biological measures, was defined as the following radiographic criteria fulfilled: tooth present with vital pulp (obliteration) or endodontic treatment with a good outcome, normal periodontal space, no progressive root resorption, further root development/apical closure (except for endodontically treated teeth) and no other signs of infection threatening the transplant or the supporting alveolar bone.

Non-successful cases showed one or several of the following factors: progressive root resorption, lack of periodontal healing, severe marginal periodontitis, apical periodontitis after endodontic treatment where apical surgery was contraindicated, or lost transplant (except if lost as a sequela to new traumatic dental injury).

Root resorptions were diagnosed on the basis of radiographs and clinical findings. The classification of resorptions was based on Fuss et al. (21) and Trope (22), and the following categories were used:

1 Replacement resorption (RR)
2 External infection-related resorption with infection in the pulp space (EIRR-P) (also called external inflammatory resorption)
3 External infection-related resorption with infection from the sulcus (EIRR-S) (also called cervical invasive resorption)
4 Internal infectious-related resorption (IIRR) (internal resorption excluding any forms of repair infection-related)

The developmental stage of the transplant root(s) was determined according to the classification of Moorrees et al. (23), as modified by Andreasen et al. (24). For analyses, the developmental stage of the root(s) was later dichotomized into 0: stage 0–4 and 1: stage 5–6.

### Data analysis

The data were coded, computerized and analysed using the Statistical Program for the Social Sciences (Version 15.0; Norusis/SPSS-PC Inc., Chicago, IL, USA). Descriptive analysis was performed and frequency distributions compared using chi-squared tests (significant level set at 5%). Chi-squared tests were used for identifying important bivariate associations ($P < 0.05$). Independent variables with a significant bivariate effect on the dependent variable (success vs failure) were entered in a bivariate logistic regression analysis for calculation of odds ratios and 95% confidence intervals. The Spearman rank correlation ($P < 0.05$) was used to check dependent variables.

## Results

A total of 409 teeth in 325 patients were transplanted at the Rogaland University Hospital during the period 1978–1999. As this study is limited to teeth transplanted to the maxillary anterior region, the numbers of teeth and patients were 41 and 31, respectively. All teeth were transplanted in the period 1978–1994. The mean observation time was 55.1 months, ranging from 1 to 158 months. Gender distribution of patients and teeth is shown in Table 1.

The age of patients at time of transplantation ranged from 10 to 30 years, with a mean age of 14.8 years (Table 2). For patients older than 19 years, most donors were third molars with the exception of the two impacted canines transplanted to their intended site at the age of 30 (endodontic treatment initiated within 10 days after transplantation) (Table 2).

The main indications for transplantation of teeth to the maxillary anterior region were aplasia (agenesis) and sequelae of traumatic dental injuries. All indications and their frequencies are listed in Table 3.

*Table 1.* Distribution of participants by sex and numbers of transplantations involved

| | Subjects | | Teeth | |
|---|---|---|---|---|
| Gender | *n* | % | *n* | % |
| Female | 13 | 42 | 17 | 41 |
| Male | 18 | 58 | 24 | 59 |
| Total | 31 | | 41 | |

*Table 2.* Type of graft and participant sex by age at the time of transplantation

| | Tooth graft | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Incisors | | Canines | | Premolars | | Molars | | |
| Age | Female | Male | Female | Male | Female | Male | Female | Male | Total |
| 10 | | | | | 1 | | | | 1 |
| 11 | | | 1 | | 3 | 3 | | | 7 |
| 12 | | | | | 2 | 3 | | | 5 |
| 13 | | 1 | | | 2 | 4 | | | 7 |
| 14 | | | | | 5 | 2 | | | 7 |
| 15 | | | | 1 | | | | 2 | 3 |
| 16 | | 1 | | 1 | | 1 | | | 3 |
| 17 | | | 1 | | | | | | 1 |
| 19 | | | 1 | | | | | | 1 |
| 20 | | | | | | | 1 | 2 | 3 |
| 23 | | | | | | | | 1 | 1 |
| 30 | | | | 2 | | | | | 2 |
| Total | 0 | 2 | 3 | 4 | 13 | 13 | 1 | 5 | 41 |

