Pulp and periodontal healing, root development and root resorption subsequent to transplantation and orthodontic rotation: A long-term study of autotransplanted premolars

Hans Ulrik Paulsen, DDS,* Jens Ove Andreasen, DDS, Odont. Dr. hc,° and Ole Schwartz, DDS, PhD*

Copenhagen, Denmark

One hundred and eighteen premolars transplanted at a stage with 3/4 to 4/4 root development with a wide open apical foramen were followed with standardized clinical and radiographic techniques for signs of pulpal and periodontal ligament healing and root development. Pulp healing, evaluated first by radiographic presence of pulp canal obliteration, appeared to be an earlier sign of pulp healing than the detection of pulp vitality with an electrometric test. Continued root growth of premolars was seen in some cases. Complete arrest of root development was usually followed by development of the missing root structure at the donor site, indicating a separation of the Hertwig's epithelial root sheath. Orthodontic rotation performed on 11 premolars induced slight surface resorption and a significant shortening of tooth length (mean 1.2 mm), compared with nontreated but transplanted control teeth. However, the extent of the apical root resorption is of minor clinical importance, and is equivalent to what has been found in previous investigations of orthodontic treatment of nontransplanted premolars. Late pulp necrosis occurred in 2 of the 11 treated cases 6 years after transplantation and 5 years after orthodontic rotation. To prevent late pulp necrosis, orthodontic rotation is recommended after periodontal healing and before total pulp canal obliteration has taken place, i.e., 3 to 9 months after transplantation. (Am J Orthod Dentofac Orthop 1995;108:630-40.)

Autotransplantation of premolars has become a reliable treatment option in the treatment of certain orthodontic problems.1-32 In conventional orthodontics, tooth movement is usually limited to minor distances in the sagittal, vertical, and transverse directions, depending on the technique used. By adding autotransplantation of teeth to the orthodontic armamentarium, a new freedom in treatment can be achieved in some clinical situations. Thus, tooth movement to distant or opposite sides of the same dental arch, as well as to the opposite jaw, becomes possible (Figs. 1 and 2).

The purpose of this study was to analyze pulp and periodontal healing, root development, and root resorption subsequent to transplantation of premolars transplanted with 3/4 to 4/4 root development, with a wide open apical foramen, and those that were orthodontically rotated, all features that are decisive for monitoring the early healing events after transplantation.

MATERIAL AND METHODS

From a previously published study of 370 premolars,26-29 118 premolars in stages 3 to 4 according to Moorrees et al.33 (i.e., 3/4 to 4/4 root length with a wide open apical foramen) were selected for a more detailed analysis of the initial healing events. This stage was chosen as representing the best compromise in achieving a successful outcome of root growth, periodontal ligament, and pulp healing (Fig. 3).26-29 All transplantations were performed at the Department of Oral Surgery and Oral Medicine, University Hospital (Rigshospitalet), Copenhagen, *J.O.A.), whereas treatment and postoperative visits were performed at the Department of Orthodontics, Copenhagen Municipal Dental Health Service, Copenhagen (H.U.P.). Autotransplantation was used as an integrated treatment method in orthodontic treatments of patients with aplasia of permanent teeth or tooth loss as a result of trauma of maxillary incisors. Transplants were followed longitudinally with a standardized technique for clinical and radiographic signs of pulp and periodontal healing, root development, and root resorption.26 Clinical and radiographic examinations were conducted 1, 3, 4, 6, 8, 12, 16, 20, and 24 weeks after surgery and once a year thereafter (range 6 to 16 years).
Pulp healing was evaluated clinically by an electro-
metric test (Siemens Sirotest II, Siemens, Munich, Ger-
many) and radiographically for signs of pulp canal oblit-
eration with a standardized radiographic technique that
used XCP film holders (Rinn Corp., Elgin, Ill.) and a
fixed film-focus distance of 33 cm.

Periodontal healing, root growth, and tooth eruption
subsequent to transplantation was also monitored by
radiographic examination. A digital sliding caliper read
to the nearest 0.1 mm was used to measure pulp canal
obliteration and root lengths. Nontransplanted homolo-
gous premolars served as controls, when possible.

Effect of orthodontic treatment on healing was ex-
amined in 11 patients who had received bilateral trans-
planted premolars (maxillary second premolars to re-
gions of mandibular second premolars). Transplants
were placed in 45° distal rotated position at surgery. In
these patients, one of the premolars was orthodontically
rotated to normal position after periodontal healing and
before pulp canal obliteration (i.e., 3 to 9 months after
surgery) and the contralateral transplanted premolar was
not treated orthodontically and therefore served as a
control. The technique of rotation was fixed appliance
with Alastik chains (Unitek, Glendora, Calif.), inserted
on the buccal side from the first molar to the transplant
and on the lingual side from the first premolar to the
transplant. The estimated initial rotational couple ap-
plied to the tooth was 200 gm-mm. Duration of rotation
was 4 to 6 weeks. Postoperative clinical and radiographic
examinations were performed, as described previously,
on the general orthodontic alignment.

