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Status of the alveolar bone after autotransplantation of developing premolars to the anterior maxilla assessed by CBCT measurements

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Abstract

Background/Aims: Autotransplantation of developing premolars is an established treatment to replace missing teeth in the anterior maxilla in growing patients with a reported success rate of over 90%. The normal shape of the alveolus is observed after transplantation, but data on the presence and amount of alveolar bone after healing has not been previously reported. The aim of this study was to look for potential differences in alveolar bone dimensions between sites where autotransplanted premolars replaced missing incisors and control sites of contralateral incisors.

Material/Methods: There were 11 patients aged between 10 and 12 years five months (mean age: 10 years and 7 months) who underwent autotransplantation of a premolar to replace a central incisor. Cone Beam Computed Tomography (CBCT) performed at least 1 year after transplantation served to evaluate bone at sites of autotransplanted premolars and controls (contralateral maxillary central incisor). The thickness of the labial bone, plus the height and width of the alveolar process were measured on scans and compared at transplant and control sites.

Results: Mean thicknesses of the labial bone at the transplant and control sites were 0.78 mm and 0.82 mm respectively. Mean alveolar bone height was 15.15 mm at the transplant sites and 15.12 mm at the control sites. The mean marginal thickness of the alveolus was 7.75 mm at the transplant sites and 7.98 mm at the control sites. Mean thicknesses of the alveolus for half of its vertical dimension at the transplant and control sites were 7.54 mm and 8.03 mm, respectively.

Conclusion: The mean values of bone thickness, width and height of the alveolar process at sites of transplanted premolars were comparable to the mean values for the control incisors. Successful autotransplantation of developing premolars to replace missing central incisors allowed preservation of alveolar bone in the anterior maxilla.

KEYWORDS
alveolar bone, autotransplantation of tooth, CBCT evaluation, premolar transplantation

1 | INTRODUCTION

Autotransplantation of developing premolars is a well-established procedure to replace missing teeth in growing patients.[1–10] The main clinical indication for the treatment is the replacement of missing teeth in a young individual in whom other treatment options (e.g. orthodontic space closure) are contraindicated because of the occlusal condition or it is impossible to implement before the cessation of growth and complete development of the neighboring dentition (e.g. dental implants and prosthetic bridges).[11–14]

According to numerous studies, the growth of the alveolar process, especially in the anterior maxilla is a continuing process which progresses long after the cessation of growth of the skeleton. This may result in esthetic failures of implant-supported restorations in the esthetic zone in young adult patients.[15–16] Young adults who have had dental trauma to the anterior maxilla are rarely suitable candidates for implant placement, even though the long-term maintenance of dental implants placed in optimal conditions is predictable in adult patients. Loss of a permanent maxillary incisor during the teenage years usually results in significant horizontal and vertical bone loss which deteriorates over the years.[17–19] Progressive bone loss may finally make it difficult or even impossible to place an implant without extensive bone regeneration procedures which would be possible only after young patients have eventually stopped growing. Many bone regenerative procedures and materials have been proposed to solve this problem but most studies have reported limited predictability and efficacy.[20–22] Additional surgical procedures may be required to augment the soft tissue at the site of implantation which make the treatment plan very complex, expensive, time consuming and vulnerable to complications and failure.

Considering all the above-mentioned factors, the aim of the treatment of a missing tooth in a young patient should focus not only on tooth replacement but also, or may be even above all, on treatment which can preserve and restore the natural alveolar bone at the site of a replaced tooth. Autotransplantation solves a problem of replacing a missing tooth and it is believed to maintain the alveolar bone at the same time. The study conducted by Andreasen[23] proved that the periodontal ligament could restore the labial bone after another type of surgical procedure – replantation of an avulsed tooth. Only several case reports have described the presence of bone at the site of autotransplanted teeth indicating the growth of new alveolar bone during healing and eruption of the transplant.[24–26] However only a few studies have documented the status of the alveolar bone after autotransplantation[27–29] whereas most studies have focused only on the survival of the transplanted tooth.

The aim of this study was to investigate the status of the alveolar bone after successful autotransplantation of developing premolars to replace single missing maxillary central incisors and to compare the dimensions of the alveolus at the site of autotransplantation with the contralateral unaffected/control site.