*Table 3*. Indications for dental auto-transplantation to the anterior maxillary region

| Indication | Frequency | Proportion (%) |
|---|---|---|
| Aplasia | 17 | 41.5 |
| Sequelae of dental trauma | 15 | 36.6 |
| Ectopic position/impacted | 7 | 17.1 |
| Root resorption | 1 | 2.4 |
| Other | 1 | 2.4 |
| Total | 41 | 100.0 |

*Table 4*. Distribution of transplanted teeth according to receiving site

| Receiving site | Tooth graft | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 12 | 13 | 15 | 18 | 22 | 23 | 24 | 25 | 28 | 34 | 35 | 44 | 45 | Total |
| 11 | | | 2 | | 1 | | | 1 | | 1 | 1 | 1 | 1 | 8 |
| 12 | | | | | | | | | | | | 2 | | 2 |
| 13 | | 4 | | 2 | | | 1 | | 2 | 1 | | 2 | 1 | 13 |
| 21 | | | 1 | | | | | 2 | | | 2 | | 1 | 6 |
| 22 | | | | | | | | | | 1 | | | 1 | 3 |
| 23 | | | | | | 3 | | | | 1 | 2 | | 1 | 9 |
| Total | 1 | 4 | 3 | 2 | 1 | 3 | 1 | 3 | 4 | 4 | 5 | 5 | 5 | 41 |

A variety of teeth were transplanted to replace maxillary anterior teeth. The most common transplants were mandubular premolars followed by maxillary premolars and canines. The mobility and applicability of transplants is shown in Table 4.

According to the criteria for success, 33 (80.5%) out of 41 transplantations were categorized as successful while eight (19.5%) were not. A case with successful transplantation of mandubular premolars to maxillary canine sites is shown in Fig. 1. The success rate by tooth graft and developmental stage showed that all non-successes had mature roots at stage 5–6 (Table 5). Among the eight non-successes, seven were ascribed to root resorption and one case (ectopic position of canine) was lost due to severe infection (pulpal and periodontal) within 1 month of transplantation.

Variables that had a significant bivariate association with the outcome are shown in Table 6 ($P < 0.05$).

Binary logistic regression analysis with the four variables with effect on the outcome (Table 6) confirmed that root resorption was the variable with significant association with the outcome (odds ratio 103.3, 95% CI = 5.3, 2004).

As root resorption is not a uniform entity, the distribution of the different forms of root resorption is given in Table 7. The dominating type of root resorption is the EIRR-S (five out of eight cases), and, for this type of resorption, the mean time from transplantation to first clinical or radiographic sign of root resorption was more than 3 years (Table 7).

A case with a transplant classified as non-successful (due to EIRR-S) is shown in Fig. 2. Tooth 25 was transplanted to region 21 in 1989 (Fig. 2a–c). After 3 months, the first sign of pulp canal obliteration was registered. After 5 months, a full healing of the periodontal ligament was registered. A composite restoration was made 3 months after transplantation (Fig. 2d) and later changed to porcelain veneer. The radiograph at 42 months (Fig. 2e) shows a healthy donor at the new site. The first signs of secondary pulp necrosis and apical periodontitis were seen 96 months after transplantation (Fig. 2f). However, the resorption was first diagnosed after 106 months (Fig. 2g). Root canal treatment and apical surgery was performed before it was lost and replaced by an implant supported crown. Although the transplantation was classified as non-success, the transplant contributed to growth of the alveolar crest and preserved bone in the region for 10 years.

