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Tooth transplantation after dental injury sequelae in children

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Abstract – Ten immature autotransplanted lower premolars from six patients from 7 to 12 years of age were studied and assessed clinically and radiographically at Regional Clinical Hospital in Temuco between January 2004 and April 2006. All transplantations were performed both because of a missing anterior tooth by dental trauma or by healing complications after injuries. The mean age at the time of the surgery was 10 years (range 7–12 years) and the postoperative follow-up period varied from 5 to 27 months with a mean of 16.9 months. All teeth were stabilized with flexible composite resin wire splints. Within the follow-up period, clinical evaluation was made through percussion and mobility tests. At radiographic evaluation, pulpal canal obliteration (PCO), presence of perirradicular area, inflammatory root resorption (IRR), replacement resorption (RR), stage of root development, *lamina dura* formation, outline of the periodontal membrane, and arrest in root growth were registered. Pulp healing was observed in 6 of 10 teeth; the other transplanted teeth developed pulp necrosis after 6–8 months possibly related to operative aesthetic procedures. Four teeth showed different grades of PCO at radiographic examination. None of transplanted teeth developed replacement resorption or ankylosis. In this 27-month follow-up period, the survival rate was 100%, regarding aesthetics, function, clinical appearance, and radiographic image of alveolar process.

In developed and developing countries where an significant decrease in dental caries is found, there is increasing interest in studying other oral health problems like dental trauma. Dental injuries are escalating all over the world, especially in school children and adolescents, because of a rise in recreational and sports activities. These oral injuries cause aesthetic, psychological, social, and therapeutic problems. They also affect a large number of people, causing irreparable dental loss not only at the accident time but also during post-treatment. Missing permanent teeth by trauma in children are a particular challenge, especially in the anterior region of the maxilla. This clinical situation is even more complex, considering that alveolar bone growth is not yet complete in these patients. Furthermore, they raise important phonetics compromise, detrimental mastication function, and aesthetics impairment. The treatment should adapt to both growth and developmental changes in the oral region to have the potential for long-term survival of the affected teeth (1). In the past few decades, tooth autotransplantation has been successfully researched for the treatment of anterior tooth loss in young individuals, especially when orthodontics space closure, fixed prosthetics, and implants are contraindicated (1–3).

Autogenous tooth transplantation or conventional transplantation may be defined as a transplantation or surgical movement of embedded, impacted or erupted teeth from one location to another in the same individual into extraction site or surgically prepared sockets (4, 5). Autotransplantation of developing premolars to replace missing anterior teeth in growing patients before the root is fully formed is now a common procedure and modality that has received increasing attention, because it has been shown to be a predictable substitution method with capacity for functional adaptation, potential for bone induction and preservation of the alveolar ridge, and re-establishment of a normal alveolar process (1, 2, 5). The autotransplantation procedure is indicated when there is a missing tooth by trauma or agenesia, or when the tooth presents a bad survival prognosis in a mouth where an appropriate donor tooth can be used without negative effects in the arch (3, 5–7).

It is well known that immediate tooth replantation after avulsion or before 15 min results in a favourable periodontal ligament healing. Also, pulp regeneration can be expected in immature replanted teeth (5). A similar healing process can be expected in well-planned tooth autotransplantation, with absence of pulpal and periapical inflammatory changes and progressive root resorption (3, 5, 6). The aim of the present study was to show the clinical, aesthetical, and radiographic evolution of 10 autogeneously transplanted teeth in six young patients of the dental service at regional clinical hospital of Temuco, Chile between January 2004 and November 2005.

