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# Survival and success of maxillary canine autotransplantation: a retrospective investigation

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SUMMARY The aim of this study was to evaluate survival and success rates following autotransplantation of permanent maxillary canine teeth. Sixty-three cases of maxillary canine autotransplantation from 49 subjects (mean age at transplantation 21.8 years, range 13–42.1 years) undertaken between 1977 and 2003 were collected as part of an audit project of transplantation success. All maxillary canines had complete root development at the time of transplantation. The sample was divided into two groups, a matched case–control study to compare 27 unilateral transplanted canines with the non-transplanted canine on the contralateral side, and all 63 transplanted canines with no controls. Teeth were assessed clinically using established criteria for success: tooth presence for survival and resorption, mobility, probing pocket depth (PPD), gingival bleeding, vitality, and colour. Radiographic investigation for success assessed internal and external inflammatory resorption (including the amount) bone levels and any signs of pathology. Data were described with descriptive statistics and analytical tests were used to assess frequencies of occurrence.

The survival rate was 83 per cent with an average duration of 14.5 years *in situ*. Thirty-eight per cent of the transplants were deemed successful. There were statistically significant associations between the transplanted and non-transplanted teeth in PPD ($P$ = 0.006), gingival bleeding ($P$ = 0.006), vitality ($P$ = 0.004), and colour ($P$ = 0.002).

Autotransplantation of impacted maxillary canines can be successful in the long term and may be indicated in selected cases. Although the rate for complete success in this study was low (no signs of resorption, mobility, and sound periodontal tissues), the survival rate can be considered favourable when evaluating autotransplantation as a treatment option for grossly malpositioned canines with little scope for orthodontic alignment.

## Introduction

The maxillary canine is an important tooth within the dentition, having a role in aesthetics, lip support, and masticatory efficiency (Fagade *et al.*, 1988; Counihan and Hegarty, 1997). However, it is the second most frequently ectopic tooth in the dental arch after the third molar (Moss, 1972). Impacted maxillary canines affect approximately 2 per cent of the population (Ericson and Kurol, 1986), with 85 per cent of these teeth being situated on the palatal side of the dental arch and 15 per cent located buccally (Ericson and Kurol, 1987). Treatment options include observation and monitoring, interception, surgical exposure (with or without orthodontic alignment), autotransplantation, and extraction.

Observation and monitoring of an impacted canine are often carried out where treatment may be required later, or the tooth is grossly misplaced and attempts at removal may damage adjacent structures. However, the patient must be monitored for root resorption of adjacent teeth and development of any pathology during the observation period (Ericson and Kurol, 1988). Twelve per cent of incisors adjacent to palatally ectopic canines on radiographic examination and 48 per cent on computerized tomographic scan have been shown to have root resorption (Ericson and Kurol, 1987, 2000).

Interceptive extraction of the primary canine tooth to encourage spontaneous eruption of the permanent canine is frequently performed, although definitive evidence to advocate this procedure is currently lacking (Parkin *et al.*, 2009). Two studies have reported favourable normalization of canine position using this method in both uncrowded (providing the extractions are carried out before 13 years of age) and crowded (Ericson and Kurol, 1988; Power and Short, 1993) arches. However, the degree of crowding, extent of overlap of the canine on the lateral or central incisor, angulation, and height of the canine are all important predictive factors for success, and these need to be taken into account before a treatment decision can be formulated (Ericson and Kurol, 1988).

Surgical exposure of the canine and subsequent alignment can also be carried out using either open or closed techniques, the choice being determined primarily by canine position. Either technique can facilitate placing a bond on the tooth and the application of traction for extrusion and alignment (Hunter, 1983). Open exposure can also permit spontaneous eruption to occur, particularly when the canine is not severely displaced (Usiskin, 1991; McSherry, 1998).

Autotransplantation involves atraumatic surgical removal of a tooth from its impacted or ectopic site, the creation of a socket at the donor site, and then reimplantation of the tooth into the correct position within the alveolus. The success of autotransplantation is thought to be determined by a number of factors, which include patient age, developmental stage of the transplanted tooth, type of tooth transplanted, surgical technique employed, and extra-alveolar time span before the tooth is transplanted (Kristerson, 1985; Kallu *et al.*, 2005; Kim *et al.*, 2005). However, the presence of healthy and viable periodontal ligament (PDL) cells on the root surface is a critical factor for healing and long-term success (Andreasen, 1981).

