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Review Article

Autotransplantation of Teeth in Orthodontics: A Biological Method to Substitute Missing or Lost Teeth and Alveolar Bone

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Abstract

Autotransplantation of teeth in Orthodontics is a biological method of replacing missing or lost teeth. However, a prerequisite for using this method is a thorough knowledge of the prognosis. Thus, the stage of root development is very important as well as the surgical technique preserving the periodontal ligament. Light-force orthodontic tooth movement or tooth rotation three to nine months after surgery are the most crucial factors for the survival of transplants and their continued development. The periodontal ligament, with bone induction potential, will induce new alveolar bone. Furthermore, the transplanted tooth will erupt in a similar manner to a contralateral, non-transplanted tooth, if the transplanted tooth is not ankylosed to the alveolar bone (caused lost or damaged periodontal ligament during surgery). Autotransplantation of teeth provides a unique orthodontic treatment approach for young patients with a complex orthodontic problem. i.e. premolar aplasia and avulsed or malformed anterior teeth can be transferred to another region in the dental arch where it can be treated more easily.

Keywords: *Autotransplantation; Orthodontics; Alveolar Bone*

Introduction

Autotransplantation of teeth is an old method of tooth replacement, but it is receiving renewed interest, as treatment today is founded on evidence-based, long-term research. Autotransplantation of premolars has become a reliable treatment option for the treatment of certain orthodontic problems [1-28]. Autotransplantation of incisors, canines and molars are not always as successful due to the more complex severity of the surgical problems during transplantation [29-39].

In conventional orthodontics, tooth movements usually are limited to minor distances. However, tooth movement is no longer limited to short distances in a quadrant of the dental arch if tooth transplantation is included as an orthodontic treatment choice. There is greater freedom to place a tooth exactly where it is needed, may it be the contralateral side in the dental arch or the opposing jaw. The periodontium is the key to bone induction and bone modelling in the recipient area. A transplanted tooth can erupt typically and in a similar manner to a contralateral, non-transplanted tooth in its normal area [12,21]. However, transplantation of teeth is far more traumatic to the pulp and periodontium than conventional orthodontics. Donor teeth with wide-open apices and with a single root canal are recommended as grafts of choice for long-term survival [9,17,21]. The surgical procedure is thus an essential key to the successful outcome of this treatment [16]. As imaginative as this technique appears to be, very careful case selection and graft choice is necessary to safeguard the health of the soft tissues; i.e. the pulp, the periodontal ligament with 2-3 mm marginal gingiva, and Hertwig's epithelial root sheath.

The technique of premolar transplantation has been described in a series of articles in which the predictors for optimal pulp and periodontal healing, as well as root growth have been described [8,14,16-19]. The survival of transplanted premolars has been studied postoperatively for more than 25 years. Orthodontists how-ever, generally would be the most competent professionals to identify available donor teeth [7,21]. Because overall occlusal status must be assessed, the orthodontist should be considered a key person in planning, referring, and coordinating treatment that includes transplantation [40]. With autotransplantation, it has become possible to move problems in the dental arches to regions where they are easier to solve orthodontically.

Treatment Planning

A comprehensive treatment plan needs to be developed prior to autotransplantation. This requires the expertise of the orthodontist, surgeon, periodontist and the restorative dentist. The orthodontist particularly needs to be aware of the patient's craniofacial morphology and growth tendencies in order to better predict success.

A radiographic screening process has been a very useful method of diagnosing premolar agenesis around 9 to 11 years-of-age when there are no erupted premolars [6,41]. Unfortunately, new restrictions on the use of radiographic screening exposures of a population have stopped this procedure in Scandinavia. However, agenesis also may be diagnosed from radiographs taken during diagnostic procedures for carries of deciduous molars or a late exfoliation of deciduous molars. Furthermore, a new long-term study of agenesis of permanent teeth has indicated a different aetiology and treatment of the deciduous molars. Auto-transplantation should be included in the treatment planning for patients who have deciduous molars with agenesis of permanent successors showing surface root resorption or replacement root resorption (ankylosis) over a period of time [21].

Non-extraction Cases: Agenesis in the Lower Jaw

In samples of Danish school children, Rølling found the rate of agencies of lower premolars to be 7.8% [6,41]. The most frequently missing teeth were the lower second premolars, representing 67% of congenitally missing teeth. Combined with the most frequently occurring mandibular growth pattern (the anterior rotational type [42]), this deviation may pose two distinct problems to the clinician.

First, where incisal support remains favourable, the mandibular incisors gradually become more proclined in relation to the mandibular base. This generally requires space closure through protraction of the posterior dentition, which is very challenging. Should incisal support fail due to distal tipping of the mandibular incisors, a deep bite and increased overjet will result. Second, conventional orthodontic treatment usually consists of a combination of mesial movement of the molars into the site of the agenesis and realignment of anterior teeth. Such treatment often is difficult to per-form satisfactorily in patients with a weak and concave profile [24]. Autotransplantation of second premolars from the maxilla to the affected or converted regions in the mandible shifts the burden of closing space to the maxillary arch. Generally speaking, space closure in the maxilla is much easier to control and carry out.

