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Autogenous tooth transplantation in a severely insufficient alveolar ridge without a bone graft: Two case reports

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ABSTRACT

Background: Autogenous tooth transplantation is a simple technique that typically results in a satisfactory outcome. However, there are still many challenges, such as insufficient alveolar bone and tooth vitality. The aim of this study was to report two clinical cases of autogenous tooth transplantation with severe alveolar bone defects, one tooth with immature root development and one with mature root formation.
Methods: Clinical and radiographic data of the two cases were collected over three and twelve years.
Results: The two cases of autogenous tooth transplantation demonstrated successful bone regeneration without using a bone graft. The gingiva regained their normal characteristics and the teeth maintained their vitality with both immature- and mature-rooted transplants surviving with almost complete pulp obliteration and without endodontic treatment through the follow-up period of twelve years.
Conclusions: Autogenous tooth transplantation in a severely insufficient alveolar ridge can be achieved based on standard success criteria. Furthermore, endodontic treatment might not always be necessary when the transplanted tooth has a completely formed root with a closed apex.

1. Introduction

There are currently many treatment options available for replacing a missing tooth. Autogenous tooth transplantation (ATT) is a simple technique that is low-cost and results in positive outcomes. Its success rate has increased rapidly from 50% in the 1950's to 94% in the 2000's [1–3] and the outcomes have become more predictable. ATT gives better results in terms of normal function, aesthetics, and regeneration based on the host cells and tissue availability, which can be achieved using a non-traumatic protocol.

Although ATT is an optimal method for tooth replacement when a donor tooth is available, there are still many challenges to achieving a satisfactory result. The most difficult cases present with an extremely insufficient alveolar bone ridge due to bony wall defects, which can be restored using bone grafting materials [3–6]. Loss of tooth vitality following ATT is also a concern. Therefore, a tooth with a completely formed root requires only additional endodontic treatment that can be performed before or after transplantation [4,7–9]. Furthermore, achieving good stabilization of the transplanted tooth has been recommended using various techniques ranging from flexible fixation with nylon crossing over the occlusal area to more rigid fixation with orthodontic wire [4,6,9,10].

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However, excessive surgical time and inflexible stabilization can result in adverse effects, such as ankylosis, insufficient periodontal regeneration, and lack of pulp revascularization [11].

Here, we report two clinical cases with severe alveolar bone defects; one tooth with immature root development and another with complete root formation. A surgical procedure based on tissue engineering concepts was performed using non-rigid stabilization and without endodontic treatment. Periapical radiographs and cone-beam computational tomography (CBCT) were used to track the alveolar bone regeneration and periodontal attachment in parallel with clinical observation of the attached gingiva and tooth vitality.

1.1. Case presentation

Two cases of autogenous tooth transplantation are reported here with the approval of the Institutional Review Board of the Faculty of Dentistry/Faculty of Pharmacy, Mahidol University (COA. No. MU-DT/PY-IRB 2012/128. 2607) and in accordance with the Helsinki Declaration. Both patients were evaluated as previously described and determined to be ASA class I [12,13]. Additional inclusion criteria were non-pathological teeth, normal crown shape, and that the tooth was easy to manipulate. Information and risks of the procedure were explained to the patients and informed consent was obtained. Furthermore, the patients received oral hygiene instruction and full mouth scaling.

All ATT surgical procedures at the oral and maxillofacialsurgery clinic were performed similarly and divided into four phases, recipient site preparation, donor tooth harvesting, fixation, and follow-up period. The recipient site was prepared after tooth removal when there were no signs of inflammation at the extraction wound. The operation was performed under local anaesthesia; 2% mepivacaine with epinephrine 1:100,000 units. A mucoperiosteal flap was gently elevated at the recipient site buccally and lingually and was buccally extended to the lower edge of the alveolar bone as needed. Harvesting was carefully performed without contacting the root surface; and any bone that obstructed tooth placement at the recipient site was removed. Granulation tissue was removed and the supporting alveolar bone was reduced and contoured to fit the root shape of the donor tooth using a bur in a low-speed handpiece. During bone adjustment, the donor tooth was repeatedly inserted back into its socket and was immersed in blood until the recipient site was fully prepared. Finally, the donor tooth was placed in the blood clot in the prepared recipient site below the occlusal level to avoid excessive load during early wound healing. The mucoperiosteal flap was replaced above the cemento-enamel junction (Fig. 1) and was stabilized using non-rigid stabilization by cross-suturing between the mesial and distal interdental papilla of the transplanted tooth using polyamide sutures (Ethicon ®, USA). 1000 mg amoxicillin and 400 mg ibruprofen were given preoperatively, and 500 mg amoxicillin every 6 h for 5 days plus 400 mg ibuprofen every 8 h as needed for pain were prescribed after the operation.