Criteria for healing and healing complications

Root development of the graft. On radiographic exami-
nation of the transplanted tooth, the extent of root
formation was registered and if a nontransplanted ho-
moslogous premolar was present, it was used as a control
for comparison.

Pulp necrosis was considered to be present when
there were radiographic signs of a periapical radiolu-
cency 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 required that the pulp canal
CHANCE OF SUCCESSFUL HEALING RELATED TO STAGE OF ROOT DEVELOPMENT OF AUTO-TRANSPLANTED PREMOLARS

Fig. 3. Prediction of optimal root development, pulpal survival, and periodontal healing (i.e., without root resorption) as related to stage of root development at time of transplantation. Graph is based on results from long-term study of 370 autotransplanted premolars.

showed no sign of obliteration 6 months after transplantation.

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

Surface resorption was defined as small resorption cavities on the root surface adjacent to a normal or slightly extended periodontal ligament space and lamina dura.

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

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

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

RESULTS

Pulp healing was found in 103 of the transplants.

The time of initial pulp healing (cumulative data) of 101 transplants is shown in Fig. 4. Pulp healing evaluated by first presence of pulp canal obliteration was an earlier sign of pulp healing than electrometric pulp testing and had a lesser range. A representative example of pulp healing in a second maxillary premolar transplanted to the maxillary anterior region is shown in Fig. 5.

One tooth with reinnervation showed partial pulp canal obliteration (Fig. 6), and one tooth without reinnervation had pulp canal obliteration (Fig. 7). Fourteen teeth showed pulp necrosis, and this condition was usually detected approximately 6 months after transplantation. One tooth had partial pulp necrosis (Fig. 8). Teeth with pulp necrosis and associated inflammatory resorption were detected 2 months after transplantation (Fig. 9).

Periodontal healing as shown radiographically showed partial periodontal ligament healing after 4 weeks. The majority of transplants showed complete periodontal healing 8 weeks after transplantation (Fig. 5). Surface resorption and inflammatory resorption was usually found in the cervical area of the root. Inflammatory resorption was seen in four cases, usually diagnosed 1 to 2 months after
Pulp healing in 101 immature autotransplanted premolars

<table>
<thead>
<tr>
<th>Months after transplantation</th>
<th>Range in months</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 4 5 6 12</td>
<td></td>
</tr>
<tr>
<td>Initial pulp canal obstruction:</td>
<td>16% 36% 60% 80% 100%</td>
</tr>
<tr>
<td>Initial sensitivity response:</td>
<td>12% 25% 43% 54% 89%</td>
</tr>
</tbody>
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Initial pulp healing in autotransplanted premolars in orthodontic treatments (cumulated)

- Initial pulp canal obliteration (first visible narrowing of the pulp canal)
- Initial sensitivity response (first sensitivity response)

Fig. 4. Clinical and radiographic signs of pulp healing (cumulative). Dark bars show first sign of pulp canal obliteration and light bars first sign of sensitivity.

Root development

The root development could go on unimpeded (Fig. 10) or root development could become impaired or could become arrested (Fig. 11). Arrested root formation was found in 19%, no arrest of root formation was found in 26%, and partial arrest of root formation was found in the majority of the transplants, 55%. Arrest of root formation was followed by development of the missing root structure at the donor site. The root tip, including the length of the transplant, was growing almost equal the anticipated tooth length (Fig. 12).

Orthodontic rotation induced a slight surface resorption and a shortening of the root. After orthodontic treatment, a new periodontal ligament space was established, leaving an indentation in the root surface (Fig. 13). The effect of unilateral orthodontic rotation on root formation of 11 pairs of transplanted premolars is shown in Fig. 14. Rotation after transplantation induced a significantly shorter root formation (mean 1.2 mm, Wilcoxon-Pratt paired rank sum test: p = 0.001). Pulp necrosis occurred later in two cases, 6 years after surgery and 5 years after orthodontic rotation. One of the cases is shown in Fig. 15.

DISCUSSION

Pulpal healing

Pulp healing can be monitored with either pulpal sensitivity or radiographic signs of pulp canal obliteration. In most of the teeth, transplanted in stages 3 to 4, both events were observed and only a few teeth showed only one sign. The results are in agreement with conclusions reported by Andreasen et al. As transplantation of teeth implies severance of the vascular and nervous supply to the pulp, serious damage can be anticipated to the architec-

Fig. 6. Transplantation of maxillary second premolar to region of mandibular right premolar. Note: Partial pulp canal obliteration 2 years after transplantation. Pulp sensitivity was elicited 3 months after transplantation.

Fig. 7. Transplantation of maxillary second premolar to region of mandibular right premolar. Note: Total pulp canal obliteration 2 years after transplantation. Pulp sensitivity was not elicited during healing period.

ture and function of the pulp.\textsuperscript{8,10} 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, likewise pulp canal obliteration without pulp sensitivity may occur where the nerve regeneration fails.\textsuperscript{35} Teeth showing early reinnervation and only partial pulp canal obliteration or no
pulp canal obliteration appear to result from fast pulp canal revascularization, i.e., end-to-end anastomoses of ruptured vessels.  