Extraction Cases: Primary Crowding

Orthodontic treatment of these types of malocclusions can include a wider donor selection of premolars. Generally, all single-rooted premolars with a wide-open apex may be candidates for transplantation. Premolars from the mandible fit very well in the recipient anterior region of the maxilla (i.e. first mandibular premolars as maxillary laterals, and second mandibular premolars as maxillary centrals). The dove-tailing of transplantation and orthodontic treatment, together with cryopreservation of extracted teeth for later purposes and restoring avulsed areas in the dental arches, provides a novel approach to the management of tooth loss in the anterior region of the maxilla. Autotransplantation of a premolar to the affected region diminishes the severity of the problem, allowing conventional orthodontic treatment approaches to manage the extraction site created [43].

Alternative Treatment

Other treatment modalities, including the use of implants, are available to this group of patients. The optimal treatment approach mandates a realistic evaluation of the long-term prognosis of the various treatment methods and cost [26]. In the following section, a summary of the results of our long-term studies on autotransplantation is presented.

Materials and Methods

We evaluated 370 autotransplanted premolars [16-19] from 16 to 26 years post transplantation. All transplantations were performed at the Department of Oral Surgery and Oral Medicine, University Hospital, Copenhagen. All treatment planning, controlling, and follow-up for healing and stability was performed at the Department of Orthodontics, Copenhagen Municipal Dental Health Service, Copenhagen, Denmark. Transplantation was used for patients with agenesis of permanent teeth or tooth and alveolar bone loss due to trauma of maxillary incisors.

All transplants were followed longitudinally using a standardized technique for both clinical and radiographic evaluation of pulpal and periodontal healing, root development and root resorption for a time period ranging between 16 - 26 years post transplantation. Twenty-four transplants were followed longitudinally with a standardized clinical and radiographic technique to examine tooth eruption at 1, 3, 4, 6, 8, 12, 16, 20 and 24 weeks after surgery [12,44] and yearly thereafter for 6 to 18 years.

The study showed that the stage of root development at the time of transplantation was the most important single factor in determining a successful outcome. Transplantation of premolars with three-quarter root formation or full root formation with wide-open apical foramina proved to have the best prognosis for long-term survival [26]. One hundred eighteen premolars in stages 3 and 4 (i.e. 3/4 to 4/4 root length with a wide open apical foramen according to [45] and colleagues, 1963) were selected to study the initial healing events following autotransplantation. This stage of root development provided the greatest success for continued root growth as well as periodontal ligament and pulpal healing [26].

Criteria for evaluating healing and complications

Pulp Necrosis

Pulp necrosis was considered to be present when there were radio-graphic signs of periapical radiolucency and/or inflammatory root resorption, plus a negative response to the electrometric sensitivity test. Where an absence of pulp sensitivity was the only sign of pulp necrosis, it was re-quired that the pulp canal show no sign of obliteration six months post transplantation.

Periodontal Healing

Periodontal healing was classified as being complete when the root periphery was surrounded entirely by a newly formed periodontal ligament space of normal size.

Repair-Related Root Resorption

Repair-related root resorption was defined as the presence of small resorption cavities on the root surface adjacent to a normal or slightly ex-tended periodontal ligament space and lamina dura, indicating that the root periphery was undergoing repair.

Inflammatory Root Resorption

Inflammatory root resorption was defined by the presence of bowl-shaped resorption cavities on the root surface associated with similar re-sorption cavities on the adjacent alveolar bone.

Replacement Root Resorption

Replacement root resorption (ankylosis) presented as a disappearance of the periodontal ligament space with or without resorption of the root. Clinically, the percussion test on a tooth demonstrated a high pitched metallic percussion sound.

Root Growth

Root growth (in mm) was evaluated from successive radiographs, and tooth length was measured to the nearest tenth of a millimetre with a sliding calliper from the cusp tip to the apex.

Healing

Pulp Healing

This was evaluated clinically using an electrometric test (Siemens Sirotest II, Siemens, Munich, Germany), and employing a standardized radiographic technique using XCP film holders (Rinn Corp., Elgin, Ill., USA) and a fixed film focus distance of 33 cm to evaluate signs of pulp canal obliteration.

Periodontal Healing and Root Growth

Subsequent to transplantation, this was monitored by radiographic examination. A digital sliding calliper reading to the nearest 0.1 mm was used to measure pulp canal obliteration and root length. Non-transplanted homologous premolars served as controls where possible.

Effect on Tooth Eruption

From a group of 90 maxillary second premolars transplanted to the region of the mandibular second premolar, 24 premolars transplanted with the cusp at gingival level were selected for a specific study of eruption. Periodontal ligament healing and root growth subsequent to transplantation were monitored from radiographic examination and tooth eruption. Trabecular structures are relatively stable in the jaw. Using these distinct structures in the spongious part of the basal part of the alveolar process as a reference, the prefunctional eruption of transplants was analysed from radiographs. Tooth eruption was measured as the distance from the cusp tip to the reference structure in the bone. Root growth, evaluated from successive radiographs, was measured as the difference in tooth length from the cusp tip to the apex. A Jocal digital sliding calliper (C. E. Johansson, AB, Eskilstuna, Sweden) measuring to the nearest 0.1 mm was used to measure the distance between distinct structures in the anatomy of the medullar bone, tooth eruption, and tooth length. All measurements were repeated, and a mean calculated. In no instance was there a difference of more than 0.2 mm between the individual measurements.