The follow-up period was 1, 3, and 7 days after the operation to evaluate the patient's oral hygiene and remove the excess blood clot covering the occlusal surface of the transplanted tooth. The patients were instructed not to chew on the transplanted side for one month, and to then eat a soft diet for one week before gradually increasing to solid food. Furthermore, they received instructions on how to properly clean the transplanted tooth. Seven days post-operation, the sutures were removed and the tooth was supported by the granulation tissue. During every re-call visit after 3 months, the patients' periodontium was examined, and pulp vitality was determined using an electric pulp test (EPT). Periapical radiographs and CBCT scans were taken immediately after transplantation and approximately 1, 3, 6, and 12 months post-operation. Subsequently, the patients' attended a recall visit once a year.

The two cases received this standard protocol, with only minor differences performed depending on the bony defect severity.

1.2. Case 1

A 16-year-old woman was referred to the oral and maxillofacial surgery clinic in April 2006 for ATT by her orthodontist due to second premolar aplasia and an accidentally lost first premolar on the left mandible (Fig. 2-a). The candidate donor tooth was the unerupted lower left third molar, which was undergoing root development, but was too large mesio-distally to fit in the recipient site

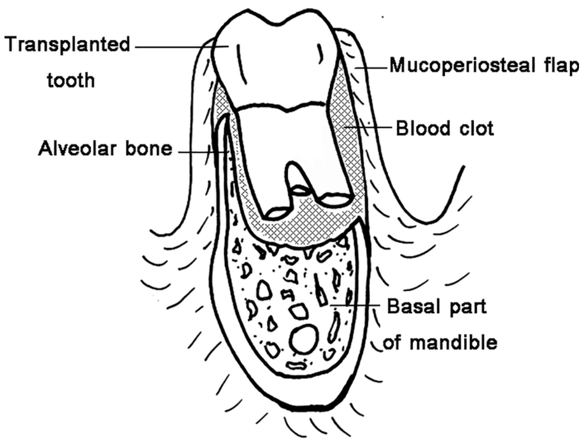

Fig. 1. Diagram of the position of the transplanted tooth encased in the blood clot and mucoperiosteal flap.

(Fig. 2-e, f). The ATT was planned in parallel with orthodontic treatment.

Knife-shaped alveolar crests with thin buco-lingual width continuing to the basal bone level were found after the mucoperiosteal flaps were opened (Fig. 2-b, c, d). Thus, the recipient site could not be prepared using the standard protocol. The alveolar crest was adjusted to a saddle shape to support the furcation of the donor tooth. During tooth transplantation, we carefully harvested and placed the donor tooth at a 90° rotation on the saddle shaped bone, without bony wall support on the entire mesial and distal roots, thus, they were supported only by the mucoperiosteal flap (Fig. 2-b, c, d). Finally, the tooth was transplanted in buccoversion and 3 mm below the occlusal level (Fig. 2-d, g and Fig. 3-a). The mucoperiosteal flap was sutured such that the flap margin was above the cemento-enamel junction (CEJ) of the transplanted tooth, and post-operative care instructions were given as described above.

At the 3-week post-operative follow-up the gingiva demonstrated normal soft tissue healing of the interdental papilla together with a healthy marginal gingiva and attached gingiva that was present at the three-year follow-up (Fig. 3-a-o). The severe tooth mobility post-transplantation was reduced to first-degree mobility at four months and normal mobility at six months when the sulcus depth recovered to the normal range (<3 mm). Similarly, the EPT was positive from six months and remained positive through 3 years when the pulp exhibited near complete obliteration radiographically (Fig. 3-d, h, l, p).

