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# Autotransplantation of Teeth: Is There a Role?

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**Abstract.** *Autotransplantation of teeth, if carried out successfully, ensures that alveolar bone volume is maintained due to physiological stimulation of the periodontal ligament. Autotransplantation has been carried out for many years, but with varying success rates. As a result, it is seldom regarded as an appropriate treatment option for patients with missing teeth especially with the continued development of osseo-integrated implants. Since placement of osseo-integrated implants in growing alveolar bone is contra-indicated, transplantation of available teeth remains a suitable choice for replacing missing units in the young patient. The role of autotransplantation of teeth in several clinical situations, the clinical techniques involved and factors influencing success of the transplant are discussed. The aim of this paper is to underline the evidence based principles for successful autotransplantation and present the technique as a viable treatment option in present day orthodontic practice.*

*Index words:* Autotransplantation, Hypodontia, Osseo-integrated implants, Space management, Trauma.

Refereed Paper

Missing teeth, whatever the aetiology, present a problem to the orthodontist. Depending on the occlusion, orthodontic treatment may be necessary to close the existing spaces or redistribute the space available to accept a prosthesis, implant or transplant. Despite rapidly improving restorative techniques, a review of the literature by Priest (1996) reveals that failure rates for resin bonded bridges range from 10 per cent over 11 years to 54 per cent over 11 months. Despite the increasing use of osseointegrated implants in patients with missing teeth, their use is contra-indicated in growing patients. If implants are placed in patients with residual facial growth, infra-occlusion of the implant occurs as the implant becomes ankylosed to the alveolar bone (Thilander *et al*., 1994). Subsequent alveolar bone growth produces a poor aesthetic result. The potential for using autogenous transplanted teeth in children thus requires further consideration.

Autotransplantation may be defined as the transplantation of embedded, impacted or erupted teeth, from one site to another in the same individual into extraction sites or surgically prepared sockets (Natiella *et al*., 1970). Clinical case reports of successful autotransplantation first appeared in the 1950s when decayed first molars were replaced with transplanted immature third molars (Apfel, 1954; Miller, 1956). Since that time an increasing number of teeth, especially premolars and canines, have been transplanted. Evidence for the success of transplanting premolars and molars to the incisor region has been presented by Natiella *et al*. (1970) and Kristerson and Lagerström, (1991).

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## Orthodontic Treatment Options

Patients who present with missing teeth often require orthodontic treatment for aesthetic reasons. The treatment plan should be based on a comprehensive evaluation including the age of the patient, the occlusion, space requirements as well as the size and shape of adjacent teeth (Stenvik and Zachrisson, 1993).

### *Space closure*

Frequently, for patients with missing teeth, orthodontic space closure may be considered as an appropriate treatment option. Several factors need to be considered before embarking on this treatment plan. Orthodontic space closure of an upper central incisor space often produces unaesthetic results for two reasons. First, dental asymmetry is inevitable and, secondly, the decreased cervical width and height of the lateral incisor compared to the central incisor results in a poor gingival contour.

The maxillary lateral incisor is the second most common developmentally absent tooth, excluding third molars (Neal and Bowden, 1988). Orthodontic space closure may be considered to align the canines mesially into the lateral incisor spaces but this treatment has inherent problems (McNeil and Joondeph, 1973) as the canine is required for canine guidance for lateral jaw excursions in dynamic functional occlusion. The morphology, colour and gingival contour of the canine will often need restorative modification if this tooth is to simulate a lateral incisor.

Despite these obstacles, space closure in patients with missing teeth have several advantages. It removes the need for prosthetic replacement, associated problems of com-

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promised gingival health (Tuverson, 1970) and long-term financial cost. Perhaps, more importantly, the alveolar bone height is preserved.

*Space opening*

If partial space closure has occurred where teeth are absent, space may be orthodontically reopened to accept either a fixed or removable prosthesis, an implant or a transplant. Traumatized incisors and developmentally absent teeth usually present in young patients with remaining growth. With the uncertainty of resin bonded bridge failure and the unsuitability of implants, the use of autotransplantation of teeth should be seen as a viable alternative to prosthetic replacement and implants in appropriate cases. Space opening is the preferred treatment option in Class I malocclusions where an anterior tooth is lost and good buccal interdigitation exists. Space opening has several advantages over space closure. These include simpler orthodontic treatment mechanics, creation of a functional occlusion and improved aesthetics (Cooke and Scheer, 1983). Once the space has been created and a transplanted tooth is placed, there are added advantages as the transplanted tooth acts physiologically to maintain the shape of the alveolar ridge providing proprioceptive stimuli, unlike a prosthesis or an osseointegrated implant.