A number of factors may lead a clinician to consider autotransplantation for an impacted maxillary canine, e.g. teeth that are markedly displaced and a reluctance of the patient to wear orthodontic appliances or undergo prolonged treatment to accommodate the canine with orthodontic traction. Other factors include the presence of adequate space for transplantation within the arch, poor prognosis associated with the primary canine, good prognosis for the transplanted tooth (no evidence of ankylosis), and the potential for atraumatic removal maintaining the viability of the PDL (McSherry, 1998; Thomas *et al.*, 1998; Kallu *et al.*, 2005).

The purpose of this retrospective study was to evaluate the long-term success of autotransplanted maxillary canines with closed apices and ascertain the survival and success rates associated with this procedure. Previously established criteria for success was used to assess the autotransplanted canines: presence of canine, radiological signs of resorption, mobility, probing pocket depth (PPD), gingival bleeding, vitality, and colour (Kristerson and Lagerström, 1991; Kugelberg *et al.*, 1994).

## Subjects and methods

A total of 191 patients who underwent autotransplantation of impacted maxillary canines with closed apices between 1977 and 2003 at Queen Mary's Hospital, Sidcup, Kent, UK, were contacted by post and invited to attend for clinical and radiographic assessment to evaluate the long-term success of these transplanted teeth. Fifty-six patients (29 per cent) responded to the postal correspondence, with seven unable to attend the department but reporting that the transplanted tooth was still present. These subjects were excluded from the study, leaving 49 patients (26 per cent) able to participate. Thus, a total of 63 transplanted maxillary canines from 49 patients over a 26.6 year time period were included. The average age of the patient at the time of transplantation was 21.8 years (range 13–42.1 years). Eleven of these teeth had been extracted, leaving a total of 52 still present. A matched case–control study was also carried out for 35 patients who underwent unilateral transplantation of a canine, each participant contributing one transplanted and one non-transplanted tooth. Data were available for 29 of the 35 canines as six had been extracted and in two further patients, the non-transplanted control tooth had been removed.

The same surgeon, using an atraumatic technique, performed all surgery. A mucoperiosteal flap was raised, bone removed with a bur, and the tooth elevated and delivered. The donor site was prepared and the tooth transplanted and placed out of occlusion. A coe-pack dressing was placed and a splint was used to stabilize the tooth for 2 weeks. Antibiotics were given to all subjects post-operatively. All teeth were transplanted when root development was complete and no endodontic treatment was performed prior to or after implantation as part of the treatment plan. All transplantations were carried out as a single-step procedure similar to that previously advocated (Andreasen *et al.*, 1990a).

The following information was recorded for those subjects who attended:

1. Date of birth.
2. Tooth transplanted.
3. Age at transplantation.
4. Radiographs used for screening the tooth pre- and post-transplantation.

The transplanted teeth were assessed clinically and radiographically by the same examiner (SP) as part of a standard protocol and the radiographs were reassessed 4 weeks later to determine intra-examiner repeatability (Figure 1). Clinical examination of the patient involved assessment of the transplanted canine and comparison with the non-transplanted canine on the contralateral side in the matched case study (intra-individual comparison). In subjects with bilateral autotransplantation or loss of a contralateral non-transplanted tooth, data were recorded only for these teeth. The following clinical parameters were investigated for both transplanted and non-transplanted canines:

1. Recession measured to the cemento-enamel junction.
2. Tooth mobility (Miller's classification: grades 0–3. 0, physiological mobility; 1, abnormal horizontal mobility less than 1 mm; 2, abnormal horizontal mobility more than 1 mm; 3, abnormal horizontal mobility more than 1 mm and axial mobility (Andreasen *et al.*, 1990a).
3. PPD; recorded at six sites for each tooth with a graduated periodontal probe and an average of these values used to compare transplanted teeth with each other and with non-transplanted teeth.