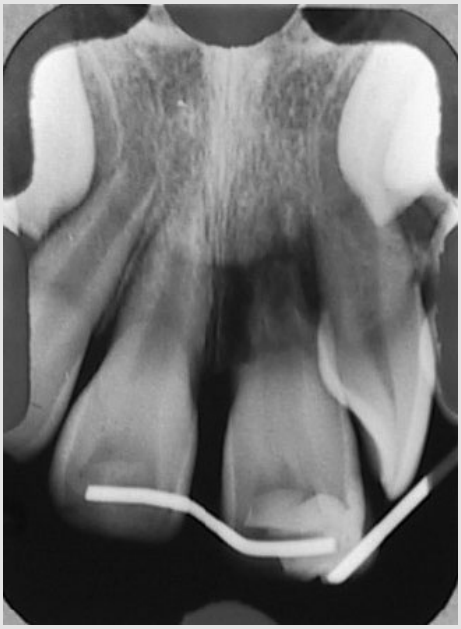
Material and methods

The research subjects consisted of six patients:one female and five male – from 7 to 12 years of age, attending The Regional Clinical Hospital in Temuco city, Chile, South America, in whom 10 mandibular

Table 1. Diagnosis of dental trauma in transplanted patients

No.	Patient no.	Age (years)	Tooth	DAT diagnosis
1	1	12	2.1	Root fracture + avulsion crown fragment. Not replanted (1)
2	2	11	1.1	Root fracture + avulsion crown fragment. Not replanted (1)
3	2	11	2.1	Avulsion. Not replanted (1)
4	3	9	1.1	Replanted + IRR (2)
5	3	9	2.1	Root fracture + no healing (2)
6	4	12	1.1	Root fracture + no healing (2)
7	4	12	2.1	Root fracture + no healing (2)
8	5	10	2.1	Replanted + IRR (3)*
9	6	7	1.1	Avulsion. Not replanted (1)
10	6	7	2.1	Avulsion. Not replanted (1)

DAT, dentoalveolar trauma; IRR, inflammatory root resorption.
(1): Teeth lost in the site of the accident.
(2): Rigid splint during 5 to 6 months.
(3): Rigid splint during 3 to 4 months; no endodontic treatment.



*Patient 5: Radiographic condition 3 to 4 months after the accident. Observe left upper maxillary central incisor with severe inflammatory root resorption, non-physiologic rigid wire-composite resin splint and absence of endodontic therapy.

bicuspids with different stages of root development were transplanted between January 2004 and November 2005. Transplantations were performed both because of missing anterior tooth by dental trauma or by healing complications after injuries. Details of dental trauma diagnosis in each patient are given in Table 1. All donor teeth were in different stages of eruption process. The pre-operative positions of the donor teeth and the locations of the respective recipient sites are given in Table 2. The mean age at the time of the surgery was 10 years (range 7–12 years), and the postoperative follow-up period varied from 5 to 27 months with a mean of 16.9 months.

Table 2. Pre-operative positions of the donor teeth and the locations on the recipient sites

Patient no.	Donor tooth	Recipient site
1	4.5: Second lower right premolar	2.1
	3.4: First lower left premolar	2.1
2	4.5: Second lower right premolar	1.1
	3.5: Second lower left premolar	2.1
3	4.5: Second lower right premolar	1.1
	3.4: First lower left premolar	2.1
4	4.4: First lower right premolar	1.1
5	3.4: First lower left premolar	2.1
	3.4: First lower left premolar	2.1
6	4.4: First lower right premolar	1.1

Intra-oral photographs and study models were used as documentations at pre-operative and postsurgery evaluation. All surgeries were performed by the same professionals, under local anesthesia and according to previous established protocol. The extra alveolar time of each donor tooth was less than 1 min, except in our first surgery, where the extra-oral time was less than 5 min. The transplanted teeth were stabilized with physiological wire-composite splints. The mean splinting time of transplanted teeth was 26.1 days (range 10–60 days). At the same day of the surgery, all patients began antibiotics regimen of Amoxicillin 500 mg, three times a day for 7 days and chlorhexidine mouth rinses twice daily. At 1, 2, and 4 weeks and 2, 3, 6, 12, 18, and 24 months after surgery, the patients were recalled for clinical and/or radiographic evaluation.

