Root length in transplanted premolars

Siv Myrlund, Eva Margrete Stermer, Bjørn Album and Arild Stenvik
Departments of Orthodontics, Maxilliofacial Radiology, and Maxillofacial Surgery and Oral Medicine, Faculty of Dentistry, University of Oslo, Oslo, Norway

Myrlund S, Stermer EM, Album B, Stenvik A. Root length in transplanted premolars. Acta Odontol Scand 2004;62:132–136. Oslo. ISSN 0001-6357.

The objectives of the present prospective longitudinal study were to establish the survival and success rates for premolars with partly developed roots transplanted according to a set protocol, and to analyze the effect of varying pre-surgery root development on final root length. Standardized periapical radiographs of 132 consecutively transplanted premolars were obtained at predetermined intervals over a 4-year follow-up period. Survival and success rates were calculated on the basis of presence of teeth and recording of defined radiological variables, respectively. Final root length was compared to normative metric data for root morphology. From the total sample, 54 patients with 68 transplanted premolars suitable for analysis of root growth relative to initial root length were identified, and divided into subsamples according to root length pre-transplantation. Survival rates were 100% after 1, 2, and 3 years, and 98.6% 4 years post-transplantation. The success rates were 92.9%, 92.8%, 89%, and 90.5% in subsamples collected 1, 2, 3, and 4 years after transplantation, respectively. The transplants obtained on average 78% of normative root length, and by dichotomizing the transplanted teeth in subsamples with 'short' and 'long' roots pre-surgery, similar final root lengths were observed even if 'short' roots had the greatest increase. Very early transplantation (roots <7 mm), however, tended to result in short final root length. It is concluded that the success and survival rates were comparable to results obtained in similar studies. Initial root length was a significant predictor of root length increase. Transplanting teeth with short roots is to risk short final root length. □ *Root growth; success rate; survival rate*

Siv Myrlund, Tannhelsetjenestens kompetansesenter for Nord-Norge, Strandveien 13, NO-9296 Tromsø, Norway. Tel. +47 77 78 84 15, fax. +47 77 78 83 74, e-mail. siv.myrlund@tromsfylke.no

Today, autotransplantation of teeth is one of the established treatment options available for growing individuals with missing teeth due to aplasia, traumatic loss, or other causes. A substantial number of articles on transplantation from Scandinavian countries have been published over the past 30 years (1–27). Only a few of these, however, have addressed the development and growth of the roots when immature teeth are transplanted before root growth is completed (2, 6, 18). Usually some increase in root length takes place, and it has been claimed that root growth is dependent on the stage of root development at the time of transplantation (2, 14). So far, the effect on root growth when immature teeth are transplanted at a very early stage compared to a late stage of root development has not been documented. Furthermore, the time when the root completes its development after transplantation has not been examined, and an answer to this question will have an impact on prognostic assessment and clinical protocols for post-surgery follow-up.

The aim of the present study was 2-fold: 1) To estimate the survival and success rates for transplantation of teeth according to an established protocol for such treatment at a university dental hospital with the purpose of providing evidence-based advice in decisions about treatment. 2) To analyse root development subsequent to transplantation in order to provide data that may serve as a basis for timing of transplantation and prognostic assessment post-transplantation.

Materials and methods

The material consisted of radiographs of all transplanted teeth, a total of 153, transplanted at the Faculty of Dentistry, University of Oslo during a predetermined period around 1990. The sample comprised 1 incisor, 20 molars, and 132 premolars. The present study is based on the premolar sample only. Since not all patients attended every follow-up visit, the numbers of transplanted teeth available for assessment of success and survival rates were 85, 70, 55, and 74 after 1, 2, 3, and 4 years, respectively. Numbers of teeth excluded after 1, 2, 3, and 4 years were 47, 62, 77, and 58, respectively, when teeth with missing data were excluded. The reasons for exclusion from the total sample of 132 transplanted premolars were because of non-compliance, missed appointments or patients moving from the area, missing and/or inadequate periapical radiographs at the different observation periods. The operations were performed at the Department of Maxillofacial Surgery and Oral Medicine. The teeth were transplanted according to a protocol described by Slagsvold & Bjercke (1). The donor teeth were placed out of occlusion in a normal position (no rotation) at the recipient site.