2 | MATERIAL AND METHODS

Thirty-eight developing premolars in 34 generally healthy patients were transplanted by a single operator (PP) between the years 2000 and 2015 to replace traumatized or missing maxillary central incisors. Eight bilaterally transplanted premolars (in four patients) were excluded from the study because no control site could be established. From the remaining 30 patients who underwent unilateral transplantation of a premolar to replace a single missing central incisor (30 teeth), there were only 11 patients who met the inclusion criteria i.e., they had a contralateral natural central incisor and a Cone Beamed Computed Tomography (CBCT) examination performed no earlier than one year after the transplantation. All the CBCT examinations were performed to evaluate the status and position of the transplanted tooth prior to initiation of orthodontic treatment and not for the purpose of this study.

The study group consisted of 11 autotransplanted premolars (7 mandibular and 4 maxillary) in 11 patients (6 males and 5 females).

TABLE 1 Baseline characteristics of patients (gender, age, type of donor tooth with stage of the root development at the time of surgery, and the recipient site)

Patient	Gender	Age at surgery	Donor tooth and its root development (according to Moorrees)	Recipient site: 11 –right upper central incisor 21 – left upper central incisor
1	Female	9 years 11 months	35 (3)	21
2	Female	10 years	45 (4)	21
3	Male	11 years 6 months	25 (4)	21
4	Male	12 years	45 (4)	11
5	Male	10 years	45 (5)	21
6	Female	10 years 11 months	15 (4)	21
7	Male	11 years	34 (4)	21
8	Male	12 years 5 months	45 (4)	11
9	Female	10 years 5 months	24 (4)	11
10	Male	10 years	34 (3)	21
11	Female	11 years 10 months	25 (5)	11

The age of the patients at the time of examination was between 10 years and 12 years 5 months (mean: 10 years 7 months) and the measurements were performed from 1 year to 14 years (mean: 4 years) after the surgery. The patients' demographics, data on donor tooth type and status of the recipient site are presented in Table 1.

The minimum 1-year follow-up period was considered to be a necessary time for healing of the autotransplanted premolar including completion of development of the roots. The transplanted premolars presented features of successful healing at the time of clinical and radiological examination.[2–4] No clinical symptoms of inflammation, no bleeding on probing and pockets depths within normal range were noted during clinical examination. The transplanted premolars had normal mobility and presented low sound during percussion tests, the features which indicated absence of ankylosis. No signs of pathosis were detected on the radiographs, and complete root development and root apex formation were present in all cases. Pulp canal obliteration of the transplant's root was observed as a typical finding in teeth transplanted with developing roots. All control contralateral central incisors (group of control teeth) were healthy and the pulps were normal. The maintenance of normal shape of the alveolus in the anterior maxilla has been clinically observed after autotransplantation of developing premolars to replace missing incisors.

Figure 1 presents the sagittal scans of a central incisor site at the time when the incisor was lost and a few months later (respectively Figure 1A,B) and then after the autotransplantation surgery (Figure 1C,D). The scans were extracted from CBCT examinations of one of the patients included in the study (patient No 11 in Table 1).

Additionally, Figure 2 presents the clinical photographs (corresponding to the time periods in Figure 1, and of the same patient) of the anterior alveolus of the maxilla from the frontal and occlusal aspects.

Figures 1 and 2 demonstrate the radiographic and clinical changes which usually take place in the maxilla from the time of incisor loss, during healing of the root socket and bone remodeling of the alveolus, changes resulting from the osteotomy during surgery and then the appearance of the alveolus a few months and finally a few years after autotransplantation of a premolar.

Because not every patient had a CBCT scan taken before the surgery, comparisons of pre- and post-operative examination were not possible. For this reason, only the latest CBCT examinations of each patient served for evaluation but comparison of the transplantation sites with natural contralateral incisor sites were performed.

The CBCT examinations were performed with a Morita, Veraview 3D scanner (J. Morita, Inc.) using a standard protocol (78 kV; 5 mA; 9,4 s; voxel size 0,125 mm) and all measurements were analyzed using Horos dental software version 2.2.0.

Informed consent for the retrospective study was obtained from the patients' parents and the Ethical Committee of Medical University of Warsaw approved the study (AKBE/86/14).