Each transplanted tooth was clinically and radiologically assessed by the same examiners. Intra-oral apical radiographs with bisecting angle technique (Equipment: Takara Belmont DX-068, Takara Belmont Corporation, Osaka, Japan; output 65 kVp–8 Ma) were taken for all transplanted teeth at the same hospital at the recall appointments. In five patients with tooth loss of upper maxillary central incisors because of trauma, tooth transplantations were used as part of an integral therapy with orthodontic appliances.

The following data at clinical examination control were recorded: percussion test, crown color change, and gingival status. Electrometric test for vitality was not made. Intra-oral radiographic evaluation was performed to assess pulpal canal obliteration (none, partial or total), radiolucency at perirradicular area (presence or absence), external root resorption (inflammatory or replacement), root development, *lamina dura* formation, outline of the periodontal membrane, and arrest in the root growth. Pulp healing was evaluated radiographically through signs of pulp canal obliteration. Pulp necrosis was considered to be present when there were radiographic signs of periapical radiolucency and/or inflammatory root resorption. Also, pulp necrosis was diagnosed when the pulp canal showed no signs of obliteration 6 months after transplantation.

Inflammatory root resorption was defined as the presence of bowl-shaped resorption cavities on the root surface associated with radiolucencies at the alveolar bone. Also, a pulp healing complication by pulp necrosis

was diagnosed when a transplanted tooth presented pathological mobility plus tenderness to axial and/or lateral percussion test and/or active fistula. Periodontal healing was also monitored by radiographic examination and was defined as successful when the entire root periphery was surrounded by newly formed periodontal space of normal size with an intact *lamina dura*. The criteria for clinical diagnosis of ankylosis was the presence of high metallic sound to axial and/or lateral percussion test and both the disappearance of the periodontal ligament space and its replacement by bone at the radiographic examination. The survival rate was calculated as the percentage of transplanted teeth still present and functioning well at the time of the recall examination relative to the total number of teeth that were transplanted. In this study a successful transplantation was defined as the one showing no root replacement resorption and/or high metallic sound to percussion test, no abnormal mobility, and no gingival inflammation at the recipient site.

Results

A total of six young patients were examined in whom 10 teeth were transplanted. These transplanted premolars were followed through different observation periods with a mean value of 16.9 months. In this follow-up period, the survival rate was 100% because all patients had their transplanted teeth functioning well and with normal appearance at the alveolar process at the last examination.

Pulp condition

All transplanted teeth presented immature root formation at the moment of the procedure; pulp healing was observed in 6 of 10 teeth; the other transplanted teeth developed pulp necrosis after 6–8 months apparently in relation to operative aesthetic procedures. Radiographic signs of pulp canal obliteration were observed in 40% of the transplanted teeth after 5–10 months (mean time 7 months). These teeth presented stage 3–4 of root development at surgery time. (Fig. 1). Electric vitality tests of transplanted teeth were not made because our service did not have Vitality Testers at the time of the study.

Four teeth showed radiographic and/or clinical signs of pulp necrosis after transplantation, therefore endodontic treatments were carried out. Teeth with pulp necrosis were detected between 6–9 months after transplantation. Radiographic signs of inflammatory root resorption were observed in one transplanted tooth. Endodontic treatment was indicated in four teeth: three teeth presented active fistula, and one tooth presented apical radiolucency with no signs of pulp obliteration 7 months after the surgery (Fig. 2). This treatment was successful as no pathological complications were evident at clinical and radiographic follow-up examinations. After composite resin aesthetic restorations, four teeth developed signs of pulp necrosis. In the youngest patient (a 7-year-old boy), two transplanted teeth with stage 3 root development, at the time of surgery did not present clinical or radiographic signs of pulp necrosis at the first 5 months of follow-up period examinations. All transplanted teeth showed no minor yellowish discoloration of the crown.

Periodontal healing and root growth

The majority of transplanted teeth showed partial or complete periodontal healing within 3–4 months after surgery. At radiographic control, they showed entire root periphery surrounded by newly formed periodontal space and intact *lamina dura*. (Fig. 3). One tooth with a 16-month follow-up period presented radiographic signs of internal periodontal ligament with bone formation in the last control. It seemed asymptomatic and had normal sound to percussion test. (Fig. 4).