## Clinical Situations in Which Autotransplantation May have a Role

*Trauma*

Maxillary incisors are the teeth most frequently involved in trauma. There are several reports in which premolars were used to replace missing upper incisors in crowded dentitions (Bowden and Patel, 1990; Oikarinen, 1990). These authors suggest that autotransplantation maintains or restores alveolar bone volume and produces an aesthetic result (Fig. 1). If necessary a definitive single tooth implant may be placed once growth has ceased. This is often impossible to achieve if the alveolus atrophies beneath a prosthesis.

*Impacted or ectopic teeth*

Autotransplantation may provide a simplified and faster treatment option for patients with ectopic teeth. This is especially the case for adults who often reject the idea of


FIG. 1 (a–e) Two mandibular premolars in a crowded arch were transplanted into central incisor sockets following trauma to the 1|1. A fixed appliance was *in situ* for 6 months post-transplantation and despite the differences in cross-sectional crown morphology, the premolars underwent successful aesthetic restoration once the orthodontic treatment was completed. (*Courtesy of P A Cook, Leeds Dental Institute.*)

wearing an appliance to align an ectopic tooth, yet would benefit from this tooth in the line of the arch.

*Replacement of developmentally absent teeth*

Mandibular second premolars, and maxillary second premolars are amongst the most commonly reported missing teeth (Neal and Bowden, 1988). Premolars from one site e.g. crowded arch, may be transplanted to another site to replace developmentally absent premolars (Kristerson, 1985; Schatz and Joho, 1994; Fig. 2).

Autotransplantation of teeth has also been used in the dentoalveolar rehabilitation of cleft patients. Hillerup *et al.* (1987) describe four cases where teeth were transplanted into alveolar bone grafts in patients with cleft lip and palate. Three premolar teeth and an upper lateral incisor tooth were transplanted 4–20 months after the bone graft had been placed and followed up for a period of 4 years. In these cases, autotransplantation of a tooth into the cleft site appears to provide functional stimulation of the new alveolar bone thereby preventing atrophy of the graft.

Autotransplantation of teeth has also proved to be a useful way to treat patients who present late with cleidocranial dysplasia. Several authors (Davies *et al.*, 1987; Jensen and Kreiborg, 1992) have discussed the orthodontic and surgical management of these patients whom, at the time of presentation were too old to expect spontaneous tooth eruption. Autotransplantation of up to 14 permanent teeth have been carried out in one individual.

*Teeth of poor prognosis*

Autotransplantation has been used in the replacement of teeth of poor prognosis. In most cases the tooth to be extracted (due to caries or periodontal disease) is the first permanent molar. In these cases transplantation of third molars or premolars to the first molar site may be considered. Kristerson *et al.* (1991) investigated the outcome of replacing molars with advanced periodontitis by autotransplanted third molars in 18 patients over an 18–72-month period. After extraction of the molar, the granulation tissue and epithelium inside the flap were removed and autotransplantation of a third molar was immediately carried out. In 15 cases, the autotransplantation was successful.

## Tooth Selection

Teeth most commonly used for autotransplantation are premolars, canines, incisors (especially supplemental teeth) and third molars (Natiella *et al.*, 1970). Slagsvold and Bjercke (1978a,b), suggest that premolars are particularly suitable for autotransplantation to the upper incisor region as they are available in the younger patients. Mandibular first premolars are the first choice for transplantation to maxillary incisor region because of their favourable morphology, size, and single root canal. It may be necessary to rotate an autotransplanted premolar to increase the mesiodistal width. These teeth may be modified to simulate incisor teeth with restorative techniques, using porcelain veneers, composites or crowns. In some cases the palatal cusp of the premolar may require enamel reduction to prevent occlusal interferences.

In theory, although any tooth may be transplanted, the donor tooth should be of limited value in the dentition, e.g. a premolar in a crowded arch, or a supplemental incisor.