## Discussion

The results in this study are based on a small subset of the 409 teeth auto-transplanted at the Central Hospital of Rogaland between 1978 and 2000. Although the number of teeth (41) transplanted to the anterior region was limited, the results showed that the success rate was 80.5%, and the principal predictor of failure was root resorption.

Trauma and its sequela were almost as common indication as aplasia, whereas impacted and ectopic position as an indication for transplantation was less common. The findings are in accordance with other comparable studies (reference!).

Most studies evaluating the transplantation of teeth to the maxillary anterior region have used premolars or canines as transplants (2, 7, 8, 11, 25, 26). The utility of auto-transplantation is, according to Slagsvold & Bjercke (7), rather limited. In this study, even some third molars (small crown) and a supernumerary tooth were used with success (Table 4). The technique is, however, constrained by the availability of suitable source teeth, their shape and their crown dimensions.

Several studies on the auto-transplantation of teeth report survival rates and not success rates. Hence, the transplant may be present, but not in an acceptable condition; it may even jeopardize the supporting alveolar bone and the soft tissue level. The survival rate will always exceed the success rate and studies using different outcome measures may not be comparable. Our criteria for success are based on the study by Kristerson (27). That author's criteria are based on clinical and biological measures and do not include objective or subjective aesthetic measures. Such criteria have been used by e.g. Czochrowska et al. (5) who evaluated the aesthetic outcome of premolars transplanted to the maxillary anterior region and included both objective measures and a questionnaire to the patient, but such evaluation was not carried out in our study.

The stage of root development is one of the most important prognostic factors (4, 24, 28–31). All teeth in our study transplanted with root development in stages 3 and 4 were successful, whereas all non-successful teeth were found in root development groups 5 and 6. This is in accordance with the literature (4, 24, 28–31).

Even failed transplants (survived but in unhealthy condition) may preserve the occlusion and contribute to the growth of the alveolar process before the failure is recognized (Fig. 1). On this basis, there may be a justification for regarding unsuccessful transplantation