Clinical and/or radiographic signs of ankylosis and replacement resorption were not observed in any of the transplanted teeth. At radiographic follow-up examinations, arrest of root formation was seen in three teeth after transplantation. During the time of the study, all of the transplanted teeth performed acceptably in their new positions. All of ten transplanted premolars were reshaped to incisor morphology, and patients were satisfied with the clinical appearance and aesthetics (Fig. 5). All transplanted teeth showed minor gingival immflamation at the recipient site. Radiographic and clinical recordings of healing conditions are showed and summarized in Table 3.

Discussion

The present manuscript describes 5–27 months follow up and the outcomes of 10 immature premolars transplanted in children. As the healing tissues after tooth transplantation procedure are the pulp, the periodontal membrane, and the alveolar bone of recipient site, our interest was focused on them, as they may be assessed by clinical and radiographic tools. Nowadays, it is well documented and well known that the primary indications for transplantation of teeth in children and adolescents are congenitally missing maxillary anterior teeth and accidentally lost by trauma (1–3, 5–7).

It is important to consider that not all patients with a missing anterior tooth present oral conditions for orthodontics closure or fixed prosthetics rehabilitation. In some patients, orthodontic space closure of maxillary central incisor has an unaesthetic result because of (i) dental asymmetry and (ii) decreased cervical width and height of lateral incisor that produce poor gingival appearance. Nevertheless, orthodontic treatment remains the best approach in the absence of skeletal or dental contraindications (4, 7). Fixed prosthodontics rehabilitation and resin-bonded prostheses in children and adolescents not always presents good results, and the long term outcome is not satisfactory over 5 years (1). Also, prosthetic rehabilitation may cause delayed aesthetic and functional problems (7). In comparisons with the above techniques, autotransplantation of developing premolars in young patients is probably the best long-term treatment alternative that should be planned with multidisciplinary equipment. (1, 2).

