Long-term evaluation of autotransplanted maxillary canines with completed root formation

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Autotransplantation of 33 maxillary canines was followed up in 29 patients with an average age of 27.5 years. The mean follow-up period was 6.0 years. Endodontic treatment was performed in 23 teeth. Signs of root resorption were found in an increasing number of canines during the follow-up period. At the last examination eight canines showed no signs of resorption. External and internal resorption of inflammatory type were the most frequent forms of resorption and were also found to be the most hazardous factors for the prognosis of the transplanted tooth. Extraction of the transplant was necessary in four cases because of root resorption or poor bone regeneration. □ *Transplantation; periodontal membrane; resorption; radiology; endodontics*

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Several investigations have revealed the posttreatment results of autotransplanted canines (1, 14, 15, 17, 18, 21, 26, 27), premolars and wisdom teeth (4, 20). The prognosis for a successful autotransplantation has been considered to be determined by a number of factors. A better prognosis has been reported if the root development is not completed (2, 23). The position of the tooth and the extent and type of trauma at the operation are also important factors. A tooth impacted in a difficult position may require a complicated operation implying an increased risk of damage to the root cement and the adjacent periodontal ligament and hence a more doubtful prognosis (1).

Resorptive processes may be prevented by cultivation of the periodontal ligament and special treatment of the root surface (7, 23). The influence of the extraalveolar time and the way the tooth is stored during the extraoral time have also been discussed (9, 11). The time of immobilization is considered to be of importance for the extent of replacement resorption (6). Early endodontic treatment has been suggested to prevent degradation products and toxins from non-vital pulp tissue to penetrate into the surrounding tissues via the apical foramen, accessory canals or dentinal tubules. Such substances might initiate and maintain an inflammatory reaction in the periodontal ligament and resorption of the cementum (2, 3, 6, 12). Pulpal repair has often occurred in immature autotransplanted teeth (13, 21), while mature autotransplanted teeth have demonstrated a high incidence of pulp necrosis (1, 8, 21). A proper endodontic treatment may therefore lead to arrest of the resorption process (12), especially in teeth with completed root formation.

Autotransplantation of maxillary canines may, for many adult patients, be an alternative therapy to complicated orthodontic treatment or to surgical treatment combined with prosthodontics. To be able to offer alternative forms of treatment, it is important to know the long-term results of autotransplantation.

The aim of the present investigation was to elucidate the long-term results and the prognosis of autotransplanted maxillary canines with completed root development.

Material

The present study comprised a total of 33

maxillary canines with completed root formation in 29 patients referred to the orthodontic department. The canines were all impacted and in a difficult malposition, so that orthodontic treatment was either impossible or would have been complicated and time-consuming. The distribution of the canines is seen in Table 1.

The age of the patients at the time of autotransplantation varied between 16 and 54 years, with a mean age of 27.5 years. The distribution of the teeth with regard to age is shown in Table 2.

Twenty-three of the canines were impacted lingually in the bone, and the remaining 10 teeth had their crowns partly or totally within the dental arch.