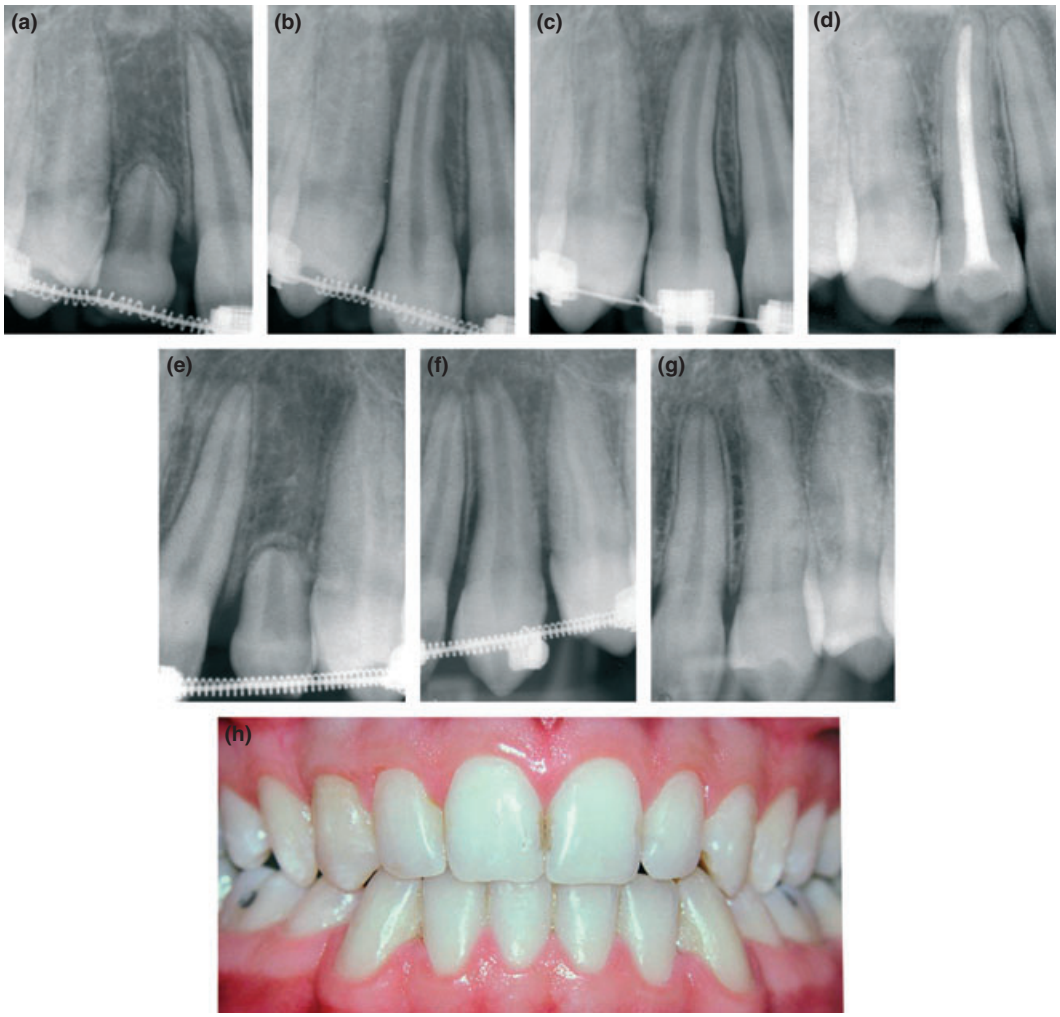


*Fig. 1.* (a–h) A case with agenesis of maxillary canines replaced with mandubular first premolars from the respective sides. Preoperative radiographs shows persistent deciduous canines 53 (a) and 63 (e). Tooth 44 was transplanted to site 13, and the radiograph shows the situation at 3 months control (b). At the 6 months control, the root has not developed further, and sign of apical lesion are present on the radiograph (c). Root canal treatment was immediate initiated, and the 4 years control shows a successful transplant in site 13 (d). Tooth 34 was transplanted to site 23 (1 month before tooth 44 to site 13), and at 7 months recall the radiograph shows full periodontal healing and closure of the root canal (f). At 4 years control the root canal of the premolar transplanted to site 23 is nearly full obliterated (g). The clinical picture (h) shows successful treatment with three premolars on each side of the maxilla.

*Table 5.* Success (+) and non-success (−) cases related to type of transplant and stage of root development

| | Stage of root development | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 3 | | 4 | | 5 | | 6 | | |
| | + | − | + | − | + | − | + | − | Total |
| Incisors | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 |
| Canines | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 4 | 7 |
| Permolars | 10 | 0 | 3 | 0 | 4 | 4 | 5 | 0 | 26 |
| Molars | 1 | 0 | 3 | 0 | 0 | 0 | 2 | 0 | 6 |
| Total | 11 | 0 | 6 | 0 | 5 | 4 | 11 | 4 | 41 |

as a non-success rather than as a failure. Especially in still growing patients, where implant treatment is contraindicated, this will be of importance. The transplanted tooth may subsequently be replaced by an implant

*Table 6.* Bivariate analysis ($\chi^2$ test): association of variables with outcome (non-success vs success)

| Variable | Non-success | Success | *P*-value |
|---|---|---|---|
| Transplant | | | |
| Molar | 0 | 6 | 0.036 |
| Premolar | 4 | 22 | |
| Canine | 4 | 3 | |
| Incisor | 0 | 2 | |
| Fistula | | | |
| Yes | 1 | 0 | 0.040 |
| No | 7 | 33 | |
| Transplant source | | | |
| Ectopic | 4 | 3 | 0.006 |
| Non-ectopic | 4 | 30 | |
| Root resorption | | | |
| Yes | 7 | 1 | 0.000 |
| No | 1 | 32 | |