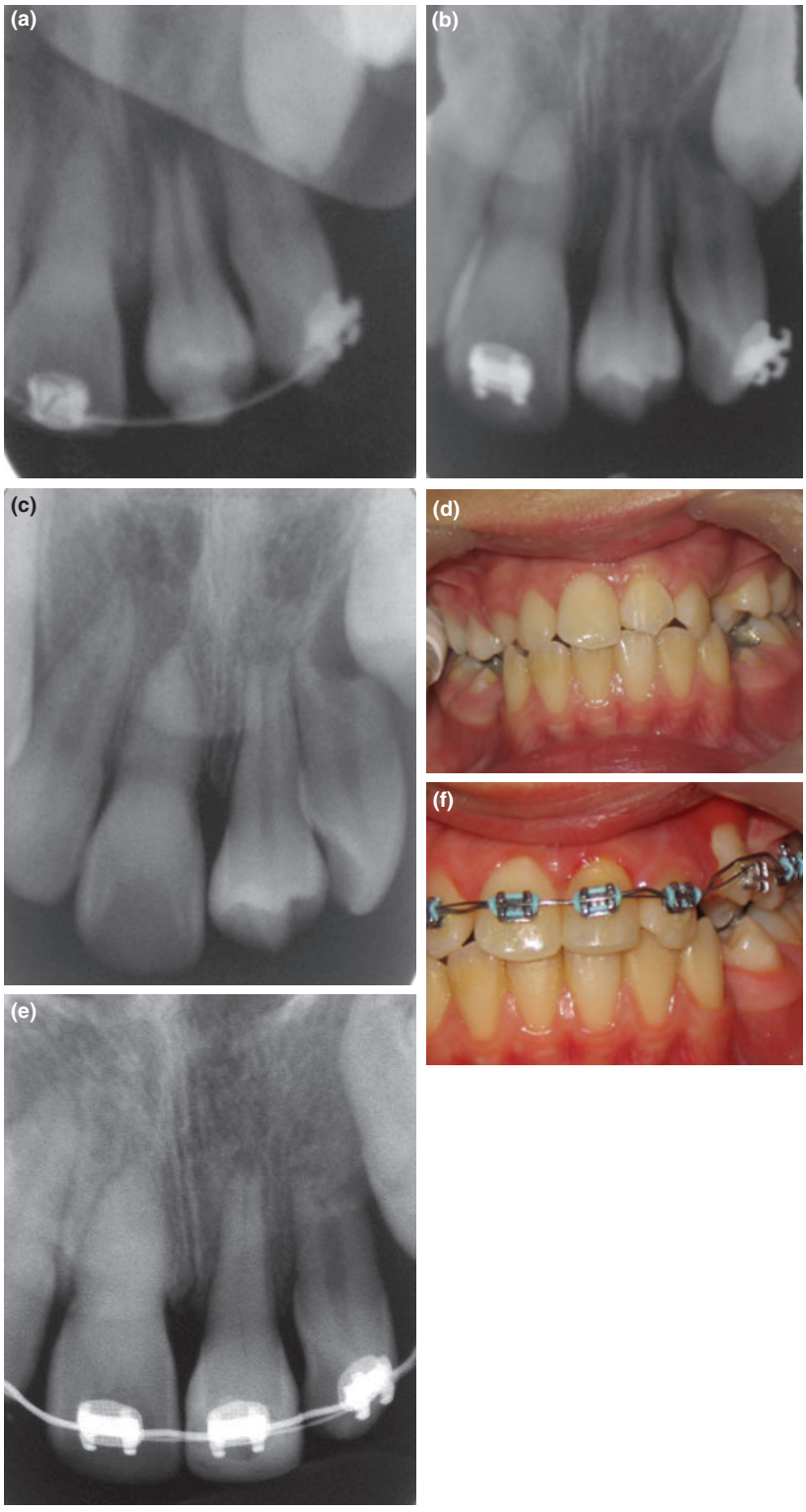


Fig. 1. Patient 2: Transplant of mandibular first premolar to left central incisor position. a) Conditions immediately after surgical procedure. Observe upper right maxillary central incisor with pulpal canal obliteration because of a lateral luxation 2 years ago. b) Four months after transplantation; note pulp canal space has become narrower. c) Six months after transplant; observe pulpal canal with partial obliteration and signs of arrested root development. d) Frontal view of transplanted teeth before aesthetic restoration. It presents normal sound to percussion test. e) Upper left maxillary central incisor (transplanted tooth) shows narrowing of the entire root canal, arrest in the root development and normal perirradicular appearance after 12 months. f) Frontal view; upper left maxillary central incisor (transplanted tooth) after aesthetic restoration and with orthodontic treatment.

The therapeutic alternatives depend on the (i) location of missing tooth, (ii) patient's age, (iii) stage of root development of potential donor teeth, and (iv) occlusion (1). On the other hand, there are several factors which will influence the results of a transplant to the maxillary upper zone: recipient site, space conditions, morphology and size of donor tooth, positioning of the transplant, and transformation of donor tooth to incisor morphology (8). Moreover, there is a big challenge in the treatment of young patients who present simultaneously missing maxillary incisors and malocclusion. In this clinical scene, how can we achieve aesthetic and