Table 1. Distribution of autotransplanted maxillary canines

Tooth	♂	♀	Total
13	3	7	10
23	9	14	23
Total	12	21	33

Table 2. Number of autotransplanted maxillary canines in different age groups

Age, years	No. of teeth
16–19	3
20–24	19
25–29	1
30–39	5
40–	5
Total	33

Methods

Surgical and orthodontic procedure

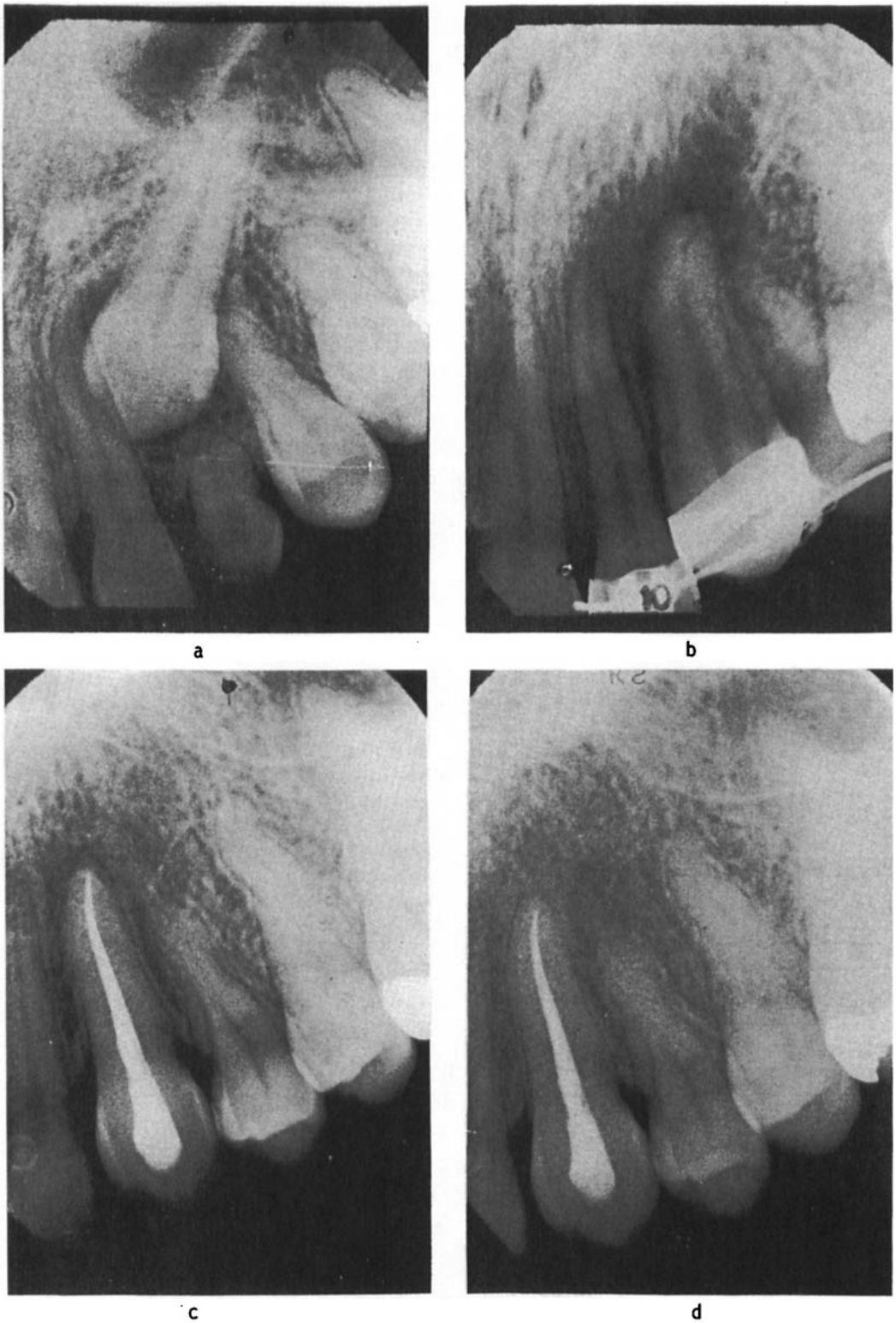
The autotransplantations were carried out at the Dental School, Karolinska Institute, Stockholm, during 1968–1973. The operations were performed under local anaesthesia (Xylocain® 2% with Adrenaline Astra, Södertälje, Sweden). A marginal incision was made on the palatal side from the maxillary third molar on the side of the retained tooth to the maxillary canine on the opposite side. If the operation was performed from the buccal aspect, a marginal incision was made from the second molar to the lateral incisor, where a vertical incision was made. After reflection of the mucoperiosteum, bone was carefully removed with a bur so as to make it possible to remove the tooth in toto and undamaged.

The removed canine was stored in physiological saline solution while the new socket was being prepared. This was done by extracting the existing deciduous canine when present and then enlarging the socket with a surgical bone bur. If no deciduous canine was present a new socket was prepared in the alveolar bone. The transplant was retained for 5 weeks with a splint or if a presurgical orthodontic treatment was necessary the transplant was banded and attached to a sectional arch.

Endodontic procedure

Endodontic treatment of the transplanted tooth was performed when the patient exhibited clinical symptoms or radiographic examination revealed signs of periapical inflammation and/or root resorption. All treatments were carried out under rubber dam in a strict aseptic manner. Necrotic pulp tissue and granulation tissue were removed from the pulp chamber and root canal, and the canal was cleaned mechanically to the apical foramen under frequent irrigation with 0.5% buffered sodium hypochlorite. Most canals had a temporary root filling of calcium hydroxide inserted for a period of time ranging from one week to two months. All root canals were examined bacteriologi-

Fig. 1a. Impacted maxillary canine with the primary canine persisting in a 18-year-old male. 1b. After the transplantation the canine was provided with an orthodontic band and attached to a sectional arch. Superior to the canine the original alveolus of the transplant can be seen. 1c. The canine is here seen 11 months after the transplantation and 6 months after the endodontic treatment. The periodontal membrane appears normal except for a minor widening in the apical area and an unsharp distomarginal root contour. 1d. The canine 6 years after the transplantation, still without obvious signs of resorption.


a
b
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cally by conventional techniques using a transport medium (27). When no clinical symptoms were present and root canal samples showed no growth, the canal was obturated by means of lateral condensation of guttapercha which had been slightly softened in rosin chloroform.