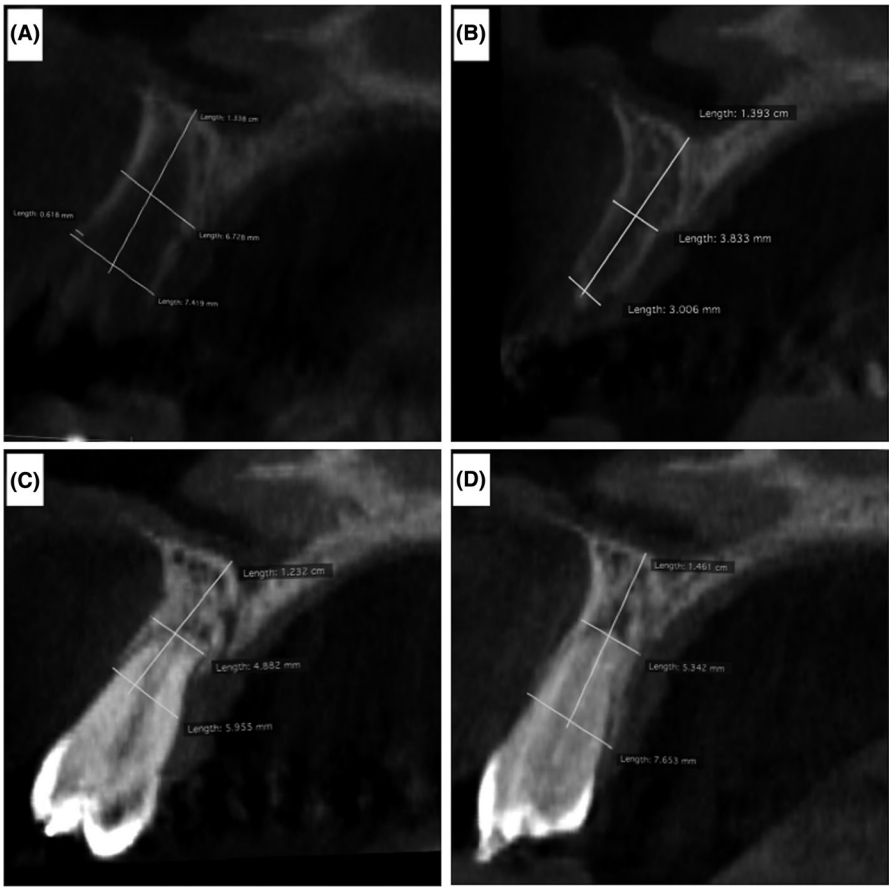

FIGURE 1 Cone Beam Computed Tomography sagittal scans of site 11 of a study patient. Alveolar socket two weeks after avulsion of the central incisor at the age of 11 years (A). Eight months later a significant horizontal bone defect can be seen (B). Eight months after autotransplantation of the developing tooth 25 to replace the missing incisor, the limited volume of bone was still observed but formation of new bone could already be detected (arrow in panel (C)). Decreased palato-labial dimension of bone was caused by remodeling after tooth loss, and a significant amount of buccal bone was removed during the surgery to accommodate the donor (C). Five years after the surgery a normal labial bone plate was present at the site of the transplanted tooth (D)