During the same period, the improved tooth stability was confirmed on periapical radiograph that showed increased trabeculation of the surrounded bone (Fig. 3-d, h) and the presence of the periodontal ligament space, lamina dura, and continued root formation (Fig. 3-l, p). Bone at the furcation formed that subsequently covered the buccal and lingual sides of the roots, and also extended to the basal area. Continued root formation was evident at six months and at three years in parallel with the gradual regeneration of the surrounding bone as shown in the CBCT images (Fig. 4). Orthodontic force was applied to upright the transplanted tooth into the correct alignment and levelling for a year post-operatively until it was moved 8 mm lingually (Fig. 3-i-o and Fig. 4-c, d).

1.3. Case 2

In June 2006, a 24-year old man was examined at the maxillofacial and oral surgery clinic. His oral cavity had an edentulous area at the lower right first molar and the panoramic radiograph revealed that both upper third molars were unerupted. The first candidate donor tooth was the upper left third molar, although harvesting the tooth was moderately difficult due to completely formed divergent roots and the crown of the donor tooth was too large mesiodistally to fit in the recipient space. Therefore, after preparing the socket at the recipient area, the donor tooth was placed upright with a 180° rotation in proper alignment and 2 mm under the occlusal plane except at the buccal cusp, which was approximately 0.5 mm lower. The mesio-buccal and disto-buccal roots were seated inside the prepared socket, however, the palatal root did not fit in the socket and was in direct contact with the buccal bone surface of the mandible (Fig. 5-a). The mucoperiosteal flaps were repositioned at the marginal ridge of the transplanted tooth for stabilization and creating a blood pouch surrounding the roots. Suturing was done and patient was instructed as described above.

Post-operatively, the sutures were removed without damaging any structures and the gingiva was well-healed. Tooth mobility decreased to normal levels at four months. Subsequently, the patient could chew normally without discomfort. The appearance of gingival contour and color, especially at the interdental papilla, had regained its normal characteristics by three months. Concurrently, the gingiva had reattached from the CEJ to the mucogingival junction due to the remodeling of the underlying bone (Fig. 6). The gingival sulcus eventually regenerated with a normal sulcus depth (≤3 mm.), which was maintained more than three years. The prominence of the buccal gingiva from the protruded root after transplantation became covered with thin bone that made the curvature blend with the adjacent area at three years (Fig. 6-j, k). The EPT was positive after four years. Therefore, endodontic treatment was not considered because pulp obliteration was observed beginning at the first year and no evidence of pulp inflammation or root resorption was seen.

Clinical improvement in tooth mobility was reflected in the periodontium changes observed on the periapical radiographs that showed increased trabecular bone and the presence of a periodontal ligament space and lamina dura beginning at six months (Fig. 6-c, f, i, l). Furthermore, the CBCT images confirmed bone formation at furcation area and cortical bone remodeling at the buccal area (Fig. 5). Remarkably at six months, evidence of bone remodeling to support the buccal root was noted (Fig. 5-b), and it continued

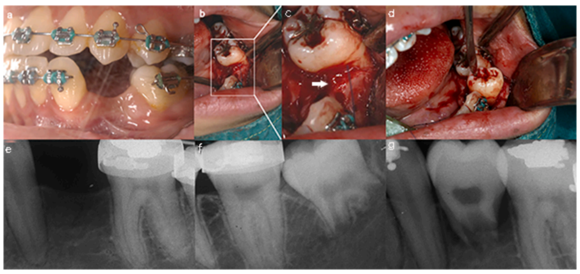

Fig. 2. Autogenous tooth transplantation in severely insufficient alveolar bone. (a) Preoperative intraoral examination and (b) the socket of recipient site prepared to reduce the interfere bone and create a proper shape and size socket for the transplanted tooth. The transplantation operation showing the narrow spacing between the lower left canine and first molar, (c) knife-edge of the alveolar crest (white arrow) before placing the autogenous tooth, and (d) buccoversion of the transplant. Preoperatively, periapical radiographs demonstrate (e) the status of recipient site and (f) the immature donor tooth, and (g) donor tooth transplantation.