In a randomly selected group of 14 teeth an initial root canal sample was taken immediately as the pulp chamber was opened. For these samples a strict anaerobic technique was applied (12).

Radiographic registration

The patients were recalled periodically. The status of the transplanted canines was assessed by orthoradial, mesialexcentric and distalexcentric radiographs. The mean time of the periodical observations were 1, 2, 3.5, and 6.0 years after the time of transplantation (Fig. 1). All canines could not be assessed within each of the four periods for various reasons. Consequently 33, 29, 27 and 24 teeth, respectively, were radiographically examined at the four observation periods. The mean total observation period for all 33 transplanted teeth was 6.0 years, with a standard deviation of 2.3 years.

Radiographic examination

The following features were recorded at the examination of the radiographs.

Periapical status. 0 = normal periodontal membrane; 1 = widening of the periodontal membrane and/or osteolytic lesion < 2 mm; and 2 = periapical lesion > 2 mm.

Marginal bone height. The bone height was recorded mesially and distally in millimetres and expressed in percentage of the root length from the cemento-enamel junction to the apex of the root. When the marginal bone level was difficult to identify, the most inferior point of the septum within 1 mm from the root surface was chosen as marginal measuring point.

Root resorption. A. External apical resorption. Resorption, both of replacement and inflammatory type, was studied in the apical third of the root. The following grades were recorded: 0 = no resorption; 1 = root contour flattened and loss of tooth tissue < 1 mm; 2 = loss of tooth tissue > 1 mm.

B. External marginal resorption. Marginal resorption, both of replacement and inflammatory type, observed within the cervical third of the root was recorded using the following scores: 0 = no resorption; 1 = resorption lacunae, diameter < 2 mm; 2 = resorption lucunae, diameter > 2 mm.

C. Internal root resorption. Internal replacement and inflammatory root resorption was registerered as follows: 0 = no internal resorption; 1 = internal resorption lacunae, diameter < 2 mm; 2 = internal resorption lacunae, diameter > 2 mm.

Intraoral examination

At the intraoral examination the following features were assessed:

Gingival and periodontal status. Pocket depth was recorded mesially, distally, labially and lingually using a measuring probe.

Ankylosis. Ankylosis was evaluated by sound through a percussion test on the transplanted canine.

Aesthetic aspects. Aesthetic aspects of the transplanted tooth were evaluated with regard to colour and position in the dental arch.

Occlusion. Occlusion was assessed with respect to the presence of the interferences.

Vitality. The vitality of the pulp was tested by means of electric stimulation (Bofors Pulp Tester, PT-1).

Results

Periapical status

The number of teeth with widening of the periodontal membrane or periapical lesions decreased during the observation time. After the third examination period (3.5 years) no

periapical lesions > 2 mm were present. At 6 years after the operation 85% of the canines showed a good periapical status (Fig. 2).

Endodontic treatment

Within the observation period 23 of the 33 teeth were treated endodontically (70%). The time when the endodontic treatment was performed is presented in Table 3.

Ten of the teeth were treated because of root resorption or clinical symptoms. The remaining 13 teeth demonstrated a widening of the periodontal membrane or periapical lesion, ranging from about 3 mm to more than 10 mm in diameter. The pulps were necrotic in a majority of the cases (19 teeth). Only four of the teeth showed vague signs of vitality, in all cases associated with granulation tissue present in the root canal. One year after endodontic treatment no periapical lesion larger than 2 mm was present.

Of the 14 initially sampled root canals 13 showed growth. The cultures were generally mixed with a high prevalence of anaerobic microorganisms such as *Bacteroides, Fusobacterium, Veillonella*, anaerobic streptococci, and diphtheroids.

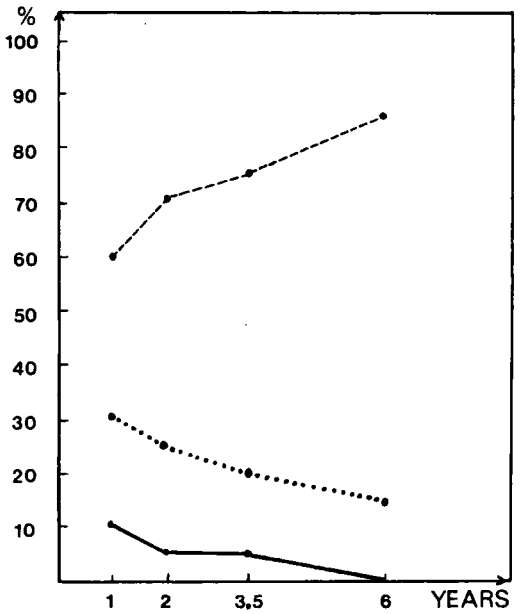


Fig. 2. Distribution of periapical status (percentage) of autotransplanted maxillary canines during the period of observation (years). Normal periodontal membrane (– – –); widening of the perical membrane (· · ·); periapical lesion > 2 mm diamter (——).