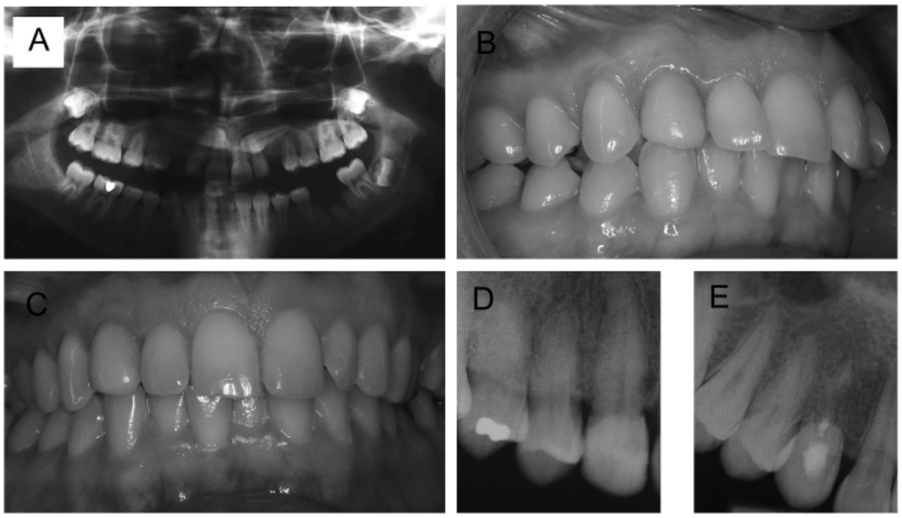


**Figure 1** Transplanted canines within the study. (A–D) Bilateral palatally impacted canines in a poor developmental position that were transplanted in a patient who declined orthodontic treatment. The clinical appearance is good and there is a lack of resorption. (E) An example of a transplanted canine demonstrating significant root resorption.

4. Bleeding on probing (presence or absence).
5. Percussion of the tooth for signs of ankylosis (and presence of tenderness).
6. Vitality testing with ethyl chloride.
7. The colour/shade of the transplanted canine was recorded and compared with the non-transplanted canine when '*in situ*'.

Radiographs taken prior to transplantation of the teeth were examined to confirm the presence of an open or closed apex and compared with the clinical notes to ensure the radiographic findings were consistent with the records. Post-transplantation radiographs were examined for the presence of internal resorption or external inflammatory root resorption (characterized by a loss of both cementum and root dentine), the extent of bone loss in relation to root length, and evidence of previous root canal treatment. Radiographic views that had previously been taken of the teeth included non-standardized periapical films and dental panoramic tomograms either pre- or post-transplantation. All radiographs taken following the clinical examination were long-cone periapical radiographs using the paralleling technique. For the transplanted canines, all pre-transplantation radiographs were available to confirm that root development was complete. A total of 40 post-transplantation radiographs were also available for examination.

### *Statistical analysis of the results*

The results were analysed using descriptive statistics. Analytical statistics were used to assess frequencies of occurrences using McNemar's test and the paired *t*-test for continuous data. A significance level of 5 per cent was used throughout.

## Results

The results are divided into two categories; firstly, the 63 autotransplanted maxillary canines and then the matched case–control study of 35 unilateral transplanted teeth and their respective non-transplanted counterparts. The overall survival rate was 83 per cent with an average duration of 14.5 years *in situ*. Thirty-eight per cent of the samples were deemed successful.

### *Transplanted canine data set*

The mean PPD of the transplanted canines was 2.24 mm (SD 0.93) with 81 per cent of these teeth bleeding on probing. Fifty-four per cent of the transplanted canines had a negative response to vitality testing with ethyl chloride and 6 per cent were judged to be tender to percussion. The majority of these teeth (83 per cent) were within normal limits for gingival recession, with the remainder demonstrating between 3 and 5 mm. Similarly, for tooth mobility, the majority of the transplanted canines were found to be within normal limits (Table 1). Sixty-three per cent of the canines retained their normal colour, while 19 per cent were darker. Eighteen per cent of these canines had been restored, either with composite, veneer, or a crown (Table 2). However, on discussion with the patients, all these teeth had been restored due to progressive changes in colouration. Discolouration was therefore associated with 37 per cent of transplanted teeth.