Periapical radiographs of the transplants were obtained at the Department of Maxillofacial Radiology according to a protocol established for the follow-up of transplanted teeth (Fig. 1). In order to obtain identical radiographs from each session, an impression of the occlusal area of the teeth

Taylor&Francis healthsciences

DOI 10.1080/00016350410006770

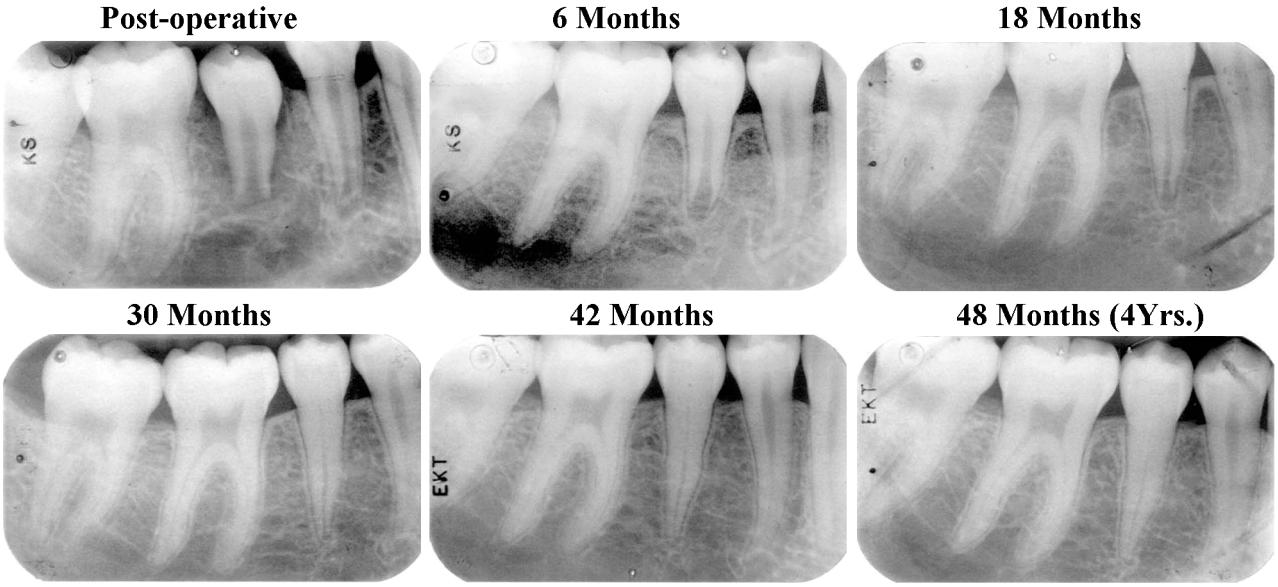

Fig. 1. Serial radiographs of upper second premolar transplanted to lower second premolar position obtained at various intervals postoperatively.

adjacent to the recipient area was made pre-operatively. This device was stored and used on every subsequent radiographic examination. The survival rate was calculated from the number of teeth present at the different time intervals after transplantation in relation to the total number of transplants at risk at that interval. The definition of success was based on the absence of the following sequela to the transplants as seen in radiographs: (a) sign of ankylosis, (b) root resorption, (c) evident pathology, and (d) short root (intra-bony root shorter than the crown) (24).