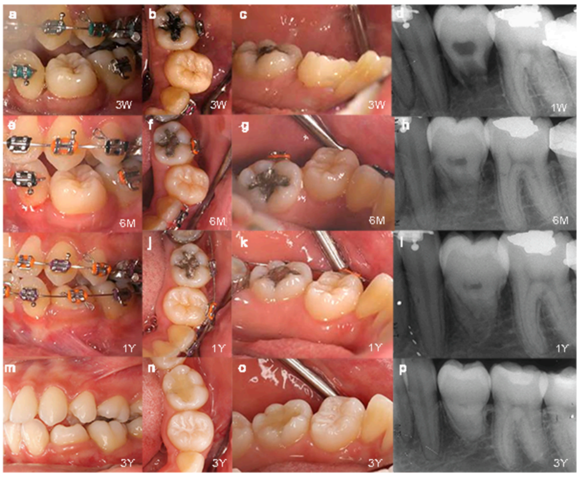

Fig. 3. Post-operative intraoral photographs and periapical radiographs of the third molar transplantation to replace the missing first and the second premolars in the lower left mandible. (a–c) At three weeks, mild gingival swelling and inflammation are seen. However, the attached gingiva is contoured up to the cervical line and interdental papilla. (d) One week post-operative radiograph shows a wide open apex. (e–g) At six months, complete formation of an intact interdental papilla and the attached gingiva is present. (h) Complete trabeculation of the surrounding roots with a periodontal ligament space and lamina dura is shown, while the pulp space was narrower. (i–k) At one year, the transplant was orthodontically moved into correct alignment. (l) The dentin wall continued growing leading to near pulp obliteration and the surrounding bone has a complete lamina dura together with alveolar crest regeneration to near the cemento enamel junction. (m–o) At three years, the orthodontic treatment was complete and (p) the transplanted tooth shows complete pulp obliteration and a closed root apex.

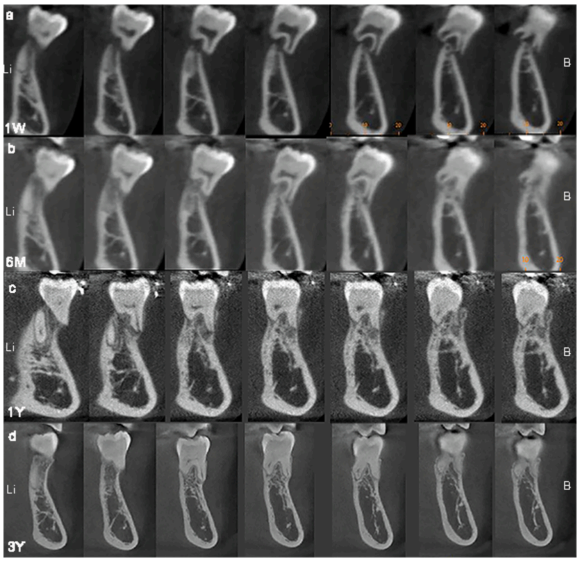

Fig. 4. Serial sections of the post-operative CBCT after autogenous tooth transplantation; the lower left third molar was placed into the area of the lower left first and second premolar. (a) At one week, CBCT shows the tooth in buccoversion on the alveolar bone crest and no bony contact of the root surface. (b) Six months later, there is remodeling of the entire alveolar crest to regenerate bone around the roots. (c) At one year, a vital pulp and bone growth are observed on the CBCT image including continued root formation, pulp narrowing, and increased alveolar bone surrounding the roots, especially at the furcation region. (d) At three years, the process of regeneration is almost complete as the CBCT image revealed pulp obliteration, closed root apex, and well-defined cortical bone surrounding the roots. CBCT-cone beam computerized tomography, B-buccal, Li-Lingual.