*Table 7.* Root resorption of 41 cases and mean time in months (and range) from transplantation until resorption was first diagnosed and the number of non-successful cases

| Resorption | Total cases with resorption | Mean time (months) when diagnosed (range) | Cases considered as non-success |
|---|---|---|---|
| Replacement resorption | 2 | 27 (12–42) | 2 |
| External infectious related resorption – pulpal infection | 1 | 3 (–) | 1 |
| External infectious related resorption – sulcus infection | 5 | 44 (4–106) | 4 |
| Internal infectious related resorption | 0 | – | 0 |
| All resorptions | 8 | | 7 |

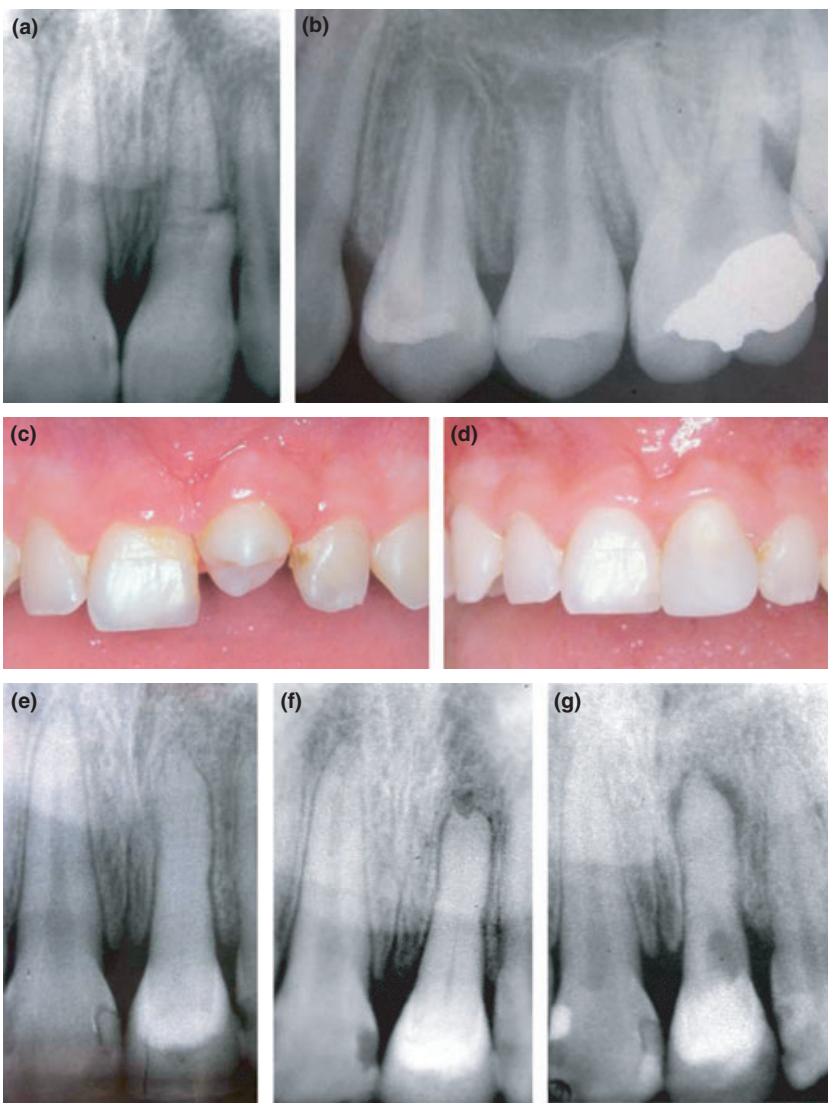


*Fig. 2.* (a–g) A case in which tooth 21 (a) was extracted due to root fracture in the cervical 1/3 of the root and replaced by tooth 25 (b). The clinical situation 1 month (c) and 3 months after transplantation (d). Radiograph taken at 42 month follow-up shows a healthy transplant (e). After 96 months, apical periodontitis was present, indicating secondary pulp necrosis (f). Careful examination of this radiograph may reveal early sign of root resorption. The radiograph taken 106 months after transplantation (g) shows severe root resorption (EIRR-S). The tooth underwent root canal treatment and apical surgery before it was lost and replaced by an implant supported crown 10 years after the original transplantation.

supported crown if the quality and quantity of the supporting tissues allow it.