Final root lengts were assessed relative to normative data for the population (28). For the analysis of the association between pre-transplantation root length and root growth after transplantation, only premolars with radiographs 1 week postoperatively and 4 years after surgery were examined, and this subsample consisted of 68 premolars. For examination of root development, the material was divided into 2 categories according to root length at transplantation: Category I: 'Dichotomized subsample' (34 transplants with the shortest roots (<8.5 mm) compared to 34 transplants with longest roots (>8.5 mm)). Category II: 'Short versus long roots' (comparison of roots <7 mm ($n = 14$) with roots >10 mm ($n = 16$) at transplantation).

Radiological examination

The periapical radiographs of the transplanted teeth were mounted on transparent sheets and scanned into a computer (Dell Precision 410, 126 Ram, 4.2 GB, P2 400 Mhz with a Trinitron 21″ screen) with the aid of an AGFA Duo Scan and an AGFA FotoLOOK 32 V.3. During the scanning procedure, the sheets were stabilized with adhesive tape. Calibration of the scanned radiographs was performed at a dissolution of 150 PPI. The program

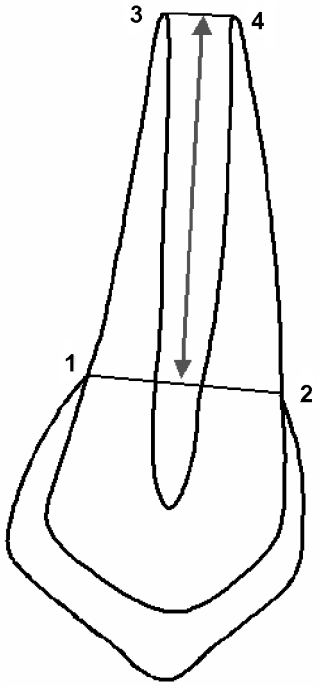

Fig. 2. Landmark used for root length measurements. The mesial and distal radiographic cementoenamel junctions (1 and 2) and the mesial and distal aspects of the radiographic root apex (3 and 4) are connected. Root length L is measured from the midpoint of line 1–2 to the midpoint of line 3–4.

Table 1. Survival and success rates for autotransplantation of partly developed premolars at the University of Oslo

No. of years after transplantation	Survival		Success		
	Total no. of teeth transplanted	No. of teeth present	Survival rate %	No of 'healthy' teeth	Success rates %
1	85	85	100	79	92.9
2	70	70	100	65	92.9
3	55	55	100	49	89
4	74	73	98.6	67	90.5

Table 2. Final root length and root length increase in relation to initial root length in a sample of transplanted premolars

	Initial root length in mm (mean ± *s*)	Final root length in mm (mean ± *s*)	Mean increase	Paired *t* test	*P* value
Category I (Dichotomized sample)					
root length <8.5 mm ($n = 34$)	7.2 mm ± 1.1	11.2 mm ± 2.3	4.0 mm	$t = -10.387$	<0.001
root length >8.5 mm ($n = 34$)	10.4 mm ± 1.5	11.9 mm ± 2.1	1.5 mm	$t = -5.151$	<0.001
Category II (Short vs long roots)					
root length <7 mm ($n = 14$)	6.0 mm ± 0.6	10.2 mm ± 3.0	4.2 mm	$t = -6.281$	<0.001
root length >10 mm ($n = 16$)	11.6 mm ± 1.3	13.1 mm ± 1.8	1.5 mm	$t = -3.322$	<0.005

s = standard deviation.

used to measure the root lengths was Olympus Micro Image version 3.0.00.00 for Windows 95/NT. The data were saved and stored using Microsoft Excel 97.

Measurement of root lengths

Root length was defined as the distance from the radiographic cementoenamel junction to the root apex (Fig. 2). The root length was measured with the aid of a measuring device incorporated in the Olympus Micro Image version 3.0.00.00 for Windows 95/NT program according to definition on intraoral radiographs. All the measurements from the periapical radiographs were obtained by the same examiner (SM). The first recording of the root length was made on the first periapical radiograph usually taken one week after the operation; the second recording was made on the periapical radiograph of the same tooth 4 years after the transplantation.