## Autotransplantation: Surgical Technique

The surgical techniques used in autotransplantation have progressively been modified and refined over the years. Good oral hygiene, self-motivation and a medical history that does not contraindicate transplantation (e.g. cardiac defects) are pre-requisites before this avenue of treatment is embarked upon. Andreasen *et al.* (1990a) carried out a long-term study of 370 autotransplanted premolar teeth to determine a standardised surgical procedure which optimised pulpal and periodontal healing. Although there are published variations for the surgical technique of autotransplantation the consistent message is one of a careful atraumatic surgical technique to maximally preserve an intact periodontal ligament. If Hertwig's root sheath is traumatised then future root growth is limited or inhibited, according to the severity of this trauma (Andreasen *et al.*, 1988). Evidence based transplantation techniques are combined in a 'protocol for transplantation' included at the end of this paper.

In some cases autotransplantation may not be possible as a one stage procedure. Two stage transplantation has been reported in which an ectopic canine was removed and initially stored in the buccal pouch whilst the recipient site was orthodontically reopened (Briggs and Burgland, 1974;

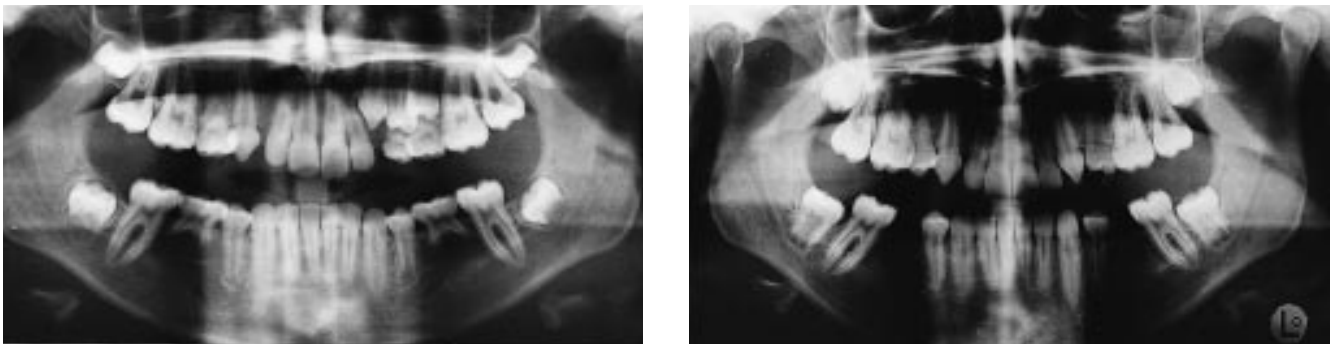


FIG. 2 (a–b) A Class II malocclusion with absent $\frac{54|}{5|5}$. A maxillary left premolar was transplanted into the contralateral side of the arch to replace one of the missing premolar units. Fixed appliances were used to correct the malocclusion and localise the spaces in the mandibular buccal segments to receive prostheses. The appliances were removed early due to lack of patient co-operation; however, an acceptable outcome was achieved.

Fig. 3). The potential problem of resorption of the transplanted tooth is minimized if contact between the tooth and periosteum is avoided during storage (Cobley and Roberts, 1987).

In some situations, there may be resorption of the alveolar ridge at the recipient site with insufficient bucco-palatal width to accommodate the transplant. In such cases, specialized investigative techniques (e.g. Scanora, CT tomography) may need to be carried out to ascertain the amount of bone present bucco-palatally. Alveolar bone grafting of the recipient site may be required prior to transplantation.

## Splinting

Once the donor tooth has been transplanted the tooth is usually held in position to promote periodontal healing. It is clear that rigid long term fixation of transplanted teeth may have adverse effects on the periodontal and pulpal healing of the tooth (Pogrel, 1987). Most reports advise flexible splinting for 7–10 days to be more appropriate as this allows for some functional movement of the transplant. It is suggested that this movement stimulates periodontal ligament cellular activity and bone repair (Sagne and Thilander, 1990). Splinting is not essential in autotransplantation but appears to be beneficial in most cases (Tsukiboshi, 1993). A suture may be used for stabilization to run across the occlusal surface of the transplanted tooth (Andreasen *et al*., 1990a; Kugelberg *et al*., 1994). In some situations, the stability of the transplant may be in doubt e.g. in trauma cases when premolars are used as transplants to the incisor region, bonded wires may be used for fixation for 1–2 weeks (Lagerström, 1997, personal communication).