The direction and speed of eruption were examined by drawing superimposed sketches from radiographs using the distinct trabecular structures as location references. The radiographs were mounted in 3-mm slide projectors with a standardized focus distance and set-up. The speed of eruption of the transplant relative to the neighbouring reference teeth was analysed by either using the distance to a plane between the buccal cusp of the first premolar and the distobuccal cusp on the first molar or, alternatively, using the cusp tip of the first premolar as a reference [12].

Effect of Orthodontic Treatment Upon Healing

Eleven patients who received bilateral transplanted premolars (maxillary second premolars transplanted to the regions of second pre-molars) were studied. Transplants were placed in a 45° distal rotation position at surgery, as the alveolar faciolingual dimension is narrower in the mandible than in the maxilla. In these patients, one of the premolars was orthodontically rotated to a normal position after periodontal healing and before pulp canal obliteration (i.e. 3 - 9 months after surgery). The contra-lateral transplanted premolar was not treated orthodontically and, therefore, served as a control.

Rotation was accomplished using a fixed appliance with elastic chains (Unitek no 639 - 0011, Glendora, California, USA) inserted on the lingual side from the first molar to the transplant and on the facial side from the first premolar to the transplant. The initial rotational couple applied to the tooth was 200 gram-mm. The duration of rotation was 4 - 6 weeks. Postoperative clinical and radiographic examinations were per-formed as described earlier [26].

Results

Pulp Healing

Pulp healing was seen in 101 of the transplants. The time for initial pulp healing (cumulative data) is shown in figure 1 and 2. Pulp healing based on the first appearance of pulp canal obliteration appeared to provide an earlier sign for pulp healing than electrometric pulp testing and demonstrated less variation. A representative example of pulp healing in a second maxillary premolar transplanted in the maxillary anterior region.

	Months after transplantation 3	4	5	6	12	Range in months
Initial pulp canal obliteration:	16%	36%	60%	80%	100%	2 - 12
Initial sensitivity response:	12%	25%	43%	54%	89%	1½ - 36

Figure 1: *Cumulative pulp healing in 101 immature autotransplanted premolars. Occurrences of the first sign of pulp canal obliteration and the first sign of sensitivity (in months and in percent), and the range (in months).*

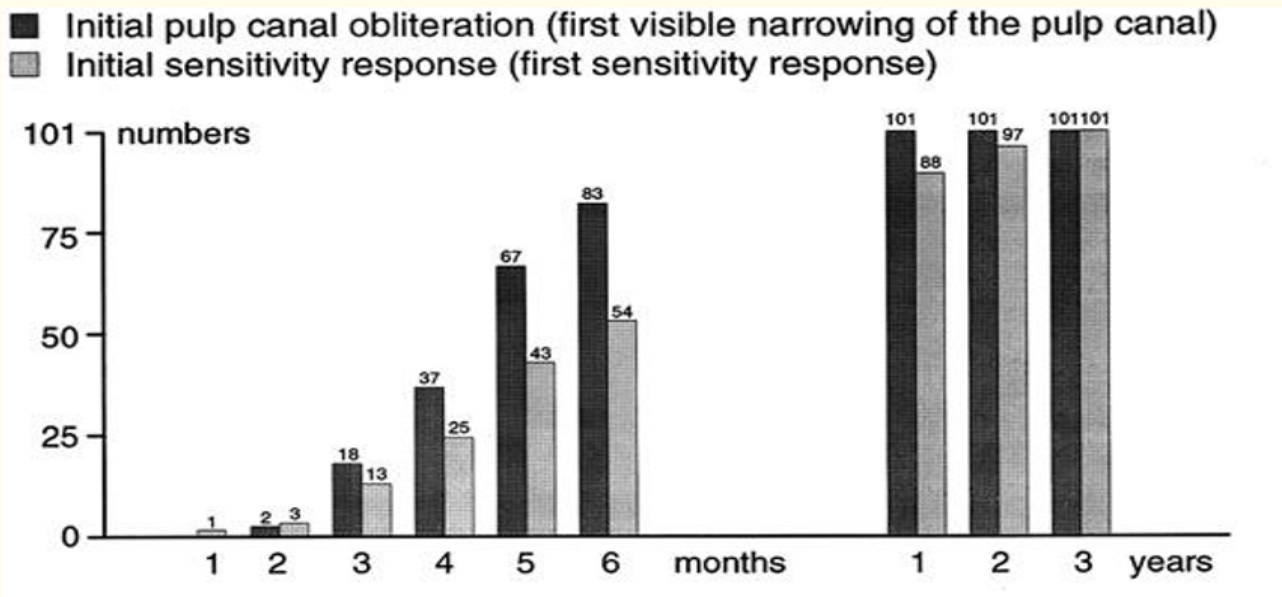


Figure 2: *Cumulative clinical and radiographic signs of pulp healing in orthodontic treatment.*

One tooth with reinnervation showed partial pulp canal obliteration and one tooth without reinnervation showed pulp canal obliteration. Sixteen teeth showed pulp necrosis. This condition was usually detected about 6 months after transplantation. One tooth had partial pulp necrosis. Teeth with pulp necrosis and associated inflammatory root resorption were detected two months after transplantation [26].