Measurement of reproducibility

A sample of 40 periapical radiographs was chosen at random. Radiographs were excluded if the apex was missing, if the cementoenamel junction was not visible, or if the root growth was not completed. To be included as one of the 40 radiographs, a neighboring tooth in which the apex and cementoenamel junction could be precisely identified had to be present. The measurement was made from the cementoenamel junction to the middle of the apical foramen, usually the mesial root of the first molar and the mesial side of single rooted teeth. The measurements were repeated twice within 6 weeks by the same observer (SM). The errors were calculated according to Dahlberg (29) and supplemented by the coefficient of reliability (%) described by Houston (30). The measurement errors of the root length estimated according to Dahlberg statistics and the coefficient of reliability were 0.25 and 89.6, respectively. Student's *t* test for paired samples for evaluation of systematic error was 0.25 (*P* value).

Statistical analysis

In addition to descriptive statistics, Student's *t* tests were performed to calculate *P* values for observed mean differences. The calculations were carried out with the aid of SPSS for Windows (release 10.0, SPSS, Inc.).

Error of the method

The mean of the difference between maximum and minimum value of the measured distance was 6.8 mm. The error of measurement was 0.58 mm and contributes to about 8% of the total variation in reproducibility of the radiographs. The intra-class correlation was high ($r = 0.89$).

Results

Survival and success rates are presented in Table 1. Root growth appeared to abate after 1 year and only a slight amount of root growth seemed to take place after that time. Annual mean root length increases were 1.9, 0.6, 0.5, and 0.2 mm after 1, 2, 3, and 4 years, respectively. On average, 78% root length was obtained when the premolar

Table 3. Survival and success rates data in previous studies on autotransplantation of premolars

Study	Observation period year (mean)	Age at follow-up (mean)	No. of transplanted premolars	Survival rate (%)	Success rate (%)
Slagsvold & Bjercke (2)	3–13 (6.2)	*	34	100	94
Kristerson & Kvint (5)	1–11.5 (4 yr 4 m)	10–64 (22.6)	52	*	80.8§ / 19.2‖
Kristerson (6)	3–18 (6.3)	*	100	93	*
Andreasen et al. (14)	1–13 (5)	9–31	317† / 53‡	95† / 98‡	90† / 60‡
Lundberg & Isaksson (19)	6 m–6 yr (5)	15.3† / 32.8‡	80† / 9‡	*	95† / 90‡
Present study	4	6.5–20 (12.3)	68†	98.6	90.5

* Not stated; Transplants with open apex † / closed apex ‡; Root development stage I-III § / stage IV–V‖ .

Table 4. Results from some studies examining root development after autotransplantation

	Andreassen et al. (14)	Lundberg & Isaksson (19)	Paulsen et al. (18)	Present study
Go on unimpeded	21%	3%	26%	19.1%
Impaired	65%	78%	55%	54.4%
Arrested	14%	19%	19%	26.5%

transplants were compared to normative data for premolar root lengths. In 19.1% of the transplants, root growth went on unimpeded, in 54.4% the growth was impaired, and in 26.5% growth was arrested. In the dichotomized subsample (Category I), the transplants which initially had the shortest roots (<8.5 mm) had a greater increase (4.0 mm) compared to the long roots (>8.5 mm), which increased on average by 1.5 mm after transplantation ($P < 0.01$). The final root length, however, was similar for both samples at 4 years follow-up (about 11.5 mm) (Table 2). When the subdivision in samples with a substantial difference in initial root length was made (Category II), the transplants which had long roots at transplantation were on average 3 mm longer after 4 years compared to teeth transplanted with short roots even if the short roots had a greater increase (4.2 versus 1.5 mm) ($P < 0.05$) (Table 2).

Discussion

The present longitudinal material is an opportunity to observe postoperative changes in transplanted teeth on the condition that measurements are reliable. Measurements on radiographs may be subject to variation caused by radiographic projection errors occurring during the recording procedure, errors related to the measuring process and errors in the landmark identification (30). Variation in the measurements arises from a combination of these three sources of errors. In the present study, the variation was within acceptable limits (below 0.6 mm), and thus the results of the study appear to be reliable.