Table 3. Number of maxillary canines endodontically treated

	Years postoperatively					
	1	2	3	4	5	Total
No. of teeth	3	7	3	8	2	23

Marginal bone height

The bone height expressed in percentage of the total root length varied between 70% and 78%. No significant reduction in bone height was recorded during the observation period. Nor was there any significant difference between the bone height mesially or distally.

Root resorption

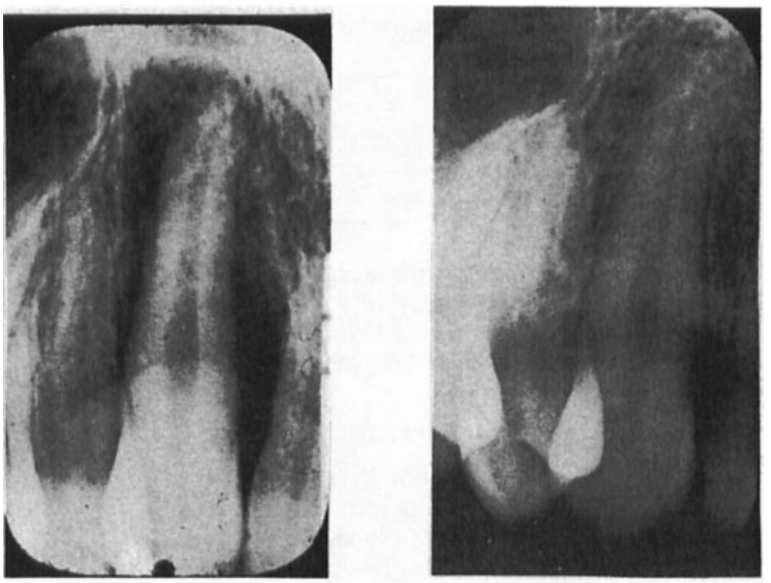
The number of teeth without any signs of resorption declined during the observation period (Table 4).

At the time of the last observation seven of the eight teeth were endodontically treated. The one tooth that was not root filled was vital and is shown in Fig. 3. Accordingly, among 25 canines the following sites and forms of resorption were present:

External apical resorption. Apical root resorption was present in 12 of the examined teeth. The resorption was generally of a small extent, and the onset of resorption was spread all over the observation period. After endodontic treatment the apical resorption showed no progress in five cases but slight progress in seven cases.

Table 4. Canines without any signs of root resorption. Number and years postoperatively

	Years postoperatively			
	1 year	2 years	3.5 years	6 years
No. of teeth	23	20	12	8



a b

Fig. 3a. Autotransplanted maxillary canine 3 months after the operation in a 25-year-old male. Note the defects in the alveolar bone mesially and distally. *3b*. Four years after the transplantation. The periodontal membrane and the lamina dura dentis have been reorganized. No signs of resorptions could be detected, and the tooth is still vital.

External marginal resorption. Marginal resorption was found in 12 teeth, mainly of inflammatory type. The number of affected teeth and the degree of resorption increased during the observation period and the time for the onset of resorption varied (Table 5).

Internal root resorption. Internal root resorption was found in 17 teeth during the observation period. The resorption was mainly of inflammatory type and of a small magnitude during the first years but increased during the follow up period (Table 6).

Eleven of the 17 canines were endodontically treated during the observation period. Nine of the teeth with internal resorption also showed signs of marginal surface resorption.

Extracted teeth

Four of the autotransplanted canines had to be extracted during the 6-year period due to poor post surgical healing or invasive external and internal root resorption. The extractions were carried out 3–5 years after the transplantation. All the extracted teeth belonged to patients who were younger than 25 years at the time of the operation.

Intraoral examination

Gingival and periodontal status. The gingival and periodontal status of the autotransplanted canines was closely related to the general oral status of the patient. No pathological pocket depth was recorded in any of

Table 5. Cumulative number of mesial and distal surfaces in maxillary canines with resorption scores for marginal surface resorption.