Periodontal Healing

Partial periodontal ligament healing was seen radiographically after 4 weeks. The majority of transplants showed complete periodontal healing 8 weeks post-transplantation (Figure 3). Repair-related root resorption and inflammatory root resorption usually were found in the cervical area of the root. Inflammatory root resorption was seen in four cases and was detected 1 to 2 months after transplantation, whereas repair-related root resorption usually was diagnosed within the first year after transplantation. Replacement root resorption occurred in 5 cases. This complication usually could be diagnosed within 6 months after transplantation [8,18].

Figure 3: *Transplantation of a maxillary second premolar to the region of the mandibular second premolar. A clinical photograph and a radiograph taken a few days after transplantation. Note that the transplant is placed in infraocclusion to avoid traumatic occlusion.*

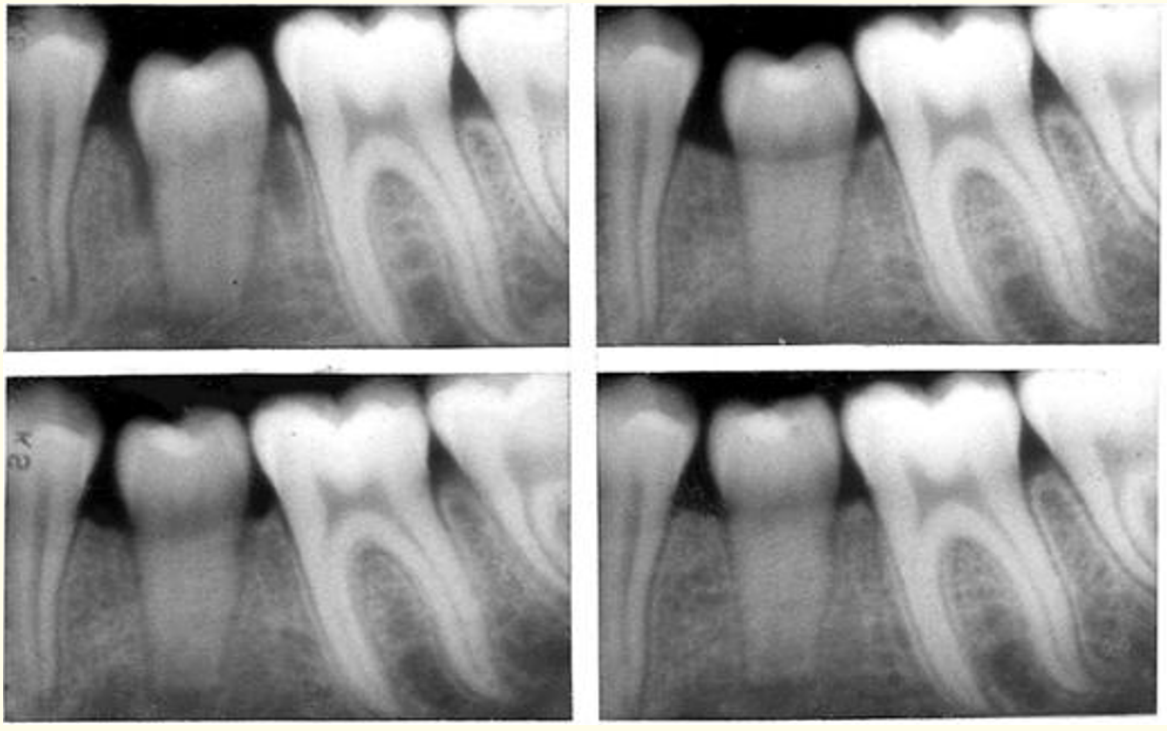
Root Development Disturbance

Root development either proceeded unimpeded (Figure) or at a de-creased rate, and in some cases was arrested (Figure). Arrested root formation was found in 14% of patients studied. Unimpeded root formation was found in 21% of patients studied and a decreased rate of root formation was found in the majority of patients, i.e., 65%. Interrupted root formation was followed by the development of the missing root structure at the donor site. The newly formed root tip growth had attained almost the length of the missing part of the interrupted root form, compared to the contralateral premolar [13,26,46].