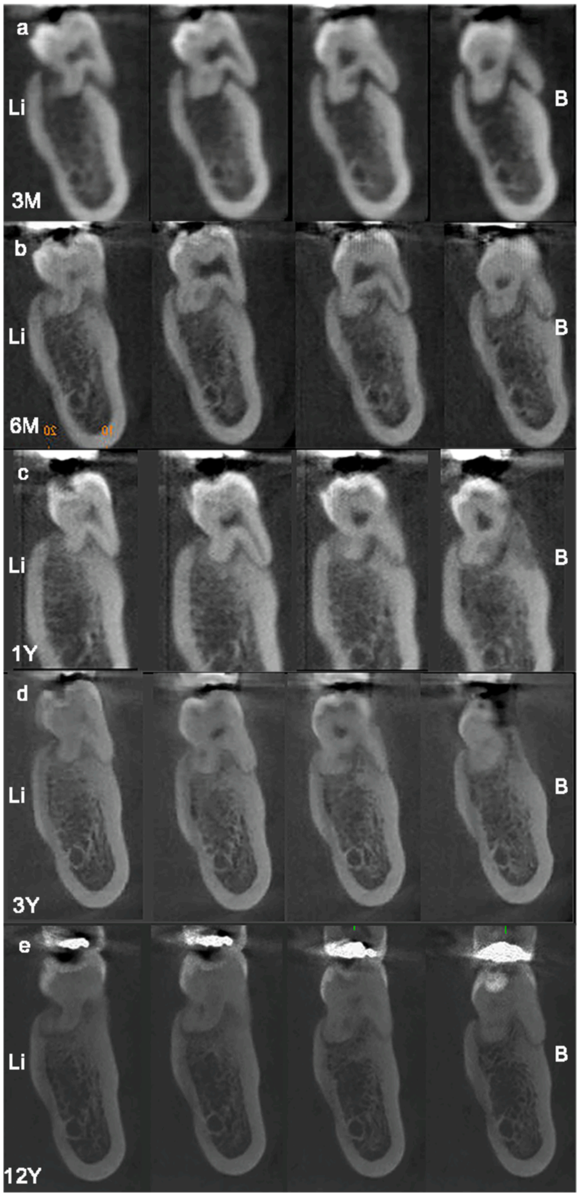

Fig. 5. Cone beam computerized tomography images after transplanting the autogenous upper left third molar into the area of the missing lower right first molar. (a) At three months, the transplanted tooth with a closed apex is seen with one root on the buccal side of the mandibular cortical bone. (b) At six months, the buccal cortex is resorbed and remodeled to fit the root shape. (c) At one year, the buccal cortex and bone trabeculation are regenerated at the furcation area and surrounding the roots. (d) At three years, the transplanted tooth shows complete socket formation around the lingual roots with the lingual cortex formed up to the cemento-enamel junction. (e) At 12 years, almost complete pulp obliteration with no periapical lesion is observed with consistent cortical and medullary bone remodeling. B-buccal, Li-Lingual.

through twelve years with the CBCT image demonstrating that the apical foramen of the buccal root was almost covered with bone (Fig. 5-e).

2. Discussion and conclusions

The success of ATT is related to the health of the periodontium, root morphology, and absence of infection. In addition, the amount of extra-alveolar time was suggested to be less than 18 min, while trauma to the tooth should be minimized [14,15]. In the two cases of ATT reported here, the teeth were at different stages of tooth development [16] and lacked alveolar bone support and had incompatible root shapes for the recipient sites. However, the standardized surgical protocol, taking special care during the transfer of the donor tooth and appropriate mucoperiosteal flap closure enhanced the success of both cases.

Fig. 6. Post-operative intraoral photographs and periapical radiographs after autogenous tooth transplantation of the upper left third molar to replace the missing lower right first molar. (a–c) At three months, the gingival tissue demonstrates normal healing of interdental papilla and attached gingiva together with complete trabeculation. (d–f) Six months later, intraoral photographs show an intact interdental papilla and increased attachment of the attached gingiva up to the cervical area. The radiographs demonstrated the lamina dura of the surrounded bone. (g–i) At the one-year follow-up, minor tooth eruption is seen in parallel with regenerated alveolar bone up to the cemento-enamel junction. (j–l) The gingival status was maintained and the lamina dura was completely formed at the three-year follow-up.

Ridge resorption typically occurs after tooth loss. The absence of masticatory forces on cancellous bone results in a reduced residual alveolar ridge. The rate of dimensional change varies between individuals and the greatest change occurs in the first year after tooth loss [17]. Insufficient alveolar bone to support the transplanted tooth is considered an obstacle to successful ATT. In these cases, additional bone augmentation or split osteotomy has been simultaneously performed to obtain optimal bone support. The graft material could be either autogenous bone fragments or allogenic bone [14,18,19], while a split osteotomy can be performed to deal with an alveolar process of inadequate size [20,21]. Bauss et al. demonstrated that bone autografts resulted in a higher success rate of the transplanted teeth compared with a split osteotomy. However, the prepared socket also presented similar results to a bone graft and the immediate insertion of the tooth into the freshly prepared site with respect to transplanted teeth in a similar condition [21]. Therefore, ATT when there is an inadequate alveolar process can regenerate new bone formation without additional management, as seen in our cases where the transplanted teeth were only placed in the prepared socket.

