The published literature contains no comprehensive studies that compare the outcome of premolar autotransplantation to the maxillary anterior region with natural incisors in the same patients. This article describes the gingival and periodontal conditions around premolars transplanted to the maxillary incisor region, subsequent to restoration. Forty-five premolars autotransplanted to the maxillary incisor region in 40 adolescent patients were evaluated after a mean observation period of 4.0 years. Mean age at surgery was 11.0 years. Established clinical criteria were used to assess tooth mobility, plaque and gingival indexes, probing pocket depth, and percussion. Recession and hyperplasia of interproximal gingival papillae were assessed according to a recently proposed index. Standardized radiography was used to evaluate presence of pathosis, pulp obliteration, root length, and crown-root ratios. Clinical variables for transplants did not differ from those of the natural incisors, except for increased mobility and more plaque in a few transplanted premolars. The interproximal gingival papillae adjacent to all transplanted teeth were normal or slightly hyperplastic. Radiographically, all transplants showed varying degrees of pulp obliteration, but no signs of pathosis. Crown-root ratios were similar for natural and transplanted teeth as were distances from cementoenamel junction to marginal bone. The overall status of the transplanted premolars and surrounding tissues indicated that this treatment modality may be recommended when maxillary incisors are missing in adolescents. In addition, tooth transplantation represents an inherent potential for bone induction and reestablishment of a normal alveolar process. (Am J Orthod Dentofacial Orthop 2000;118:592-600)
changed from studies of survival rates to concerns about the esthetic outcome and the patient satisfaction with these procedures.27-35

The purpose of a series of studies in progress is to illuminate both the objective and the subjective esthetic results of premolar autotransplantation in cases with accidentally lost or congenitally missing teeth, and to compare these results with alternative clinical procedures, including single-tooth implants, orthodontic space closure, resin-bonded bridgework, and new and conventional forms of prosthetic restorations. Subsequent articles on premolar autotransplantation will deal with (1) the long-term outcome 20 to 30 years after the operation, (2) the esthetic results of the restoration of premolars transplanted to the maxillary anterior region, and (3) the patient’s subjective esthetic and psychological evaluations of the short-term and long-term treatment results.

The aim of the present report is to assess the follow-up (4 years) status of premolars transplanted to the maxillary incisor segment during the period from 1989 to 1995 were included in the study. Those 62 persons living within 150 km of the University were invited by letter for an evaluation of the results. Twenty-two respondents had to be excluded because they were still in orthodontic treatment, thus leaving a study group of 40 (20 male and 20 female) patients. In these patients, a total of 45 premolars had been transplanted to replace maxillary incisors (39 central and 6 lateral incisors). The mean age at the time of surgery was 11.0 years (range, 6.6 to 14.4 years). The mean observation period was 4.0 years (SD, 1.10 years), at which time root development should be completed. The majority (30) of patients had lost incisors in association with traumatic injuries. In the remaining patients, the premolars were transplanted due to congenitally missing incisors or developmental disturbances.

The surgical procedure was carried out according to the guidelines established by Slagsvold and Bjercke5 and Andreasen et al.13 The first step in the procedure was the preparation of a socket in the recipient area; the donor tooth germ was then carefully dissected and immediately transferred to its new site with the dental follicle intact, if possible. The transplanted teeth were placed out of occlusion and secured with sutures for a period of 1 to 2 weeks. Orthodontic treatment was generally delayed until about 6 months after the surgical procedure.

**Fig 1.** Pretreatment and posttreatment intraoral photographs and panoramic radiographs of 10-year-old girl with lower right first premolar transplanted to position of the maxillary left central incisor. 

- **A** and **D**, Upper left central and lateral incisors were both malformed as a result of a previous trauma. After transplantation, (B) premolar was reshaped to incisor morphology by a composite build-up; orthodontic treatment was performed to close extraction spaces and align the transplanted tooth. **C** and **E**, Intraoral photograph and panoramic radiograph 7 years after transplantation.
The same oral surgeon (B.A.) performed the majority of the transplantations (n = 30). Six other surgeons performed 1 to 3 operations each. At the time of examination, all premolars had been restored to maxillary central incisor morphology by either a composite resin build-up (41 teeth, Fig 2) or a porcelain laminate veneer (4 teeth, Fig 3).