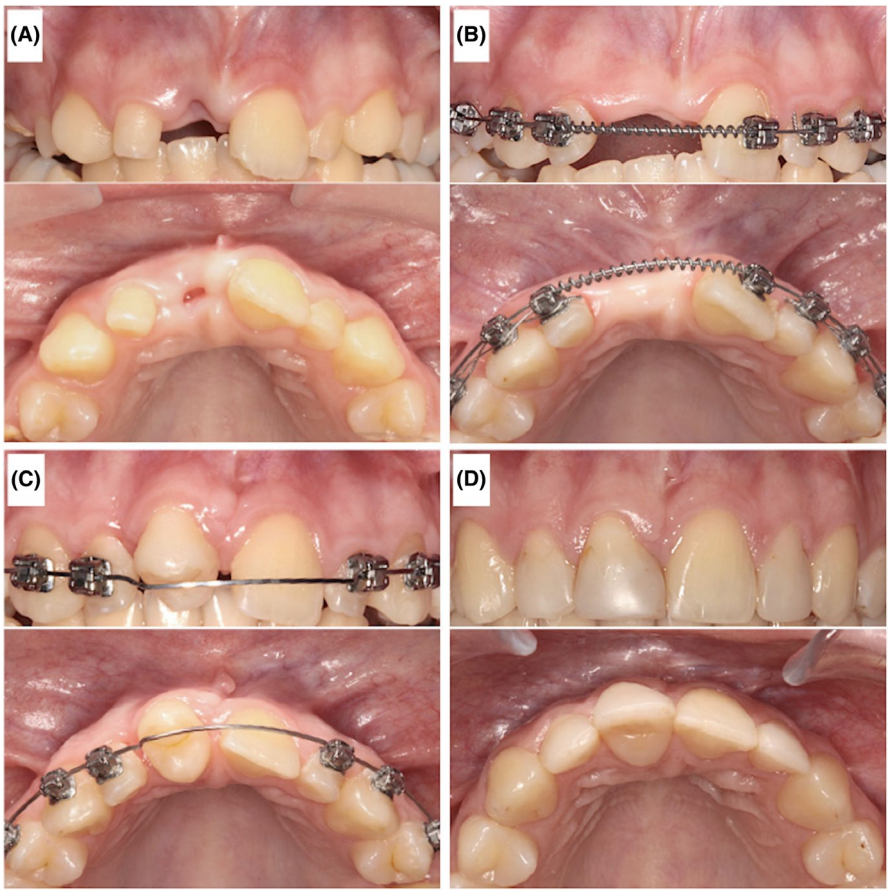

FIGURE 2 Clinical presentation of the dental arch after avulsion of the right central incisor which was replaced by autotransplantation of the developing premolar (at the time of CBCT examinations of the patient presented in Figure 1). Frontal and occlusal views of the alveolus two weeks after avulsion shows a vertical defect (A). Eight months after the trauma, the horizontal defect of bone was more pronounced especially on the labial side of the alveolus (B). Normal dental papillae and wide zone of keratinized gingiva were present eight months after autotransplantation of the premolar to replace the missing incisor. The presence of the transplant allowed filling of the soft tissue defect in the anterior maxilla (C). One year after the transplantation, the transplanted premolar was provisionally built-up with composite resin and was included in the orthodontic treatment which was done over two years. Panel D demonstrates frontal and occlusal views of the anterior maxilla five years after transplantation. The maintenance of the normal shape of the dental arch corresponds to the presence of labial bone as shown in the CBCT examination (D)

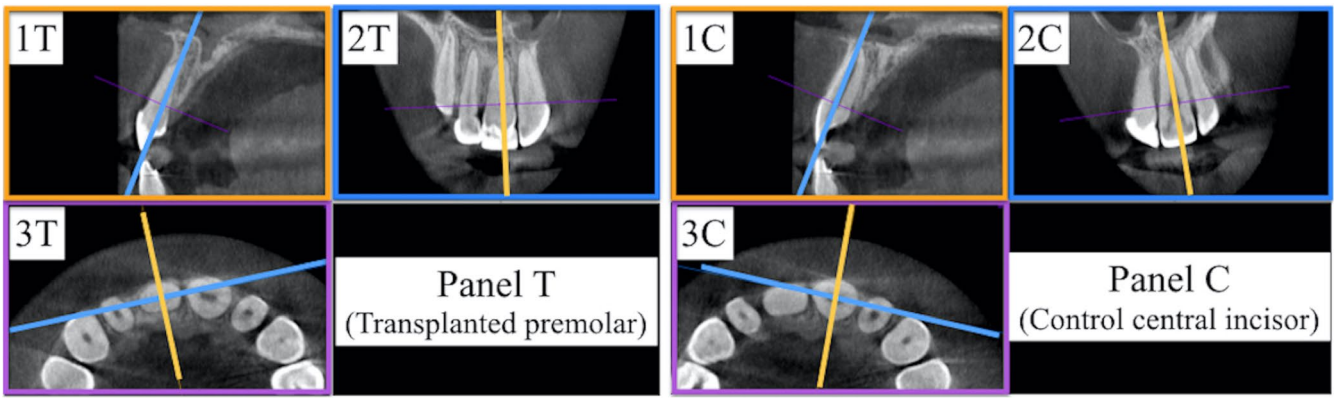

FIGURE 3 The 3D alignment of planes was selected in the software to perform measurements on the CBCT examination. Panel T (for transplanted premolar) is presented on the left side and panel C (for control central incisor) is presented on the right side. After adjustment of the planes (described in the text) only the left upper window in each panel (1T and 1C; framed in orange lines) for each patient served for all measurements

Two experienced examiners (PP and EC) analyzed the CBCT scans at the same time and registered the results after achieving unanimous measurement agreements.

Measurements for the transplanted and control teeth were performed. A view was obtained separately for transplants (panel T, left side in Figure 3) and for controls (panel C, right side in Figure 3) in the windows on the multiplanar reconstructions which were generated using standard dental software (Horos 2.2.0). First, the long axis of the tooth was determined manually in the view in windows 1 and 2 (framed in orange and blue in Figure 3) in such a way that orange planes (windows 1T and 1C) were perpendicular to the labial side of the alveolar bone at the site of the examined tooth and intersected at a right angle with the blue plane (windows 2T and 2C) along the line that overlapped the long axis of the tooth. The third violet planes (windows 3T and 3C) were automatically reconstructed to be perpendicular to the long axis of the tooth and they were then manually located at the level of the marginal alveolar bone.