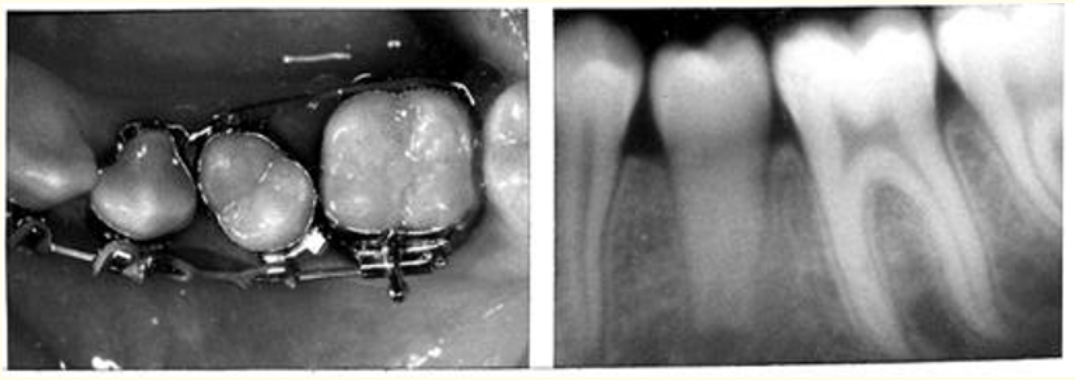
Tooth Eruption

Tooth eruption took place from 3 to 24 weeks after transplantation (Figure 3-11). The speed of eruption accelerated from 3 to 8 weeks post trans-plantation, was fastest during the period of 6 - 12 post transplantation weeks and declined after the period of 12 - 24 weeks post transplantation when the transplant approached the occlusal plane and before any significant root growth had occurred. The maximum rate was 0.24 mm/week (range 0.19 - 0.29 mm) 8 weeks post transplantation. Eruption distance from gingival emergence to occlusal plan was 2.4 mm (range 1.2-5.0 mm) over 24 weeks post transplantation. When the occlusal plane had been reached, a very slow but continuous eruption was recorded that was similar to the rate of eruption of the adjacent teeth (Figure 4-7). One tooth with a broken

Hertwig's epithelial root sheath showed similar eruption, but the rate of eruption was slower. The newly formed apex, after extraction, could be seen growing in the donor region during the healing and closing period (Figure 8-10). One tooth with replacement root resorption (ankylosis) showed no sign of eruption and therefore was excluded from the calculation of the eruption rate of transplants (Figure 11). Additionally, the periodontal membrane of the autotransplanted premolars created new alveolar bone growth along with tooth eruption [12,22].



Eruption of the transplant can be seen in radiographs exposed one, two, three and four months after transplantation.



A clinical photograph and radiograph taken 6 months after transplantation when orthodontic treatment was begun to correct rotation.

A clinical photograph and radiograph taken 18 months after transplantation. Note that root growth has continued in spite of the orthodontic rotation.

Orthodontic Rotation

Orthodontic rotation of 11 premolars induced slight repair-related root resorption and a significant shortening of root length (a mean of 1.2 mm) compared with transplanted, nontreated control teeth. After orthodontic treatment, a new periodontal ligament space was established, leaving an indentation in the root surface. In addition, the periodontal ligament of autotransplanted premolars created new alveolar bone growth along with the healing- and the orthodontic rotation process. Late pulp necrosis occurred in 2 of the 11 treated cases six years after surgery and five years after orthodontic rotation [21,26].

Discussion

Pulp Healing

Pulp healing can be monitored using pulpal sensitivity and/or radiographic signs of pulp canal obliteration [17]. In most of the teeth transplanted in stages 3 - 4, both events were observed. Only a few teeth showed signs of only one or the other event. As transplantation of teeth implies, severance of the vascular and nervous supply to the pulp can cause serious damage to the architecture and function of the pulp. Subsequent healing processes usually restore the content of the pulp canal including the nervous supply. Pulpal sensitivity without pulp canal obliteration may take place in rare cases; similarly, pulp canal obliteration without pulp sensitivity may occur where nerve re-generation fails. Early reinnervation and partial pulp canal obliteration or no pulp canal obliteration appear to be signs of fast pulp canal revascularization (i.e., end-to-end anatomises of ruptured vessels) [26].

Periodontal Healing

Root resorption occurred in some patients even though transplantation was performed during the initial stages of root development. Inflammatory root resorption diagnosed within two months after transplantation was mostly related to later stages of root development. Replacement root resorption (ankylosis) also was noted in situations where more than 25% of the periodontal ligament was damaged [18,26].

Figure 4: *A transplant with normal root development. Radiographs show healing a few days, 4 weeks, 6 weeks, 8 weeks, 12 weeks and 16 weeks post-surgery. Refer to schematics in Figures 5, 6, and 7.*

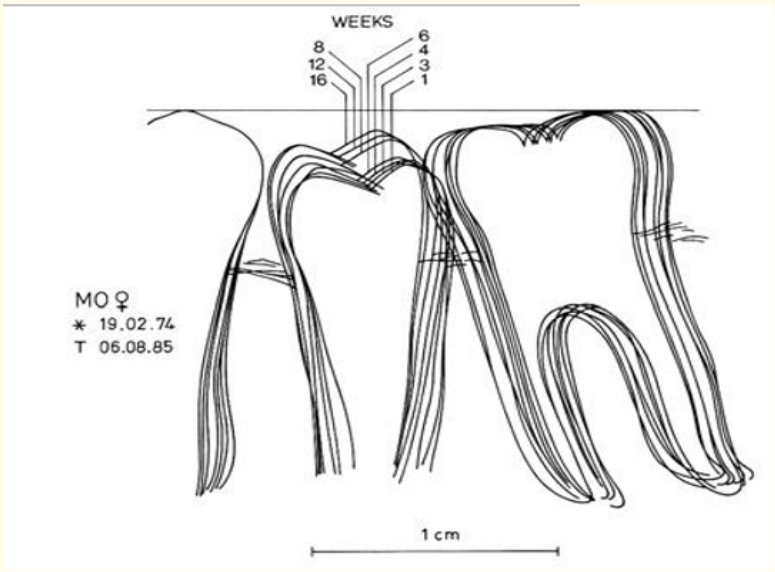


Figure 5: *Drawing of radiographs from the transplant. The speed of eruption, relative to neighbouring reference teeth, measured using the distance to a plane be-tween the buccal cusp of the first premolar and the distobuccal cusp on the first molar as a reference.*