### *Case–control data set*

The mean PPD for transplanted canines within the case–control set was higher (2.33 mm; SD 0.97) than for the non-transplanted canines (1.76 mm; SD 0.85) and this

**Table 1** Tooth mobility of transplanted teeth.

| Mobility | Number of teeth (%) |
|---|---|
| Grade 0 | 44 (84) |
| Grade 1 | 5 (10) |
| Grade 2 | 2 (4) |
| Grade 3 | 1 (2) |

**Table 2** Tooth colour of transplanted teeth.

| Colour | Number of teeth (%) |
|---|---|
| Normal | 33 (63) |
| Darker | 10 (19) |
| Composite | 5 (10) |
| Veneer | 3 (6) |
| Crown | 1 (2) |

was statistically significant ($P$ = 0.006). In addition, transplanted canines bled on probing more readily than non-transplanted canines ($P$ = 0.006). Seventy-four per cent of the transplanted canines had a negative response to vitality testing and this was also statistically significant between the transplanted and non-transplanted teeth ($P$ = 0.004). In contrast, there was little difference in the amount of recession associated with transplanted and non-transplanted canines ($P$ = 0.38). Using the classification of Miller (1985) to assess relative mobility (Table 3), 23 of the 27 transplanted and all non-transplanted canines had no mobility, while only two transplanted teeth (and none of the non-transplanted) exhibited tenderness to percussion ($P$ = 0.50). Table 4 shows that just over half (14 teeth; 52 per cent) of the transplanted canines retained their normal colour, the remaining teeth had darkened and were treated with a crown, veneer, or composite restoration to mask the colour changes. A statistically significant difference existed between the groups ($P$ = 0.002, normal versus other categories combined). Within the groups, no teeth had been bleached. Survival times for the transplanted canines are shown in Figure 2. Amongst these, the tooth *in situ* for the longest time was 27.8 years and the shortest duration was 1.4 years. The mean duration *in situ* was 14.5 years.

*Radiographic results*

Intra-examiner repeatability of the radiographic findings was 94 per cent (32/34). The total number of radiographs examined was 40, of which six could not be assessed for root resorption, but records revealed that they had been previously root treated. These teeth were excluded from any analysis, which left a total of 34 canines. Three canines (9 per cent) showed signs of internal root resorption and two of these teeth had been root treated. Seven teeth (21 per cent) showed signs of external inflammatory root resorption and two of these (29 per cent) were root treated. Among the total sample, 22 canines had been root treated (65 per cent) and were still *in situ*. The majority of transplanted canines (94 per cent) presented with less than one-third of root length bone loss; however, the remaining 6 per cent demonstrated more than half, which can be seen as a sign of replacement resorption.

**Table 3** Evaluation of tooth mobility of transplanted and non-transplanted teeth.

| Mobility | Transplanted | Non-transplanted |
|---|---|---|
| Grade 0 | 22 | 27 |
| Grade 1 | 3 | 0 |
| Grade 2 | 1 | 0 |
| Grade 3 | 1 | 0 |

McNemar's test ($P$ = 0.06).

**Table 4** Evaluation of tooth colour of transplanted and non-transplanted teeth.

| Colour of tooth | Transplanted | Non-transplanted |
|---|---|---|
| Normal | 14 | 25 |
| Darker | 7 | 0 |
| Composite | 2 | 0 |
| Veneer | 3 | 1 |
| Crown | 1 | 1 |

McNemar's test ($P$ = 0.002).