Resorption score	1 year		2 years		3.5 years		6 years	
	m	d	m	d	m	d	m	d
1	3	2	4	3	9	2	5	1
2	—	—	—	1	1	5	6	6

Table 6. Cumulative number of maxillary canines with resorption scores for internal root resorption.

Resorption score	Years			
	1	2	3.5	6
1	0	1	6	9
2	0	1	2	8

the patients or on any of the investigated surfaces. However, gingival recession lingually was noted in four cases.

Ankylosis. Ankylosis was present in all investigated canines.

Aesthetic and functional aspects. The majority of the canines were aesthetically pleasing as regards position in the upper dental arch, form and colour. A greyish colour was noted in five cases and hypomineralisation in four.

Occlusion

Facets of incisal attrition were noted in all the autotransplanted canines. In none of the cases did the canines exhibit occlusal interferences.

Sensitivity test. Positive response to electric stimulation was found in one case only.

Discussion

The position in the jaw and the developmental stage of the transplant are of great importance to the success of autotransplantation of teeth (1, 27). In the present investigation the 33 autotransplanted upper canines were all fully developed with a closed apex. Most of the teeth were located palatally and presented from a surgical point of view difficulties of access. When a tooth is extracted the trauma causes damage to the periodontal ligament tissue. This may influence the result of a transplantation. In this study external marginal resorption was found in 12 of the transplanted teeth and apical resorption was also seen in 12 teeth. These resorptions may be ascribed to trauma during the extraction or to inadequate space for the canine in the prepared alveolus (18). This view is supported by Andreasen, who found that external root resorption is associated with damage in the cementoblast layer of the root surface (8).

In this investigation 23 of the 33 transplanted teeth were treated endodontically. The endodontic treatment was performed when signs of infection, inflammatory resorption or clinical symptoms were observed. The pulp tissue was necrotic (19 teeth) or replaced by granulation tissue (4 teeth). In thirteen teeth periapical lesions were found on the radiographs. One year after the treatment the majority of the periapical lesions were healed. The teeth which were endodontically treated because of inflammatory root resorption showed arrest of the resorption. These findings correspond well with the results of earlier investigations by Andreasen (5) and Cvek (12) but are in contrast to observations by Moss (19), who reported that progressive apical resorption was impossible to stop, even with root treatment.

Bacteriological examination showed that 13 of 14 initially sampled root canals were infected. Since the crowns of the transplanted teeth were all intact, the microorganisms may have entered the canal through the apical foramen, accessory canals or, at a later stage, through perforating resorption defects, most likely via the socket. Under such conditions persistent population of the canal may result and bacterial enzymes and endotoxins (15, 22) may diffuse into surrounding tissues, contribute to inflammatory reactions and interfere with the healing of the periodontium.

The number of teeth with external root resorption increased during the observation period. The frequency of root resorption, both marginal and apical, in the transplanted teeth was about 75%, which is similar to that found in other investigations (1, 21). However, at the intraoral examination, ankylosis was found in 100%. It is possible that this figure is the most correct one for root resorption, as all small resorption lacunaes cannot

be seen radiographically. In the present investigation the onset of resorption was spread over the entire observation period, while Moss (19) found no resorption starting later than 3 years after the transplantation.

Internal root resorption was found in 17 teeth (55%), which is a higher frequency than Oksala & Kallioniemi (21) found. This can be explained by the difficulty to determine, on the radiographs, if the resorption is external or internal when it is located bucally or lingually.

It appears that changes take place in the transplant and surrounding tissue over several years. It was necessary to extract four transplants 3–5 years after the operation, because of continuously progressing inflammatory resorption and poor bone regeneration due to factors such as complicated surgical treatment and poor oral hygiene. A similar frequency of extracted teeth was found in studies of Nordenram (20) and Oksala & Kallioniemi (21).

In this study all transplanted canines had a closed apex. Positive response to electric stimulation was found in only one of the transplanted teeth, which is a lower frequency than other investigators have found (1, 19, 21). On the other hand, pulpal necrosis was found in all transplanted fully developed maxillary canines (13). It has been claimed that an open apex at the time of transplantation is a prerequisite for the maintenance of vascularisation (15, 24). According to other studies, however, revascularisation is possible in fully developed teeth (4, 20, 21).

The results obtained in this investigation indicate that upper permanent canines can be transplanted with good prognosis, even if the root apex is closed. Autogenous transplantation can therefore be undertaken at any age but may be more applicable to the older age group where orthodontic treatment has a comparatively poorer prognosis and, in addition, needs to be reduced to a minimum for aesthetic and social reasons. A careful surgical technique during the extraction and transplantation procedure and an early preventive endodontic treatment seems to be of great value in order to improve the prognosis.

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