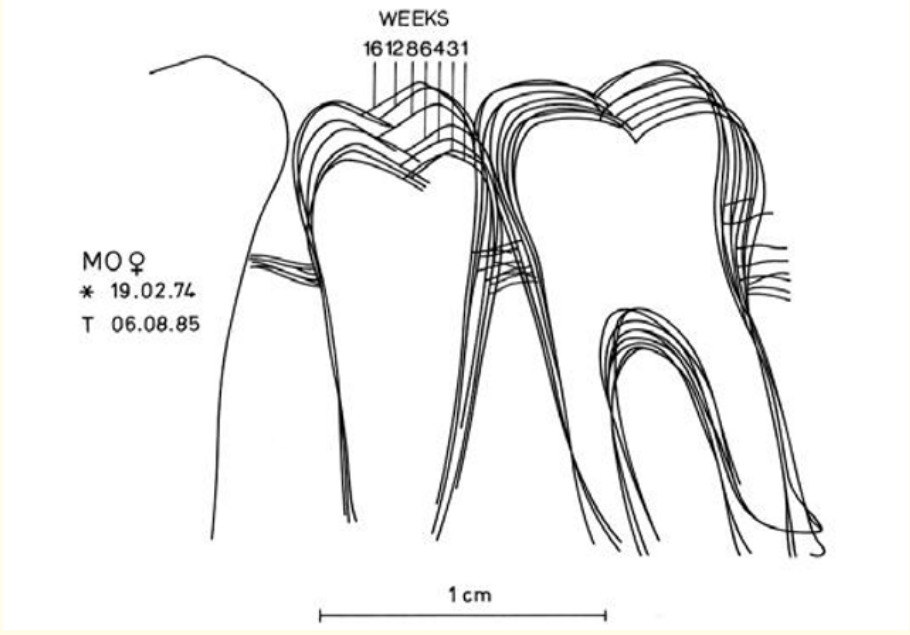


Figure 6: *Drawing of radiographs from the transplant. The speed of eruption, relative to neighbouring reference teeth, measured using the buccal cusp of the first pre-molar as a reference.*

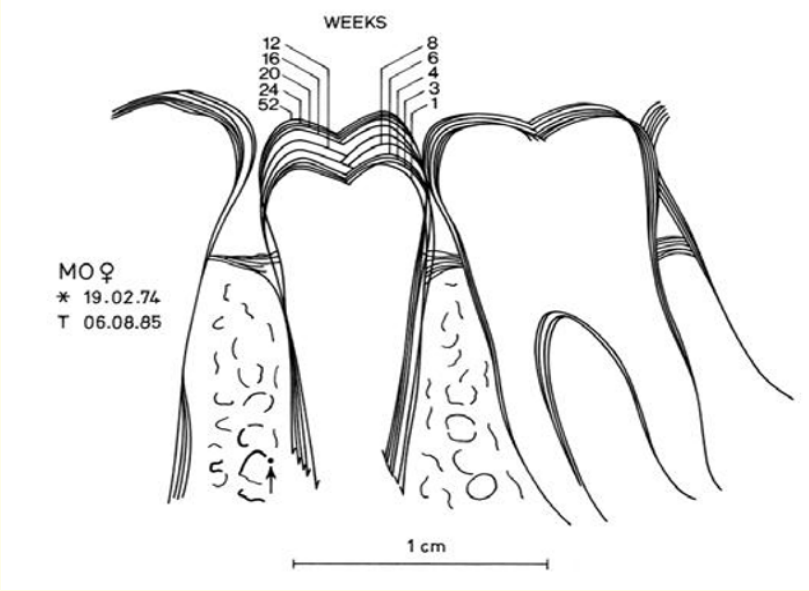


Figure 7: *Drawing of transplant radiographs. The speed of eruption is based on distinct structures in the trabecular structures of the medulla bone. The selected measuring point is marked with an arrow*

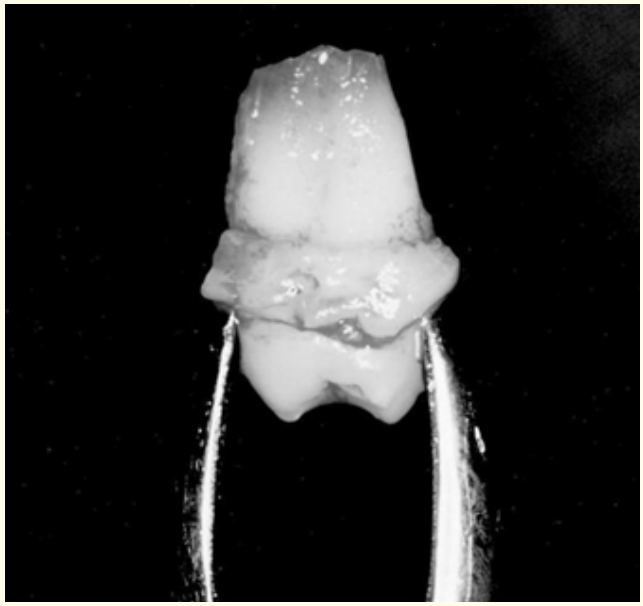


Figure 8: *A transplant with arrested root development (i.e. a broken Hertwig´s epi-thalian root sheath). The specimen during surgery: Note the broken apex region.*