As the transplants were transplanted in a non-rotated position, with no need for later orthodontic correction, positional changes of the transplants did not affect root length measurements. The reduced number of teeth in the study sample because of exclusion criteria and drop-out of patients is a weakness of the study.

The survival rate in the present study is comparable to figures from similar studies (Table 3). A study by Czochrowska et al. (27) reported a survival rate of 90% and a success rate of 79% in a sample of transplanted teeth, mainly premolars, after a mean observation time of 26.4 years (range 17–41 years) transplanted by a single operator. The future prognosis for the transplanted premolars in the present study seems promising in the light of these results. The various definitions of success in different studies imply that reservations have to be made in the comparison of results (Table 3). The general observation, however, is that surviving teeth are without iatrogenic changes.

Assessment of final root length has been made in other transplantation studies (2, 6, 14, 23). In the present study, the definition of impaired root growth was adapted from Andreasen et al. (14), and figures for unimpeded, impaired, and arrested root growth are comparable to results obtained by others (Table 4). Slagsvold & Bjercke (2) observed that final root length was only 10% shorter compared to *in situ* contralateral teeth, and similar studies support these findings (6, 14). The present findings that transplanted premolars attained 52–91% of normative root length is similar to the 58–98% attainment of expected root length reported by Andreasen et al. (14). In the present study, only limited root growth was observed after the first year, which is in agreement with findings from another study (25).

Initial root length was a significant predictor of root length increase as roots that were short initially had the greatest increase. In general, however, this had only limited effect on final root lengths. Accordingly, there may be a range of 8–10 mm in root length during which transplantation can be scheduled without the apparent risk

of deleterious effects on final root lengths. Transplantation of teeth with roots shorter than 6–7 mm, however, increases the risk for short roots long term. Protocols for referral of patients for transplantation should therefore include measurements of root length to ensure optimal timing.

Acknowledgements.—We express our gratitude to Professor Dagfinn Svanæs for his invaluable assistance and advice in digitalization of the radiographs and approach for measuring the root lengths. Berit Sollum, now deceased, gave excellent radiographic support.