## Endodontic Treatment

Loss of pulp vitality, poor periodontal healing and root resorption are complications of autotransplantation. These complications can be minimised if mature transplants are root filled within 4 weeks of transplantation (Andreasen and Kristerson, 1981; Andreasen *et al*., 1990c). Andreasen *et al*. (1990b) demonstrated that premolar transplanted teeth with incomplete root formation had a 95 per cent survival rate whilst premolar teeth with complete root formation, endodontically treated at 4 weeks, had a 98 per cent survival rate. Extra-alveolar endodontic treatment carried out at the time of transplantation increases the risk of subsequent root resorption as the root sheath is damaged during handling (Andreasen and Kristerson, 1981).

## Factors Contributing to Successful Autotransplantation

Successful transplantation is achieved when a tooth has normal periapical healing with neither inflammatory pulpal changes or progressive root resorption, and continued root development to maintain tooth function (Kristerson, 1985). Several factors known to contribute to the success of transplantation are now reviewed.

(a)

(b)

(c)

(d)

(e)

FIG. 3 (a–e) This patient presented with a Class I malocclusion and two unerupted maxillary ectopic canines. A two stage transplantation technique was carried out in which the ectopic canines were removed and initially stored in the buccal pouch. Fixed appliances were used to re-open the spaces to accommodate the transplants. The canines were then successfully transplanted into their correct positions and the appliances were removed 6 months later. (*Courtesy of D J Birnie, Portsmouth*.)

*Root maturity at transplantation*

Transplantation of teeth with immature roots produces high success rates. The results of a clinical and radiographic study of 100 autotransplanted premolars (Kristerson, 1985) revealed that transplants with half to three-quarter root development had the best prognosis for successful autotransplantation. A further study by Kristerson and Lagerström (1991) of 50 autotransplanted teeth, revealed a success rate of 87 per cent for teeth with immature roots (<70 per cent of normal root length) and 67 per cent for teeth with mature roots (these teeth were not root filled). Similarly, evaluation of transplants to the maxillary incisor region (after 4 years) show a 96 per cent survival rate with immature roots, whilst teeth with mature roots produced an 82 per cent survival rate (Kugelberg *et al*., 1994). Lundberg and Isaksson (1996) investigated the outcome of 278 autotransplanted teeth (molars, premolars, and canines) over a 6-year period. The study revealed a success rate of 94 per cent in teeth with open apices and 84 per cent of teeth with closed apices, the latter group being root filled within 3 weeks.

Although these studies suggest that greater success rates are achieved using teeth with immature roots, these teeth show less post transplant root growth than those teeth transplanted with more mature apices. Andreasen *et al*. (1990d), demonstrated that transplants carried out at the early stages of root development cause a reduction of post-treatment root growth compared to root growth in non-transplanted teeth. Most studies show that successfully transplanted teeth have a small, but usually insignificant reduction in final root length. Premolar transplants with immature roots have a reduction in root growth of up to 1·3 mm on average (Slagsvold and Bjercke, 1974).

Few studies have reported on the effect of orthodontic movement on transplanted teeth. Lagerström and Kristerson (1986) investigated the effect of orthodontic treatment on root development of autotransplanted premolars. This study compared transplanted premolars that had been orthodontically-treated with transplanted premolars that had received no orthodontic treatment. Contralateral teeth in both groups served as controls. Orthodontic treatment was carried out at least 6 months after transplantation. These authors found no statistically significant difference between the original and final root lengths of the transplants in the two groups or between the contralateral control teeth. However, they did find that transplanted premolars had a shorter root length (1–2 mm) compared to the control teeth. Orthodontic movement of teeth with completed root formation resulted in a slight increase in the frequency of surface and inflammatory root resorption (Andreasen *et al*., 1990c).

*Vertical occlusal height of the transplanted tooth*

Tooth germs transplanted at the original occlusal level at the donor site develop a longer root than teeth placed in a superficial, more occlusal position (Kristerson and Andreasen, 1984). Apfel (1950), showed that transplanted tooth germs placed in an erupted position did not develop roots. Most authors suggest teeth should be placed in the alveolus at the same occlusal level as that of the donor site. If the donor tooth has a mature root and is fully erupted, then it should be placed slightly below the occlusal level. For some patients where the mandibular canal is situated relatively high, or where the maxillary sinus is low, it is advisable to place the transplanted tooth further occlusally (Slagsvold and Bjercke, 1978b).