All individuals were examined clinically and radiographically by 2 calibrated examiners (E.C. and A.S.). Standardized intraoral photographs and study models were also used for documentation purposes. All the transplanted teeth were included in an overall assessment, whereas an intraindividual comparison was restricted to those patients having an intact contralateral incisor in situ.

**Overall Assessment**

Standardized intraoral radiography was used to evaluate (1) obliteration of the pulp cavity, (2) the general status in the periradicular area, (3) root length, (4) the outline of the periodontal membrane, and (5) external root resorption. A percussion test and recording of distinct infraocclusion were included for detection of ankylosis. The interproximal gingival papillae on the mesial and distal aspects of the transplanted teeth were recorded according to an index recently proposed for implants by Jemt. This index is based on the measurement of the papillae from a reference line through the highest curvature of the marginal buccal gingiva of the transplanted tooth and the adjacent permanent tooth (Fig 4). The distance from this line to the contact point was also assessed with the following index scores:

0 No papilla is present.
1 Less than half of the height of the papilla is present.
2 Half or more of the height of the papilla is present but does not extend all the way up to the contact point between the teeth.
3 The papilla fills up the entire proximal space and is in good harmony with the adjacent papillae. There is optimal soft tissue contour.

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**Fig 2. A.** Intraoral photographs of 11-year-old boy with 2 lower first premolars transplanted to the anterior maxilla because of traumatic loss of all 4 maxillary incisors. **B.** After orthodontic closure of the remaining spaces, autotransplanted teeth and canines in lateral incisor positions were reshaped to incisor morphology by composite build-ups.

**Fig 3. A.** Intraoral photograph of the initial result when an accidentally lost maxillary right central incisor had been replaced with a premolar transplant and then restored with a composite build-up. **B.** Because of unsatisfactory esthetic result, orthodontic treatment was performed to level the gingival margins; composite was replaced with porcelain veneer crown.
The papilla is hyperplastic and covers too much of the transplanted or adjacent tooth. The soft tissue contour is more or less irregular.

**Intraindividual Comparisons**

Twenty-two patients were used in the intraindividual comparison where the restored transplanted premolar was directly compared with the intact contralateral, natural maxillary central incisor; in the remaining 18 patients, for various reasons, an intact maxillary central incisor was not available (Table I). This group of 18 patients was not used in the intraindividual comparisons.

Established clinical procedures were used to record tooth mobility, plaque accumulation, gingival condition, and probing pocket depths for the transplant as well as for the reference (control) tooth. Tooth mobility was scored according to the mobility index proposed by Nyman and Lindhe, using a scale from 1 to 3, where 1 is movability of the crown of the tooth 0.2 to 1 mm in the horizontal direction, 2 is movability exceeding 1 mm in the horizontal direction, and 3 is movability in the vertical direction as well. Plaque index and gingival index were assessed as described by Silness and Löe. Probing pocket depth was measured at 4 sites around each tooth with a graduated periodontal probe.

In addition, an attempt was made to measure the crown and root lengths and compare these for the transplanted and in situ central incisors. Using a digital caliper (Mitutoyo Corp, Japan), measurements were made to the nearest 0.1 mm on the mesial aspects from the incisal edge and apex to the coronal level of the marginal bone (Fig 5, A). The most coronal point where the periodontal membrane still maintained its normal width was used as the reference point. The linear distance between the marginal bone level and the cementoenamel junction was also recorded for both groups of teeth to assess potential marginal periodontal attachment loss (Fig 5, B).

The measurements were repeated twice within a 4-week interval by the same observer, and the measurement errors were calculated according to Dahlberg and supplemented by the calculation of the coefficient of reliability described by Houston (Table II). The measurement errors of the crown lengths and root lengths estimated according to Dahlberg statistics ranged from 0.89 to 1.23 and the coefficients of reliability varied between 90% for the crown length of the control tooth to 95% for the root length of the control tooth.

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RESULTS

Overall Assessment

At the follow-up examination, all transplanted teeth were present in a normally appearing alveolar process (Figs 1-3). Signs of ankylosis (infraocclusion) were present in one of the transplanted teeth (2.2%).