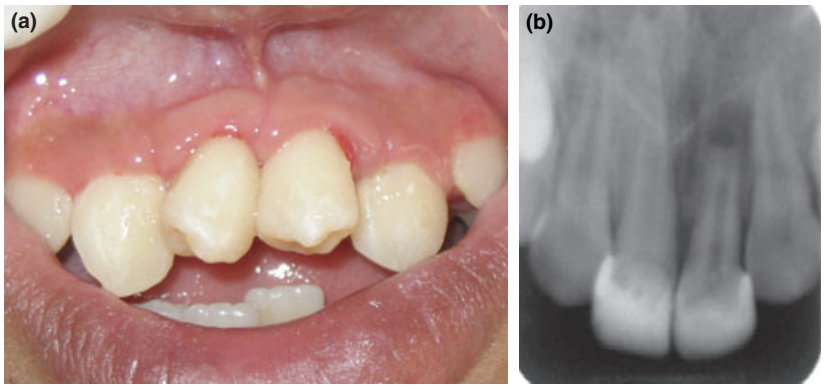


Fig. 2. Patient 4: a) Frontal view of two transplanted premolars at 1 month post-operative. The teeth were asymptomatic with no tenderness to percussion test. b) Transplanted upper left reshaped premolar with apical radiolucency and no signs of pulp obliteration 7 months after the surgery. Observe right premolar with signs of adequate pulpal healing and pulpal canal obliteration.

functional outcome in a long-term period? Tooth transplantation represent a biological approach, because induced alveolar growth has a normal periodontal membrane that can receive orthodontics strengths and its position can be changed in the arch. A previously established protocol for teeth autotransplantation is a very important step to obtain successful results; and it includes: clinical and radiographic examination, diagnosis, treatment planning, surgical procedure, endodontic treatment in some cases, orthodontic treatment, restorative treatment, and follow-up period (5).

This clinical and radiographic study showed that immature mandibular premolar transplantation to maxillary incisor region is a good treatment option to replace missing anterior tooth by trauma. It has been demonstrated that this treatment to upper anterior region may be a realistic alternative. Several studies have shown a predictable good outcome for this treatment in mature and immature premolars (1, 6, 9, 10). The optimal time for transplantation of premolars is when they have reached 2/3 to 3/4 the final root length (6). The survival and success rates of transplanted teeth varies depending on the type of transplanted tooth, stage of root development of donor teeth, surgical technique, the follow-up period, and methodology of the research (3, 5). Multiple criteria have been used to determine the success rate of transplanted teeth. In our clinical experience, we think that successful tooth transplantation is the one that does not present periapical inflammatory changes and/or progressive root replacement resorption, because one of the most important factors for the outcome of transplanted teeth is the periodontal ligament healing.

The transplanted teeth with immature root formation and open apex present a favorable condition for the healing process; it recovers vascularization. But in mature transplanted teeth, at stage 5 and 6 of root development, revascularization is rare and in those cases endodontic treatment is necessary and recommended within 3 weeks after the surgery (6). At stage 5 and 6 of root development, the apical foramen is small and there is risk of pulp necrosis.

The transplanted immature teeth with pulp revascularization always present different increasing degrees of pulp obliteration in time. Pulp revascularization and regeneration are expected when apical foramina presents at least 1 mm radiographically (5, 9). Generally, radiographic signs of pulp obliteration are observed within 6 months after surgery; these are in agreement with this sample, where it was observed between 5–10 months after procedure. (6, 9–11). The frequency of pulpal healing appears to be closely related to stage of root development at time of transplantation (9). Pulpal healing evaluated radiographically by the first evidence of pulpal canal obliteration appeared to be an earlier sign of pulp healing in immature transplanted teeth (10). This healing is related to ingrowths of connective tissue from the periodontal ligament into the pulp canal and chamber, and therefore is an important criteria for determining vitality in transplanted teeth (6, 11, 12).

Considering that all of the transplanted teeth had immature root formation at the moment of the surgery, and also with regard to the mean extra-alveolar time of donor teeth were less than one minute, the factors that are most likely to be the cause for pulp necrosis may have been an extensive pressure, heat, and dissecation with diamond and carbide burs during the aesthetic composite resin build-up. Dentine exposure may cause bacterial invasion resulting in apical periodontitis. The clinical importance of pulpal obliteration is the difficulty to perform endodontic treatment. In this study, three teeth needed endodontic treatment after crown preparation. The extra-oral storage period before transplantation appeared to be significantly related to pulp necrosis in mature teeth, but not in immature teeth (9). This extensive extra-oral time indicates excessive handling of the graft, difficult to adapt the donor tooth to the socket, and major risk of contamination.