*Pulp survival and the size of the apical foramen*

Pulp survival is obviously an important factor for the completion of root growth. Kristerson (1985) demonstrated pulpal revascularization occurred in 100 per cent of cases of transplanted premolars with immature roots. However, the likelihood of revascularization and pulpal healing decreased with increasing root maturity. It is now established that the diameter of the apical foramen of the transplanted tooth is a significant factor in pulpal healing (Andreasen *et al*., 1990c). An apical foramen diameter greater than 1 mm decreases the risk of pulpal necrosis since revascularisation is more likely (Andreasen *et al*., 1990b).

*Promotion of periodontal healing and avoiding root resorption*

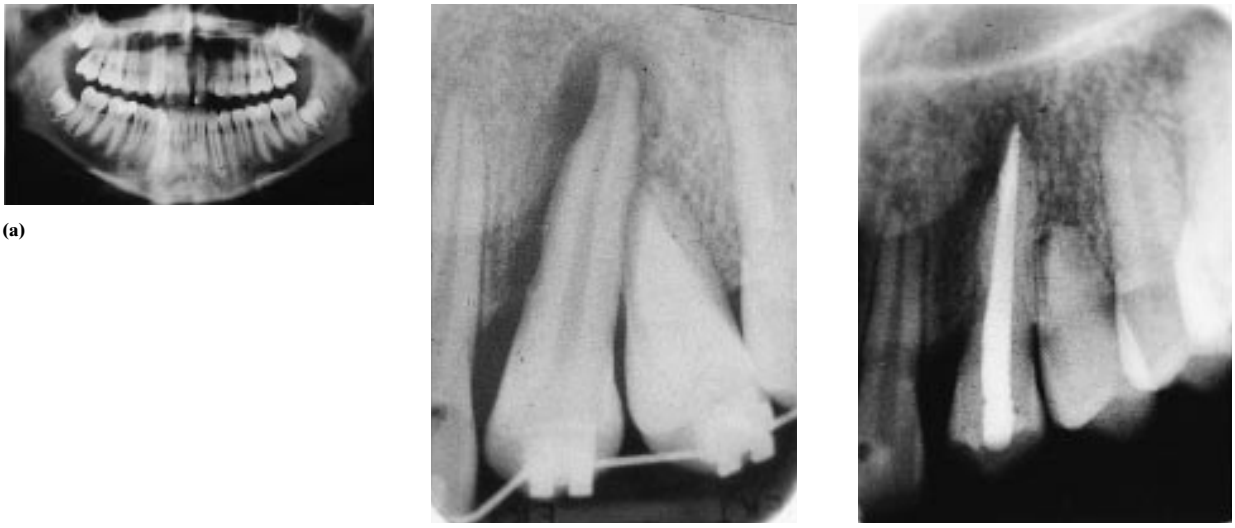
Successful periodontal healing is marked by the absence of root resorption and by the presence of a lamina dura. Periodontal healing is complete within two months in most cases (Andreasen *et al*., 1990c). Resorption occurs more frequently in transplanted teeth with mature root development compared to teeth with immature roots and may be detectable radiographically within 6 months of transplantation. (Andreasen *et al*., 1990c). Inflammatory resorption may be apparent at the 4-week stage on periapical radiographs and may be arrested if the transplanted tooth is root treated with calcium hydroxide (Andreasen *et al*., 1990c; Fig. 4). Ankylosis is diagnosed within the first year by radiographic appearance (loss of lamina dura) and a 'high metallic percussive sound'. Luxation of ankylosed teeth using small rotatory movements with extraction forceps under local anaesthetic may be successful in moving these teeth to a normal occlusal height. Alternatively, immediate orthodontic extrusion or restorative build-up of the transplant to occlusal height may be attempted (Andreasen *et al*., 1990c).

## 'Protocol' for Autotransplantation of Teeth

*Assessment of patient*

- History: medical history, and motivation/co-operation
- Examination: good oral hygiene, suitable donor tooth
- Special tests: intra-oral radiographs of donor and recipient sites.

Ideally, the roots of immature donor teeth, should have half to three-quarter root development (Kristerson, 1985). The recipient site should have adequate bucco-palatal bone to accommodate the transplant.