Periodontal healing

Root resorption occurred although transplantation was performed at initial stages of root development. The results are in agreement with conclusions reported by Andreasen et al.  that root resorption was still found to occur when transplantation is performed at initial stages of root development. Inflammatory resorption diagnosed within 2 months after transplantation was mostly related to later stages of root development. Replacement resorption (ankylosis) has likewise been reported if more than 25% of the periodontal ligament was damaged.
Root development disturbances

Transplantation of premolars implies surgical removal, whereas root growth is still not complete and continued root growth is therefore anticipated after transplantation. Findings that some of the transplants attained almost their anticipated tooth lengths show that Hertwig's epithelial root sheath can function normally subsequent to a transplantation (Fig. 10). Arrest of root development in other transplants was found to be related to a severance of the Hertwig's root sheath during transplant removal (Fig. 11).37 Arrest of root formation of the transplant is usually followed by development of the missing root structure (a newly formed apex) at the donor site, and, including the length of the transplant, the root tip can grow almost to the anticipated tooth length (Fig. 12).

Orthodontic treatment of transplanted premolars

The positive relationship between orthodontic treatment and surface resorption is to be expected when the known relationship between resorption and orthodontic therapy is considered.38,39 The extent of apical root resorption found in this study is similar to the amount found in previous investigations of orthodontic treatment of nontraumatized
teeth. The occurrence of pulp necrosis subsequent to orthodontic rotation could be related to a strangulation of the vascularization entering the apical foramen. It is known that the apical foramen may deviate slightly from the anatomic apex. If the foramen is eccentrically located, orthodontic rotation might damage apical blood vessels, especially in late stages of pulp canal obliteration.

Fig. 13. Transplantation of maxillary second premolar to region of mandibular right second premolar. A, Three months after orthodontic rotation (9 months after transplantation): surface resorption on distal side of root. B, One year later, there is repair of surface resorption.

Fig. 14. Effect of orthodontic rotation on root formation. Rotation after transplantation induced significantly shorter root formation (mean 1.2 mm).
Fig. 15. Transplantation of maxillary second premolar to mandibular left second premolar region. A, Four years after treatment. B, Pulp necrosis with periapical radiolucency, 6 years after transplantation, and 5 years after orthodontic rotation.

Fig. 16. Autotransplantation of second maxillary premolar as replacement for lost central incisor. A, Condition after avulsion of one incisor. B, Transplantation of second premolar to central incisor region. Graft was rotated 45° to accommodate narrow alveolar process. C, Fixed orthodontic appliance inserted to rotate position of transplanted premolar and to normalize position of teeth in maxilla. D, Orthodontic rotation of transplanted premolar finished. E and F, After slight grinding of "labial" and "palatal" surface of grafted premolar, tooth was restored with composite 1 year after transplantation.
Autotransplantations versus osseointegrated implants

Recently, single standing implants have been found to be a reliable substitute for missing teeth. However, because of the osseous-integration of the implants, disturbance in jaw growth will be found if implants are installed before termination of alveolar growth. On the contrary, autotransplanted premolars will create alveolar growth along with the eruption process. This process is presently under investigation. In the choice between implants and autotransplanted teeth, the age of the patient and teeth with incomplete root formation available to be transplanted is therefore decisive.

CONCLUSIONS

1. Pulpal healing evaluated radiographically by the first evidence of pulp canal obliteration appeared to be an earlier sign of pulp healing than electrometric pulp testing.
2. Continued root growth of premolars was usually found.
3. Arrest of root development was usually followed by development of the missing root structure at the donor site.
4. Orthodontic rotation induced a slight surface resorption and a significantly shorter tooth length (mean 1.2 mm). Furthermore, a few cases showed a late pulp necrosis.
5. To prevent interference with graft healing by orthodontic rotation, it is suggested that such treatment be postponed until after pulpal and periodontal healing has taken place and before total pulp canal obliteration, i.e., 3 to 9 months after transplantation.

Autotransplantation, which provides the possibility for a natural tooth rather than a prosthesis or an osseous-integrated implant to replace a missing tooth, is a unique treatment possibility in orthodontics of young patients. By means of this technique, a complicated treatment problem can be transferred to another site in the dental arch where it is easier to solve orthodontically. Autotransplantation, combined with orthodontics, in the treatment of premolar aplasia and anterior tooth loss opens up new avenues of treatment (Fig. 16). A prerequisite for the use of this method, however, is a thorough knowledge of the expected long-term success rate. If used with care, this method may supplement and enhance orthodontic treatment.

REFERENCES


Reprint requests to:
Dr. H.U. Paulsen
Department of Orthodontics
Copenhagen Municipal Dental Health Service
Peder Lykke School
Brydss Alle 25
DK-2300 Copenhagen S.
Denmark
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