Figure 9: *Radiographs show healing and eruption a few days, three weeks, four weeks, six weeks, three months, four months and nine months after surgery and one month of orthodontic rotation of the transplant (first seven radiographs). Donor region nine months after surgery; note the newly formed apex. Donor region 16 months after surgery; note that the apex has grown.*

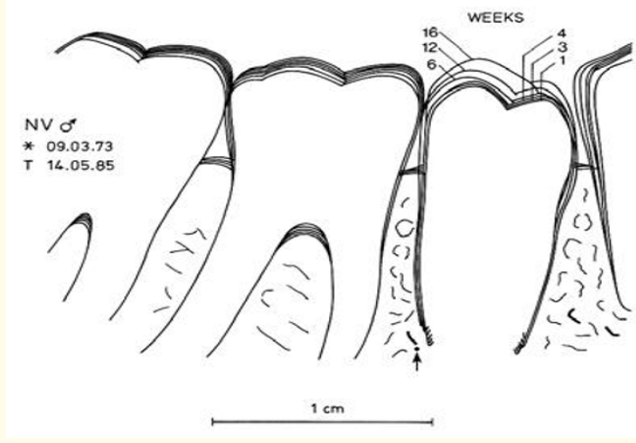


Figure 10: *Drawing of radiographs from the transplant. The speed of eruption is based on distinct structures in the medullary bone. The selected measuring point is marked with an arrow.*

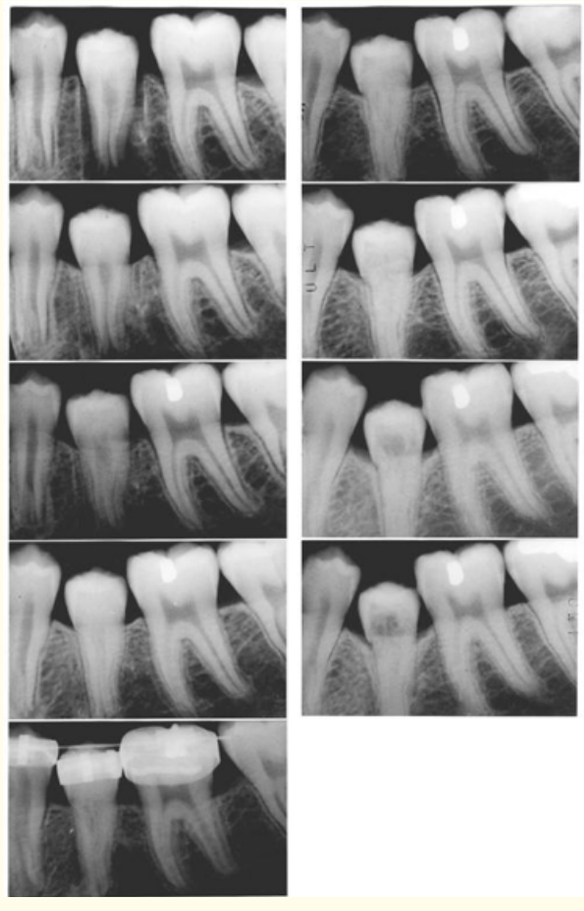


Figure 11: *A transplant with normal root development but replacement root re-sorption. Radiographs show healing at a few days, 12 weeks, 24 weeks, one year and two years after transplantation (left). Note that orthodontic force was applied to the ankylosed tooth immediately after surgical luxation to accelerate eruption. Radiographs taken three years, four years, and five years after transplantation (right: first three radiographs). Treatment was unsuccessful with pronounced in preposition of the transplant during puberty. A radiograph taken seven years after transplantation shows a marked internal resorption of the crown (right: last radiograph). The relative eruption of neighbouring teeth resulted in further in preposition of the transplant (as it became part of the bone) like an implant inserted in the jaw of a growing person.*

Root Development Disturbances

Transplantation of premolars requires surgical removal while root growth is still not complete. Continued root growth is anticipated, there-fore, after transplantation. Findings that some of the transplants attained nearly normal root lengths demonstrate that the Hertwig's epithelial root sheath can function adequately subsequent to transplantation. Arrest of root development in other transplants was related to a severance of the Hertwig's root sheath during transplant removal [12,14,19,26]. The initial arrest of root formation due to transplant usually is followed by development of the missing root structure (a newly formed apex) at the donor site. The root tip can grow almost to the anticipated tooth length including the length of the transplant [12].

Tooth Eruption after Transplantation

Tooth eruption after transplantation appears to depend on wound healing and nerve induction. The fibroblasts will produce and replicate collagen with a high rate of turnover. Newly synthesized collagen fibrils will reorganize the periodontal ligament with an increase in tensile strength during wound healing and probably will cause the tooth to erupt. By the third week post-transplantation, a new socket has formed, and newly-developed periodontal fibers extending from the cementum to the alveolar surface might cause the tooth to erupt together with an ingrowth of nerve fibers. Furthermore, the autotransplanted premolars create new alveolar bone growth along with the eruption process; the periodontal membrane induces the bone formation. Transplantation of teeth thus can be used as a viable method for restoring missing or lost alveolar bone in edentulous areas. In contrast, the autotransplanted premolar with ankylosis showed the same reaction as implants with osseous-integration. Disturbance in jaw growth is found when implants are placed before termination of alveolar growth [12]. Furthermore, teeth will not erupt without nerve supply [47]. Reestablishment of the nerve connection will probably stimulate tooth eruption.