Complete periodontal healing after majority of transplantation is observed radiographically 8 weeks after procedure (13). Replacement resorption is commonly mentioned as a serious complication of teeth transplantation; Andreasen et al. (13) and Czochrowska et al. (1) reported it in 5.7 and 6% of the patients, respectively. Failures or complications such as ankylosis and replacement root resorption of donor teeth are associated with damage to periodontal membrane during the surgery procedure (6, 14). Also, this healing complication could be related with stage of root development of donor teeth (13, 14). In the studies carried out by Kristerson (6), progressive root resorption was observed in 8% of the pats in teeth with immature root formation and in 48% in teeth with closed apex. The explanation could be that the immature teeth sometimes are easy to remove with gentile movements to preserve an intact periodontal

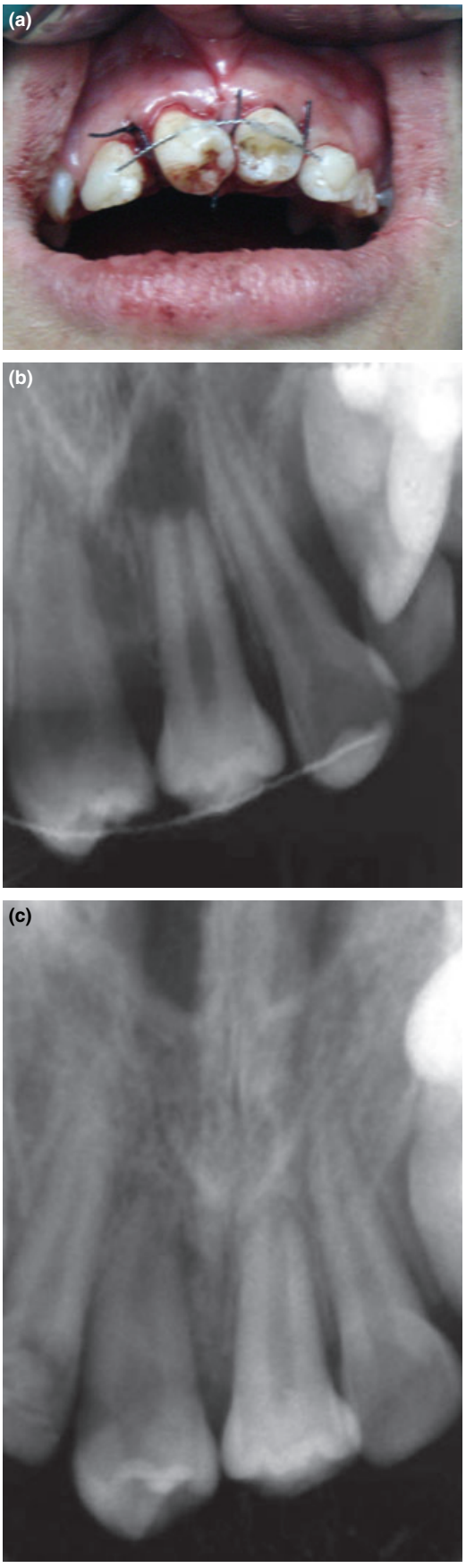


Fig. 3. Patient 3: a) Intra-oral photograph of a 11-year-old boy with two lower premolars transplanted to anterior maxilla. b) Immediate radiographic control. c) Radiography after 5 months; it shows two transplanted premolars with entire root periphery surrounded by normal size, newly formed periodontal space with an intact *lamina dura* and bone formation.

Fig. 4. Patient 3: In the same patient after 16-month transplantation, radiography shows internal periodontal ligament with bone formation. Both transplanted premolars present complete periodontal healing and no signs of replacement resorption.

membrane. According to Schwartz et al. (14), root replacement resorption is a healing phenomenon that needs a long-term follow up for survival evaluation in transplanted teeth and determination of control strategies seem mandatory. In this sample of 10 immature transplanted teeth, there were no clinical and radiographic signs of ankylosis; this successful outcome could be the result of (i) careful management of the transplant during the surgical procedure and (ii) good multidisciplinary planning.