All measurements of height and width of the alveolus were performed in windows 1T and 1C (i.e. on the orange plane).

The measurements performed in windows 1T and 1C were recorded for each patient at the transplant and control (non-affected contralateral central incisor) sites and included:

1. The height of the alveolar process (AH) which was measured from the marginal ridge of the tooth to the osseous lower border of the inferior meatus of the nasal cavity.
2. The thickness of the alveolar process at the marginal ridge (ATMR).
3. The thickness of the alveolar process at the mid-height (half of the vertical dimension) of the alveolar process (ATMid).
4. The thickness of the labial bone of the marginal ridge (LBT).

Measurements were taken at 3-fold magnification to obtain an image allowing sufficient assessment of bone contours and hard tissue of the root. The method of performing the measurements is presented and described in Figure 4 for a transplanted premolar (which corresponds to window 1T in Figure 3). The same methodology was used for control teeth (in windows 1C respectively).

Additionally, the scans were searched for possible presence of dehiscence and fenestration of bone over the roots of the transplanted premolars and the contralateral central incisors.

2.1 | Statistical analysis

Distribution of AH, ATMR, ATMid, and LBT for the autotransplanted premolars and control incisors was summarized by using the sample mean, range, and standard deviation (SD). The 95% confidence interval for the mean differences of AH, ATMR, ATMid, and LBT between them were obtained by applying single-sample Student's *t*-based confidence interval to the within-patient differences of measurements for the autotransplanted premolar and control incisor.

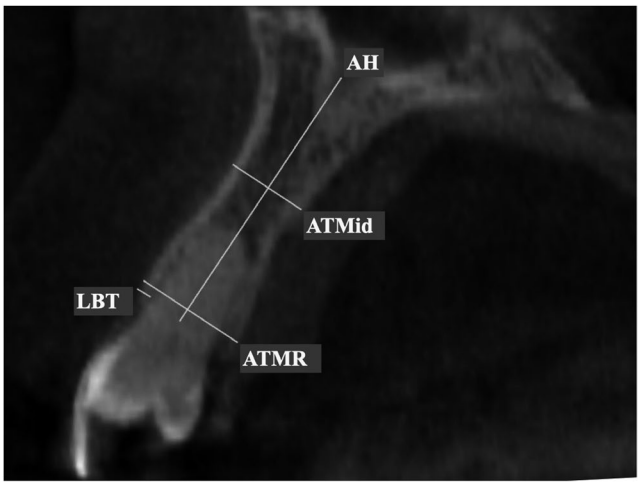

FIGURE 4 Presentation of the lines along which the measurements of the height and the thickness of the alveolus were performed in window 1T (in panel T - for a transplanted premolar). Line AH - height of the alveolar process; line ATMR - thickness of the alveolar process at the marginal ridge; line ATMid - thickness at the mid-height of the alveolar process; line LBT - labial bone thickness

3 | RESULTS

The alveolar process in the anterior maxilla at the follow-up CBCT examinations had a normal appearance and the labial cortical plate for all transplanted premolars and contralateral natural incisors was intact. Neither dehiscence nor fenestrations of the alveolar bone were seen.

Table 2 presents the means, ranges and standard deviations of the measurements of the alveolar process surrounding the autotransplanted and control teeth. Additionally, the means, ranges, standard deviations and 95% confidence intervals of the differences between the samples are included. The values for the transplants and controls did not show major differences in any of the performed measurements. All confidence intervals of the differences between samples presented in Table 2 included 0. Therefore, they do not allow rejecting the null hypothesis of no mean differences in any of the performed measurements of the alveolar bone.