References

1. Slagsvold O, Bjercke B. Autotransplantation of premolars. Gothenburg's Dental Association's Article series. 1967;351:45–85.
2. Slagsvold O, Bjercke B. Autotransplantation of premolars with partly formed roots: a radiographic study of root growth. Am J Orthod 1974;66:355–66.
3. Slagsvold O, Bjercke B. Indications for autotransplantation in cases of missing premolars. Am J Orthod 1978;74:241–57.
4. Slagsvold O, Bjercke B. Applicability of autotransplantation in cases of missing upper anterior teeth. Am J Orthod 1978;74:410–21.
5. Kristerson L, Kvint S. Autotransplantation of teeth: 10 years of experience. Swed Dent J 1981;73:598–606.
6. Kristerson L. Autotransplantation of human premolars: a clinical and radiographic study of 100 teeth. Int J Oral Surg 1985;14:200–13.
7. Schwartz O, Bergmann P, Klausen B. Autotransplantation of human teeth. A life-table analysis of prognostic factors. Int J Oral Surg 1985;14:245–58.
8. Kristerson L, Lagerström L. Influence of orthodontic treatment on root development of autotransplanted premolars. Am J Orthod 1986;89:146–50.
9. Sagne S, Lennartson B, Thilander B. Transalveolar transplantation of maxillary canines. An alternative to orthodontic treatment in adult patients. Am J Orthod 1986;90:149–57.
10. Nethander G, Andersson JE, Hirsch MJ. Autogenous free tooth transplantation in man by a 2-stage operation technique. A longitudinal intra-individual radiographic assessment. Int J Oral Maxillofac Surg 1988;17:330–6.
11. Andreasen JO, Paulsen HU, Yu Z, Ahlquist R, Bayer T, Schwartz O. A long-term study of 370 autotransplanted premolars. Part I. Surgical procedures and standardised techniques for monitoring healing. Eur J Orthod 1990;12:3–13.
12. Andreasen JO, Paulsen HU, Yu Z, Bayer T, Schwartz O. A long-term study of 370 autotransplanted premolars. Part II. Tooth survival and pulp healing subsequent to transplantation. Eur J Orthod 1990;12:14–24.
13. Andreasen JO, Paulsen HU, Yu Z, Schwartz O. A long-term study of 370 autotransplanted premolars. Part III. Periodontal healing subsequent to transplantation. Eur J Orthod 1990;12:25–37.
14. Andreasen JO, Paulsen HU, Yu Z, Bayer T. A long-term study of 370 autotransplanted premolars. Part IV. Root development subsequent to transplantation. Eur J Orthod 1990;12:38–50.
15. Sagne S, Thilander B. Transalveolar transplantation of maxillary canines. A follow-up study. Eur J Orthod 1990;12:140–7.
16. Nethander G. Periodontal conditions of teeth autogenously transplanted by a two-stage technique. J Periodontal Res 1994;29:250–8.
17. Nethander G. Oral restoration with fixed partial dentures on transplanted abutment teeth. Int J Prosthodont 1995;8:517–26.
18. Paulsen HU, Andreasen JO, Schwartz O. Pulp and periodontal healing, root development and root resorption subsequent to transplantation and orthodontic rotation: a long-term study of autotransplanted premolars. Am J Orthod Dentofac Orthop 1995;108:630–40.
19. Lundberg T, Isaksson S. A clinical follow-up study of 278 autotransplanted teeth. Br J Oral Maxillofac Surg 1996; 34:181–5.
20. Sagne S, Thilander B. Transalveolar transplantation of maxillary canines. A critical evaluation of a clinical procedure. Acta Odontol Scand 1997;55:1–8.
21. Nethander G. Autogenous tooth transplantation by the two-stage operation technique. An analysis of treatment factors. Acta Odontol Scand 1998;56:110–15.
22. Paulsen HU, Andreasen JO. Eruption of premolars subsequent to autotransplantation. A longitudinal radiographic study. Eur J Orthod 1998;20:45–55.
23. Josefsson E, Brattström V, Tegsjö U, Valerius-Olsson H. Treatment of lower second premolar agenesis by autotransplantation: four-year evaluation of eighty patients. Acta Odontol Scand 1999;57:111–15.
24. Czochrowska EM, Stenvik A, Album B, Zachrisson BU. Autotransplantation of premolars to replace maxillary incisors: a comparison with natural incisors. Am J Orthod Dentofac Orthop 2000;118:592–600.
25. Paulsen HU, Shi XQ, Welander U, Huggare J, Scheutz F. Eruption pattern of autotransplanted premolars visualized by radiographic color-coding. Am J Orthod Dentofac Orthop 2001;119:338–45.
26. Czochrowska EM, Semb G, Stenvik A. Non-prosthodontic management of alveolar clefts with 2 incisors missing on the cleft side: a report of 5 patients. Am J Orthod Dentofac Orthop 2002;122:587–92.
27. Czochrowska EM, Stenvik A, Bjercke B, Zachrisson BU. Outcome of tooth transplantation: survival and success rates 17–41 years posttreatment. Am J Orthod Dentofac Orthop 2002;121:110–19.
28. Frederiksen OG. The clinical average tooth's external and internal order of magnitude. Oslo: Universitetsforlaget; 1972.
29. Dahlberg G. Statistical methods for medical and biological students. London: George Allen and Unwin Ltd; 1940. p. 122–32.
30. Houston WJB. The analysis of errors in orthodontic measurements. Am J Orthod 1983;83:382–90.

Received for publication 7 January 2004
Accepted 5 March 2004