Radiographic and clinical recordings are summarized in Table III. The most striking difference between the transplanted and control teeth was the partial pulp obliteration in all transplanted teeth (Fig 5). No such obliteration was observed in the intact natural incisors. Two transplanted premolars (4.4%) had undergone endodontic treatment because of signs of inflammatory root resorption. This treatment was successful, and no pathosis was evident at the time of examination.

The interproximal gingival papillae next to the transplanted premolars generally were well preserved or slightly hyperplastic. The gingival papilla index scores for the transplanted teeth are presented in Table IV. In only 4 cases did the papilla not extend all the way up to the contact point between the transplanted tooth and the control central incisor (score 2). Even in these cases, however, the gingival papillae on the distal side of the transplanted teeth filled the entire interdental space.

Intraindividual Comparisons

Table V summarizes the intraindividual comparisons between the transplanted and reference teeth with regard to mobility, plaque and gingival bleeding scores, and probing pocket depth. No teeth had increased mobility in the vertical direction (score 3). Four of the 6 transplanted teeth with a mobility index score higher than that of the contralateral central incisor also had increased plaque and gingival bleeding scores. One transplanted tooth with more horizontal mobility than the contralateral incisor had no antagonist and was nonoccluding.

In 6 of the transplanted teeth, probing pocket depths were increased compared with the transplants, but no pockets probed deeper than 4 mm.

The average crown-to-root ratio when measured to the marginal bone level was 0.89 (SD, 0.23) for the transplanted teeth and 0.88 (SD, 0.41) for the natural incisors.
Fig 6 illustrates crown length in relation to root length for the transplanted and control teeth. Few transplanted and control teeth had a crown-to-root ratio of more than 1 (positioned under the diagonal line). However, these teeth had no increased mobility compared with the contralateral central incisors. The mean distance from the marginal bone to the cementoenamel junction measured at the mesial aspect was 0.94 mm (SD, 0.74 mm) and 1.33 mm (SD, 1.33 mm) for the transplanted and intact natural teeth, respectively ($P < .05$).

DISCUSSION

The present study has demonstrated that autotransplantation of premolars to the maxillary incisor region may be a realistic treatment alternative for replacement of missing maxillary incisors. After subsequent root growth, contouring by grinding as needed, and veneering with composite resin or (preferably) bonded porcelain to restore the “normal” central incisor crown morphologic conditions, the periodontal condition, including the crown-to-root ratio, was shown to be about the same as that of the intact natural central incisors in the same patients. This finding confirms the observations in previous studies by other investigators on smaller samples or in case reports (Table VI).

It is emphasized that only premolars with partly formed roots were included in this study. The reason for this selection is that several studies have previously shown a predictably good documented result for such teeth. The autotransplantation of premolars with fully formed roots reduces the success rates and introduces an element of unpredictability regarding the long-term outcome that, in our opinion, is not compatible with outcome requirements for a method intended for routine use. The high survival rate in the present study is comparable to that in other studies in which the indications and surgical procedures have been in accordance with the guidelines established by Slagsvold and Bjercke. Failures such as ankylosis or progressive root resorption of the donor tooth are strongly correlated with damage to the root surface during the operation.

A common approach to examining the outcome after autotransplantation of premolar teeth is to present suc-
cess rates by recording the occurrence of sequelae to the transplant. On the assumption that the success criteria have been defined, this constitutes a valid method because intact premolars left in situ represent a gold standard. When premolars replace maxillary central incisors, however, assessment of the outcome has to take other factors into account as well. Some morphologic and biologic characteristics inherent in premolars differ from those of incisors, which can lead to undesirable effects in the anterior region. This applies to gingival conditions (shape and volume of marginal gingiva and the gingival papillae, plaque accumulation, sulcus bleeding, and pocket depth) as well as dental characteristics (crown-to-root ratio, tooth mobility). In order to control such differences, the design of this study included a comparison in the same patients between the transplanted premolar and the contralateral natural maxillary central incisors, which were used as reference teeth whenever present.