Seven of the eight cases defined as non-success were associated with root resorption. Root resorption in this study was frequent (19.5%), compared with other studies. In a study from 1985, Kristerson showed that 18% of transplants ended up with root resorption (27). Andreasen et al. reported 14% of transplants with

resorption (28), Kristerson & Lagerström had 12% (2), Paulsen et al. 7.2% (32), Lundberg & Isaksson 7.9% (4) and Czochrowska et al. 4.4% (11). Josefsson et al. stated that the main reasons for failure were ankylosis and persistent external resorption, but the number for root resorptions were not given (33). Only the study by Schwartz et al. showed a prevalence of root resorption as high as 50% (34). However, there are different types of root resorption and the most frequent in the present study was the EIRR-S (also called cervical invasive root resorption) that is not described in any of the other studies mentioned above. This type of resorption was found 12.2% of all transplanted teeth in our study, representing 62.5% of all root resorptions. The occurrence of other root resorptions (RR and EIRR-P) was 7.3%, a proportion comparable with other studies. The high prevalence of EIRR-S suggests that the identification of this resorption is an important prognostic factor.

Early diagnosis and endodontic treatment of pulpal infection can be expected to avoid the development of EIRR-P in transplanted teeth. Immediate endodontic treatment after diagnosis of this resorption may arrest further development and improve the success rate. In this study, only one case had EIRR-P, and, unfortunately, due to lack of infection control, the tooth was lost.

The EIRR-S was the most frequent resorption observed in this study and it may be difficult to treat. Successful treatment depends on early intervention. Heithersay has classified this resorption into four categories according to progression (35). In general, categories 1 and 2 had rather good prognoses, while categories 3 and 4 had a more doubtful or poor prognoses (36). Only one of the transplants with EIRR-S was classified as a success in our study, and four were considered lost. The non-success outcome of these teeth may be explained by limited of knowledge concerning root resorptions in general, and EIRR-S in particular, during the years covered by the study. Some of the EIRR-S in our study were diagnosed and treated as cervical caries by the patient's general dentist.

The mean time for diagnosing EIRR-S was 44 months. An extended observation period is therefore necessary in order to diagnose this resorption at a stage where it can be treated with a predictable prognosis.

Ankylosis with osseous RR is due to their nature, impossible to treat and its progression is rapid in young individuals (21, 22, 37). The influence of different splinting methods and fixation periods of transplanted molars have shown that rigid fixation significantly increased RR and ankylosis, compared with more flexible fixation (sutures) (38). At present, there is no treatment that can predictably stop the progression of RR. However, careful surgery and flexible fixation may prevent its development. Teeth with RR will arrest alveolar bone growth and should be removed in young individuals to preserve the bone. According to Malmgren, this is best carried out by a decoronation procedure (39).

No cases of internal infection-related resorptions were seen; this type of resorption is rare in permanent teeth (37).

We concluded that auto-transplantation of teeth to anterior maxillary sites has a high success rate from a biological point of view and is a valuable treatment alternative in young growing patients. Teeth under root development are successful transplants while non-successful cases are found in full or late stages of root development. The main challenge is to avoid root resorption that may lead to tooth loss. However, with the exception ankylosis of RR, teeth with root resorption may remain for several years and contribute to normal alveolar bone growth and development. Hence, auto-transplantation represents an important treatment option for missing and lost teeth in adolescents, particularly in the anterior maxillary region. Owing to the late occurrence of the EIRR-S, the observation period for transplanted teeth should exceed 5 years.

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