4 | DISCUSSION

Autotransplantation of a premolar to replace a missing incisor in the anterior maxilla is a biological treatment option with the immediate effect of replacing a tooth. The survival and success for this type of treatment depend on many factors but the stage of the root development and gentle handling of the transplant during the surgery seem to be the most important.[30] Developing premolars transplanted with immature roots with wide open apices have proved to be the most predictable type of transplants.[5–7,9,31–35] In this study, this type of donor-tooth was chosen to replace missing central incisors in the maxilla. Most patients who undergo autotransplantation

TABLE 2 The means, ranges and standard deviations of the measurements of the alveolar process surrounding the autotransplanted and control teeth

	Autotransplanted Premolars	Control Incisors	Difference
	Mean Range SD	Mean Range SD	Mean Range SD 95% CI
AH (mm)	15.15 8.92–21.31 3.66	15.12 9.12–21.41 3.11	0.03 −3.28–4.45 2.44 [−1.61, 1.67]
ATMR (mm)	7.75 5.87–9.92 1.28	7.98 6.46–8.86 0.72	−0.23 −1.43–1.41 0.87 [−0.81, 0.36]
ATMid (mm)	7.54 4.72–10.98 1.77	8.03 4.63–9.87 1.71	−0.50 −2.56–2.09 1.64 [−1.44, 0.45]
LBT (mm)	0.78 0.47–1.67 0.34	0.75 0.60–1.00 0.15	0.03 −0.46–0.79 0.35 [−0.20, 0.26]

Additionally, the means, ranges, standard deviations and 95% confidence intervals of the differences between the samples are included.

Abbreviations: AH, height of the alveolar process; ATMid, thickness at the mid-height of the alveolar process; ATMR, thickness of the alveolar process at the marginal ridge; LBT, labial bone thickness.

of a premolar to the anterior maxilla require orthodontic treatment in order to align the transplant with adjacent teeth after the surgery.[36–39] The normal healing of the periodontal ligament of transplanted premolars allows later orthodontic movement. The aim of the orthodontic treatment is to create desirable space conditions for an aesthetic restoration to change the premolar crown to the morphology of the incisor.

Cone Beam Computed Tomography of the anterior maxilla performed before initiating the orthodontic treatment provides the orthodontist with invaluable information regarding the position and morphology of the transplant root after its development is complete. Additionally, CBCT allows assessment of the quantity and quality of alveolar bone, including the labial bone plate over the root of a transplant. This information allows safe orthodontic movement of the transplant with respect to root morphology, bone thickness and status of the attached gingiva in order to avoid moving the root of the transplant outside the alveolar envelope, which could cause bone dehiscence or gingival recession. To avoid these complications, radiographic assessment by CBCT examination limited to a small area of the incisors seems to be justified before the orthodontic treatment.[40] However, in the baseline material, only one third of all patients had CBCT performed after the surgery and for this reason only 11 patients were included in the assessment. The small number of patients included in the examinations may be a limitation of the study. This resulted because the CBCT's were only taken when orthodontic treatment was necessary after the surgery to align the transplanted tooth and to improve its position within the arch. All performed CBCT's were required to make sure that the root of transplanted tooth was positioned within the bone before orthodontic treatment could be initiated. The number of patients was additionally limited because only patients after a specific type of the autotransplantation (i.e., single unilateral transplantation) and those who had the contralateral natural incisor present in their mouth were included in the study.

The results of the present study support the previous clinical assumptions and clearly confirmed the presence of a normal alveolar process after autotransplantation of developing premolars following loss of a maxillary central incisor in growing patients. According to the authors' knowledge, this is the first case-series that has reported the three-dimensional examination of the alveolar bone using CBCT for transplanted premolars in the anterior maxilla. The presence of the alveolar bone on the side of the transplant was seen 1 year after the surgery and a normal labial plate was maintained for up to at least 14 years after the surgery. The mean observation time between the surgery and CBCT examination was 4 years, which can be regarded as a reliable period of observation after autotransplantation.[32]

Figures 1 and 2 may not be representative for all patients included in the study. However they were included to illustrate the sequel of bone changes after the most severe type of trauma (tooth loss) and after healing of an autotransplanted developing premolar. They also clearly demonstrate the potential of the periodontal ligament of a transplanted developing tooth to maintain and restore the normal shape of the alveolar ridge in a young patient.

Further investigations with larger numbers of patients and potential comparisons of CBCT taken before and after the treatment may bring more detailed information on the amount of new bone

which forms as a result of healing after surgery and due to maturation and function of autotransplanted teeth.

5 | CONCLUSIONS

The results proved the presence of the labial bone after a minimum of 1 year and the maintenance of normally appearing labial bone plates for at least 14 years after transplantation. Successful autotransplantation of a developing premolar to replace a lost central incisor allows preservation of the alveolar bone in the anterior maxilla over long-term observation periods.

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CONFLICT OF INTERESTS

The authors state, that there is no conflict of interest regarding the study (disclosures of interest are submitted separately).

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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