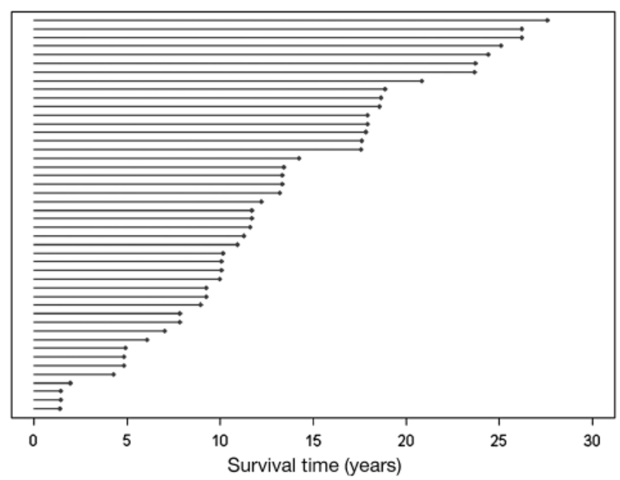


**Figure 2** Survival times of transplanted teeth.

## Discussion

This retrospective investigation analysed autotransplantation of maxillary canine teeth with closed apices carried out over a 26 year period. The response rate during sample recruitment was low and only approximately one-quarter of the potential samples were included, which may have led to bias. A major factor influencing response rate was almost certainly the time interval following transplantation; however, patients may also have failed to respond because of loss of the transplanted tooth and this would potentially have influenced the findings. The lack of intermediate assessment also meant that no information was available with regard to the development of complications in some of the transplanted teeth. The long-term and retrospective nature also resulted in some case notes and radiographs being unavailable for inclusion and therefore further sample wastage.

The criteria used for the assessment of success in autotransplantation are quite varied and range from the tooth simply being present intra-orally to present and completely free from resorption, discolouration, and pocketing, while maintaining vitality. This study used established criteria for the clinical assessment of both transplanted and non-transplanted teeth. The gingival and periodontal condition, tooth mobility, and radiographic assessment for root resorption were assessed in accordance with previous studies (Altonen *et al.*, 1978; Urbanska and Mumford, 1980; Hardy, 1982; Czochrowska *et al.*, 2002); the transplanted tooth still being present, with no signs of resorption or mobility and sound periodontal tissues, was determined a success.

Clinical examination revealed greater periodontal problems associated with the transplanted teeth, with statistically significant differences in PPD and bleeding on probing when compared with matched controls, findings consistent with other studies (Altonen *et al.*, 1978; Hardy, 1982; Chambers *et al.*, 1988; Schatz and Joho, 1993; Czochrowska *et al.*, 2002; Kallu *et al.*, 2005). However, the mean PPD for all the transplanted teeth was only 2.24 mm, which is considered to be within the normal range (Manson and Eley, 1995). There were no significant differences in the amounts of recession or mobility.

The majority of the matched transplanted maxillary canines were non-responsive to ethyl chloride. However, the total sample showed that approximately half were non-responsive. This can be explained by the lack of a control tooth for comparison, periodontal membrane transmission giving rise to positive readings in non-vital teeth (Hardy, 1982) or re-inervation, and vascularization of the tooth (Musselwhite *et al.*, 1997; Tsukiboshi, 2002). Ethyl chloride pulp testing is also not as robust as 'Endo ice' or electric pulp testing, although the presence of restorations can compromise the latter. In addition, it is generally considered that fully developed teeth are not expected to survive the trauma of transplantation (Hasselgren *et al.*, 1977) and that endodontic treatment should be implemented for optimal results (Andreasen and Kristerson, 1981; Chambers *et al.*, 1988; Andreasen *et al.*, 1990b; Tsukiboshi, 2002). However, the suggested timing of this endodontic treatment varies from before transplantation (Tsukiboshi, 2002) to 4 weeks post-transplantation (Andreasen and Kristerson, 1981; Chambers *et al.*, 1988; Andreasen *et al.*, 1990b) or when symptoms arise (Pogrel, 1987).

There was no statistical difference between the matched case–controls for tenderness to percussion, and within the transplanted teeth, only 6 per cent were tender. This was an expected result as symptomatic teeth would presumably have been treated with either root canal therapy or extraction. Statistical analysis for the matched case–controls involved only a small number of patients for the comparison of recession, mobility, and tenderness to percussion, and hence, the interpretation of the results is limited by the small sample size. Radiographic examination also revealed that the amount of bone loss associated with transplanted teeth was minimal; 94 per cent had normal bone levels and only 6 per cent had lost greater than two-thirds of bone.