Orthodontic Treatment of Transplanted Premolars

The extent of apical root resorption found in this study is equivalent to that found in previous investigations of orthodontic treatment of non-traumatized teeth. The occurrence of pulp necrosis subsequent to orthodontic rotation could be related to a strangulation of the blood vessels entering the apical foramen. It is known that the apical foramen may deviate slightly from the anatomic apex. If the foramen is located eccentrically, orthodontic rotation might damage the apical blood vessels, especially in late stages of pulp canal obliteration [26].

Restoration of Transplanted Teeth

Subsequent to transplantation, an intense production of secondary dentin occurs that contributes to the rapid maturation of the root (i.e. pulp canal obliteration). The newly formed dentin contains vascular canals, and if a deep preparation of a transplant is performed, these canals may be ex-posed and lead to pulp necrosis. For similar reasons, carious lesions may invade post-traumatic formed dentin rapidly. Tooth preparation for restorative purposes should involve only enamel preferably. If dentin has to be removed, it should be removed only to the level of post-traumatic formed dentin [11,24]. The use of composite materials for young patients and porcelain veneers for adult patients is advocated due to the difference in pulp maturity.

Osseous integrated Implants Versus Autotransplantation of Teeth

Single standing implants have been found to be a reliable substitute for missing teeth. However, because osseointegration occurs with such implants, they behave like ankylosed teeth; i.e. they limit the growth of the alveolar process in their vicinity because they lack the potential to erupt. However, no soft tissue is transferred with this procedure (i.e. no marginal gingiva and papillae). Autotransplanted teeth continue erupting allowing for normal development of the alveolar processes [12]. Furthermore, soft tissue is transferred with this procedure, including marginal gingiva with papillae. The optimal treatment approach mandates a realistic evaluation of the long-term prognosis of the various treatment methods and cost. However, no commercial interests measure to make tooth transplantation more

available, such as companies arranging training courses in the surgical procedure for implants. Treatment must be initiated by professionals, because there is no demand for treatment option with which the public is unfamiliar [40].

Autotransplantation of teeth in orthodontics is a biological method of replacing missing or lost teeth. However, a prerequisite for using this method is a thorough knowledge of the prognosis. Thus, the stage of root development of the transplant is very important. Performing transplantation when there is 3/4 to full root development of the transplant with wide open apices, employing a surgical technique that preserves the periodontal ligament, and using a light-force orthodontic tooth movement or tooth rotation three to nine months after surgery are the most crucial factors for the survival of transplants and their continued development. The periodontal ligament, with bone induction potential, will induce new alveolar bone. Furthermore, the transplanted tooth will erupt in a similar manner to that of the contralateral, non-transplanted tooth if the transplanted tooth is not ankylosed to the alveolar bone [12,21]. Autotransplantation provides the potential to replace a missing tooth with a natural tooth with bone formation, rather than with a prosthesis or an endosseous implant without bone formation. It provides a unique orthodontic treatment approach for young patients as a complex orthodontic problem (i.e. premolar agencies and avulsed or malformed anterior teeth) can be transferred to another region in the dental arch where it can be treated more easily. A prerequisite for the use of this treatment approach mandates a thorough knowledge of the risk factors associated with poor prognosis. If used with care, transplantation may greatly enhance orthodontic treatment results in selected cases [24,26].

Conclusion

- The first evidence of pulp canal obliteration as seen radiographically appeared to provide an earlier sign of pulp healing than electrometric pulp testing.
- Root growth of transplanted premolars usually continued.
- Arrest of root development usually was followed by development of the missing root structure at the donor site.
- Marginal gingiva with papillae normally was transferred with the soft tissue.
- Periodontal ligament of autotransplanted teeth created new alveolar bone surrounding the transplant. During orthodontic tooth movement and/ or rotation, alveolar bone reformed alveolar bone to fit the contour of the root.
- Eruption of transplanted premolars occurred from 3 to 24 weeks after transplantation and apparently before root growth continued, with a maximal eruption rate occurring from 6 to 12 weeks after transplantation.
- During the eruption process, new alveolar bone appeared and followed the eruption path of the transplant.
- Orthodontic rotation induced a slight surface resorption and a significant shorter tooth length (the mean was 1.2 mm), and few cases showed late pulp necrosis.
- To prevent late pulp necrosis, orthodontic rotation is recommended after periodontal healing and before total pulp canal obliteration (i.e., three to nine months after transplantation).
- There should be clinical and radiographic follow-up for many years to ensure long-term results.

Osseous integrated Implants Versus Autotransplantation of Teeth

Implants

- Implants can be a substitute for normal tooth material without soft tissue.
- No transmission of marginal gingiva with gingival papillae is possible.
- No periodontal ligament induction of alveolar bone modelling and growth occurs.
- Eruption of implants not possible along growth.
- Orthodontic tooth movement and/or rotation is not possible

Autotransplanted Teeth

- Patient's normal tooth material with soft tissue is used.
- Transmission of marginal gingiva with gingival papillae is possible.
- Periodontal ligament induction of alveolar bone modelling and growth occurs.
- Normal tooth eruption is possible along with growth.
- Orthodontic movement and/or rotation are possible.

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