For most variables investigated, there were no clinically important differences between the transplanted and reference teeth. A slightly increased probing pocket depth was probably due to gingivitis caused by plaque accumulation in the area of the composite resin-enamel border in the restored premolars, and the interdental gingival papillae were sometimes hyperplastic around the transplants. On the other hand, there were no instances of interdental gingival recession. The gingival papillae adjacent to the transplanted teeth completely filled the interdental spaces in all but a few cases (Table IV). This is in contrast to findings around single-tooth implants in the maxillary anterior region, where a frequent lack of the interdental gingival papillae may compromise the esthetic outcome.30,33 The transplanted teeth were not entirely free of sequelae, as one tooth apparently was ankylosed, which presumably may lead to long-term loss of that tooth. However, the varying degrees of pulp obliteration, which were seen in all transplanted teeth, are a regular finding associated with autotransplantation.5-7 Obliteration is generally seen in the part of the root that is formed before the operation, whereas the part that develops afterwards may appear normal (Fig 5). In a long-term study (10 to 23 years) after traumatic injuries, Jacobsen and Kerekes43 showed that teeth with partial pulp obliteration have a good prognosis. Further studies of long-term consequences of pulp obliteration will be made in our 30-year follow-up of transplanted premolars as mentioned earlier.

It should be emphasized that transplantation may involve other benefits in addition to the actual tooth replacement. Most important is the potential for bone induction and reestablishment of a normal alveolar process after traumatic bone loss.7,23 Even if the transplant should fail at a later stage, an intact

Table IV. Distribution of the gingival papilla index scores for 45 premolars autotransplanted to the maxillary central incisor region

<table>
<thead>
<tr>
<th>Gingival papilla index</th>
<th>Gingival papilla mesial to the transplant</th>
<th>Gingival papilla distal to the transplant</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>35</td>
<td>39</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

Scoring system based on a method adopted from Jemt.30

Table V. Distribution of 4 characteristics for 22 premolars transplanted to the maxillary central incisor region when compared with the intact contralateral central incisor in the same patient (unit for comparison is one score level and/or mean depth of 1 mm)*

Table VI. Comparison of studies about premolars autotransplanted to replace missing incisors (premolars transplanted to the anterior region represent subsamples in some studies)

<table>
<thead>
<tr>
<th>Study</th>
<th>Number of transplanted premolars</th>
<th>Observation period (y) mean/range</th>
<th>Success rate of transplant (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slagsvold and Bjercke, 1978</td>
<td>4</td>
<td>7.5/7.3-7.9</td>
<td>100*</td>
</tr>
<tr>
<td>Andreasen et al, 199014-16</td>
<td>33</td>
<td>NS/1-13</td>
<td>70†/88‡</td>
</tr>
<tr>
<td>Kristerson and Lagerström, 1991</td>
<td>23</td>
<td>7.5/4-17</td>
<td>87</td>
</tr>
<tr>
<td>Kugelberg et al, 1994</td>
<td>31</td>
<td>NS/1-4</td>
<td>87</td>
</tr>
<tr>
<td>Lundberg and Isaksson, 1996</td>
<td>6</td>
<td>NS/0.5-6</td>
<td>67</td>
</tr>
<tr>
<td>Present study</td>
<td>45</td>
<td>4/0.6-7.7</td>
<td>93</td>
</tr>
</tbody>
</table>

*Selected cases.
†Transplanted teeth without pulp necrosis.
‡Transplanted teeth without root resorption.
§Immature teeth, total sample.
||Mature teeth, total sample.
NS, Not stated.
recipient area may be preserved by the transplant and could subsequently be used to accommodate an implant.

In conclusion, the overall status of the transplanted premolars and of the surrounding hard and soft periodontal tissues indicates that this treatment modality may be recommended for patients when one or more maxillary incisors are missing. As the procedure is performed in adolescents, data from extended follow-up periods are desirable. As mentioned in the introduction, such aspects, as well as the short-term and long-term esthetic outcome, will be addressed in other reports from the premolar autotransplantation material in our department.

We are grateful to Dr Bjørn Bjercke of Oslo for his continued interest in the transplantation projects in our department and for his encouraging enthusiasm. The selection of transplantation records from the files of the Department of Oral Surgery and Oral Medicine, University of Oslo, by Dr Pål Barkvoll is also appreciated.

REFERENCES