This study shows a high rate of resorption in comparison with the findings of others, which could be due to the longer mean observation period (Akkocaoglu and Kasaboglu, 2005; Kallu *et al.*, 2005) and older mean age at transplantation (Kallu *et al.*, 2005). The stage of root development of a transplanted tooth seems to be an important factor in predicting success (Kristerson, 1985; Kallu *et al.*, 2005). Modified surgical techniques to ensure the atraumatic removal of these teeth may have increased the success rates of transplantation; however, as there are few long-term studies, it is difficult to accurately determine success. Patient age at transplantation has been reported to be important, the younger the patient the greater the chance of success (Fagade *et al.*, 1988; Schatz and Joho, 1993). The mean age of the patients at the time of transplantation of the teeth in this study was 21.8 years. This is reported to have a lower success rate than those carried out at an earlier age when root development is ideally only half to three-quarters complete (Kristerson, 1985).

Among the surviving teeth, the longest duration was 27.8 years and the shortest 1.4 years, with an average of 14.5 years. Transplantation is not usually the first line of treatment for patients with impacted canines; however, in the light of an average survival of 14.5 years for 83 per cent of the transplants, it should be considered as an option. The use of autogenous transplantation as an alternative for both osseointegrated implants and resin retained brides can be assessed by comparing success rates and survival times for each procedure. The benefits of autotransplantation include the provision of a biological replacement tooth that retains the potential to induce alveolar bone growth, maintains proprioceptive function and a normal PDL, is able to erupt with neighbouring teeth during continued facial growth, maintains a normal interdental papilla, and can be moved orthodontically (Zachrisson *et al.*, 2004; Kim *et al.*, 2005). In comparison, implants are an artificial replacement, which may require alveolar bone grafting if the bony support is insufficient, are osseointegrated and non-adjustable after placement and thus do not adapt to facial growth (Salinas *et al.*, 2004; Zachrisson *et al.*, 2004). In addition, aesthetics of the gingival papilla can be compromised, especially with placement of two adjacent implants (Kokich, 2002; Salinas *et al.*, 2004). The failure to obtain adequate aesthetics when aligning impacted or ectopic canines can also be an important factor when considering treatment options. Surgical exposure and alignment can lead to resorption of the adjacent teeth, poor gingival margins, loss of periodontal support, ankylosis, and protracted treatment times; all these factors would need to be considered before definitive treatment is proposed (Hunter, 1983; McSherry, 1998; Burden *et al.*, 1999).

With the introduction of osseointegrated implants and advanced dental adhesives for resin retained bridges, autotransplantation has increasingly been overlooked as a treatment option; however, both these restorative options can have problems associated with them. Implants should ideally be placed after growth is complete (Thilander *et al.*, 1994; Kokich, 2002; Zachrisson *et al.*, 2004) and resin bonded bridges have variable success rates (Priest, 1996). Indeed, Djemal *et al.* (1999) found a median survival rate of 7 years 10 months for all adhesives bridges. An important question is whether a role for maxillary canine auto-transplantation still exists, particularly when reported success rates for osseointegrated implants range from 79.2 to 98.5 per cent over a 4–8 year period (Lee *et al.*, 2000) and when non-invasive resin retained bridges can be re-cemented or replaced without deleterious effects on adjacent teeth. This study found that 38 per cent of autotransplanted canines were successful, displaying no signs of resorption or mobility and sound periodontal tissues, while 83 per cent were still *in situ*. These teeth were transplanted with closed apices and were still present on average after 14.5 years. This is comparable to a 79.2–98.5 per cent survival rate for osseointegrated implants over a 4–8 year period (Lee *et al.*, 2000) and better than the survival rate of less than 10 years for resin retained bridges (Priest, 1996; Djemal *et al.*, 1999). However, even with this comparable survival, a success rate of 38 per cent must be regarded as low, especially when single-tooth implants are associated with success rates of 90 per cent or more (Salinas *et al.*, 2004). However, there are currently few long-term studies evaluating implant performance in the maxillary canine region.

## Conclusions

Autotransplantation of impacted maxillary canines may be indicated in selected circumstances, but a low long-term success rate should be expected. Individual success is difficult to predict and patients must be informed of the potential for failure and associated risks before undergoing such a procedure. Autotransplantation of canines should be considered in patients who are unwilling to undergo lengthy orthodontic treatment to accommodate ectopic canines, particularly if there is an otherwise mild malocclusion as this approach could obviate the need for orthodontic treatment. The procedure is technique sensitive and success rates are higher in teeth with open apices. Autotransplantation can be considered as an interim measure to maintain bone levels during facial growth prior to the placement of osseointegrated implants.

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