**(a)** **(b)** **(c)**

FIG. 4 (a–c) (a) Radiograph of a 15-year-old boy with a Class I malocclusion and absent |13. Fixed appliances were used to move the |2 mesially into the |1 region and a premolar with a mature apex from the crowded lower arch was transplanted into the |2 region. (b) There was a delay in carrying out the endodontic treatment resulting in root resorption. (c) The resorptive process was stabilized once the endodontic treatment was completed and this radiograph taken 1 year after root treatment revealed no evidence of further root resorption. (*Courtesy of P A Cook, Leeds Dental Institute.*)

*Surgical procedure*

- Sedation, local anaesthesia/relative analgesia/general anaesthesia.
- Prophylactic antibiotic cover for 7 days starting 1 hour prior to surgery.
- Recipient site should be prepared with a large round bur internally cooled with saline.
- Donor tooth should be removed atraumatically—contact with root surface should be avoided.
- Transplant donor tooth to a 'loose fit' into the recipient socket.
- Place the tooth at a level in the alveolus corresponding to its original pretransplant position (teeth with complete root formation should be left out of occlusion).
- Vicryl/silk suture (e.g. 4–0) 'splint' over occlusal surface and ensure there is a good gingival cuff.
- If stability of transplant is in doubt, e.g. in cases of trauma, wire fixation may be needed for 1–2 weeks.
- Chlorhexidine mouthwashes for 7 days.

*Follow-up*

- 1 week post-transplantation: suture removal and base line post-operative periapical radiographs.
- 4 week post-transplantation: teeth with completed root formation or signs of pathological changes start endodontic treatment with calcium hydroxide.
- If no pathological changes: see 12 weeks post-operatively.

12 weeks post transplantation: periapical radiographs and register; tooth position and mobility; percussion tone/tenderness; gingival condition and pocket depth.

- Long-term follow-up: electric pulp tests at 6 months, 1 year, 5 years, and 10 years.

*Long-term survival*

- Transplanted premolar teeth with incomplete root formation: 95 per cent 5-year survival rate (Andreasen *et al.*, 1990b).
- Transplanted premolar teeth with complete root formation (root treatment at 4 weeks): 98 per cent 5-year survival rate for premolars (Andreasen *et al.*, 1990b).
- Transplanted teeth with incomplete and complete root formation (root treatment at 3 weeks): 85 per cent survival rate (Isaksson, 1997, personal communication).

*Pulpal healing/periodontal health*

Transplanted premolars with incomplete root formation.

- Positive pulpal response in at: 8 weeks = 2 per cent, 6 months = 90 per cent, 1 year = 95 per cent (Andreasen *et al.*, 1990b).
- Stage of root development is the best predictor of pulpal healing. An apex diameter of >1 mm = low risk of pulpal necrosis. Pulp canal obliteration due to dentine formation is found in almost all teeth. However, 90 per cent still give a positive response to electric pulp testing.
- Most transplanted teeth show complete periodontal healing radiographically after 8 weeks (Andreasen *et al.*, 1990c).

*Root resorption*

- Risk of root resorption is greater with increased root development at transplantation.
- Inflammatory root resorption may be diagnosed at 1–2 months.

- Surface resorption and replacement resorption may be diagnosed radiographically within 1 year.
- Treatment of inflammatory root resorption is by pulpal extirpation and dressing with calcium hydroxide prior to conventional root filling.

*Root development subsequent to transplantation*

- In most cases if the transplant has immature root development a reduction in the final root length is seen because of trauma to Hertwig's root sheath.
- A transplanted tooth usually achieves less than half the expected post-transplant root growth and half to two-thirds root development is the optimum.

*Orthodontic tooth movement subsequent to transplantation*

- Post transplantation: in most cases wait a minimum of 3 months, but preferably 6 months before applying active orthodontic forces (Lagerström, 1997). Personal Communication.
- Orthodontic tooth movement of transplanted teeth with complete root development results in a slight increase in the frequency of both surface and inflammatory root resorption.

## Summary

Experimental and clinical studies have shown that missing teeth may be replaced successfully by autotransplantation. The vigorous attention to detail by Kristerson (1985) and Andreasen *et al.* (1990a) provides much of the information on which current clinical techniques for successful autotransplantation should be based. Future research into existing samples, (Andreasen *et al.*, 1990a) may strengthen current dogma and increase our confidence in choosing autotransplantation as an option especially in the growing patient. Successful autotransplantation of teeth with both open and closed apices may be the long-term goal, but in some cases transplantation may be an interim measure. A transplanted tooth ensures preservation of the alveolar bone and will facilitate future placement of an osseo-integrated implant once growth has ceased or if ankylosis/resorption of the transplant occurs. Autotransplantation is a technique sensitive procedure requiring forward planning. Success is more likely for teeth with immature roots; however, any suitable donor tooth may be used. The evidence demonstrates that the combined efforts of the surgical and orthodontic team is necessary for a successful outcome.

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