The root growth can reach the final length when: (i) surgical procedure is performed under ideal conditions, (ii) Hertwig's epithelial sheet is preserved, and (iii) it is dependent on the stage of root development at moment of the transplantation (6, 9, 10). In the studies carried out by Paulsen et al. (13), the results indicated that the main factor that influenced the final root length in transplanted premolars was the stage of root formation at the time of the surgical procedure. In some cases of transplantation performed at early stage of root development, an important reduction in the final root length can be seen (13). According to Paulsen et al., the amount of root growth after transplantation is difficult to be predicted by the stage of root development of donor tooth. Moreover, the reduction of root growth could be because of trauma at periodontal ligament and root

Fig. 5. Patient 6: Pretreatment and post-treatment intra-oral photographs and radiography of a 7-year-old boy with lower right and lower left premolars transplanted to upper maxillary central incisors; clinical and aesthetical appearance. a) Absence of both upper maxillary central incisors. b) Radiography immediately after transplantation. Observe root formation of donor teeth. c) Frontal view before aesthetic treatment 4 months after surgical procedure. d) Reshaped transplanted premolars to incisor morphology by composite build-up.

Table 3. Ten immature transplanted premolars: healing conditions, radiographic, and clinical recordings

Patient no.	Age (years)	Donor tooth	Root development	Root resorption		Pulp healing			Root growth		Follow up (months)
				IRR	RR	PS	PCO	PN	Normal	Arrest	
1	12	4.5	4	+	–			+(1)	+		27
2	11	3.4	4	–	–			+(1)	+		27
2	11	4.5	4	–	–			+(1)	+		27
3	9	3.5	4	–	–	+	+(2)			+	16
3	9	4.5	4	–	–	+	+		+		16
4	12	3.4	4	–	–			+(3)		+	15
4	12	4.4	4	–	–	+	+		+		15
5	10	3.4	3–4	–	–	+	+			+	16
6	7	3.4	3	–	–	+(4)					5
6	7	4.4	3	–	–	+(4)					5

IRR, inflammatory root resorption; RR, replacement resorption; PS: pulp survival; PN, pulp necrosis; PCO, pulpal canal obliteration.
(1): Pulp complications after composite aesthetic restoration.
(2): Internal periodontal ligament with bone formation.
(3): Apical radiolucency with no signs of pulp obliteration seven months after the surgery.
(4): Composite rehabilitation 4 months after surgical procedure.

surface (13). In this study, the three teeth that showed arrest root formation were placed in function at moment the transplantation.

The aesthetic outcome of transplanted premolars to replace maxillary incisors requires particular attention by the clinicians, especially to assess: morphology, color,

gingival tissues appearance, and position in the arch with their natural contralateral. The outcome of transplanted premolars to upper maxillary incisor region may not be considered successful if the aesthetics is less than optimal; then an objective evaluation of the patient's judgment is needed. Multidisciplinary planning is important for successful aesthetic results (15, 16).

Conclusions

In the present study and according to this material:

1 Tooth transplantation of developing premolars in children had shown to be a real therapeutic alternative with good prognosis, especially when it is planned with multidisciplinary team.

2 Replacement resorption occurrence in transplanted teeth is a rare and infrequent healing complication, especially when surgical procedure is performed with adequate planning and according to previously established protocol. In this study, none of transplanted teeth presented ankylosis.

3 There are high probability of pulp revascularization and vitality in transplanted teeth, especially when donor tooth presents 2/3 to 3/4 of root formation and open apex at the surgical time.

4 It is very important to consider that the composite resin build-up of transplanted teeth should be made with gentile movement, adequate irrigation, and light pressure of the diamond/carbide burs onto the enamel and dentine, avoiding the risk of pulp necrosis development.

5 In summary, immature tooth transplantation in children with dental trauma sequelae is a conservative surgical technique for the management and replacement of loosened upper maxillary incisors and presents favourable prognosis in relation to other treatment modalities.

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