Insufficient bone did not present a problem for ATT in our cases. Although one transplanted tooth was placed with a root projecting beyond the prepared socket, the alveolar bone remodeled, generating a proper alveolar-bone shape. This occurrence confirmed that bone regeneration and periodontium improvement occurred after the surgical transplantation. During bone removal for placing the donor tooth, the saucerization and surgical trauma along with chewing forces led to the physiological, not pathological, response of the supporting tissue [22,23]. The newly formed bone began immediately at the cortex and periosteum by intramembranous bone formation [24]. After calcification and trabeculae development, bone remodeling ultimately re-shaped the alveolar bone to fit with the adjacent bone and roots of the transplanted tooth [25]. Additionally, maintaining the cementum layer via careful technique provided a protective barrier against root resorption, and induced extensive remodeling of the buccal bone [26–28].

Surprisingly, root canal treatment was not required in our two cases because positive EPT findings coupled with either continuous pulp obliteration or root growth were radiographically apparent beginning at the first year. The reason for this is that in our clinic the inclusion criteria are young adults less than 27-years old with a donor tooth with an immature or recently closed apex. Therefore, endodontic treatment would be performed only when there were signs of pulp necrosis or root resorption as previously suggested [9].

In tissue engineering, three major elements, cells, scaffold, and growth factors, are required to form new tissue. Likewise, the bone regeneration in ATT corresponds to the availability of osteogenic progenitor cells, an intrinsic scaffold, and bone stimulating factors that are expressed following inflammation, such as bone morphogenic proteins, vascular endothelial growth factors, and fibroblast growth factors [29]. The cells that can participate in regeneration reside in the periosteum, periodontal ligament, and bone marrow [30]. Similarly, a blood clot, which was intentionally created in our cases through the recipient site preparation, acts as a scaffold that also contains growth factors [31]. The health of the periodontal ligament was preserved by removing the bony wall to allow the transplanted tooth to be inserted with minimal trauma to the roots and by supporting the donor tooth in its socket filled with the resilient blood clot as a reservoir rather than using a chemical solution as was done in other cases [32,33]. The transplanted tooth did not receive masticatory forces because we gave the patients instructions to eat a soft diet and the tooth was placed under the occlusal plane allowing the regeneration of a fully-developed periodontium. Cell migration continues until the late phase of inflammation when the wound contracts and various cell types move into the injured area where the mucoperiosteal flap is opposed to the root surface. Therefore, the external wound boundaries mainly consist of periosteum and some gingival flap connective tissue, whereas the internal interface is the root surface where the periodontal ligament and cementum remained due to gentle manipulation during tooth acquisition.

Contamination is a primary concern prior to regeneration of the periodontium and alveolar bone. The wound healing cascade begins with the migration of inflammatory cells, predominantly neutrophils, followed by monocytes. Bacteria that enter the wound site are attacked by the innate immune response through phagocytosis and oxidative stress. Moreover, any necrotic tissue was removed to prepare the surgical area for wound healing [34]. Thus, our patients were prescribed antibiotics and their oral cavities were cleaned prior to ATT to eliminate any subclinical infection that could impede tissue regeneration.

ATT gives better results in terms of normal function, aesthetics, and regeneration based on the host cells and tissue availability, which can be achieved using a non-traumatic protocol. Our cases were successful, however the recipient bone was less than ideal in quality and quantity. Irregular knife-edged bone was found in the first case and a divergent root that extended beyond the buccal bone surface of the transplanted site was present in the other case. In these circumstances, the ATT in these two cases might have received bone augmentation to enhance the survival of the transplanted tooth [3]. Here, we showed that using the concepts of tissue engineering and atraumatic surgery resulted in bone regeneration. However, we cannot guarantee that these techniques will result in a favorable outcome in every case due to unforeseen variations between cases, such as where the crown size and root shape of the donor tooth is not compatible with the recipient site. Thus, the surgical time can be excessive, resulting in a traumatic wound. Furthermore, hard and soft tissue healing varies between individuals. To draw more definitive conclusions and set the criteria for case selection, future studies should analyze a greater number of cases.

In summary, these two case reports demonstrated that ATT in a severely insufficient alveolar ridge that entirely lacked at least one wall of alveolar bony wall support. The outcomes of these cases met the standard success criteria of Chamberlin et al. [35]. Near pulp obliteration was found and no endodontic treatments were required.

3. Informed consent

Informed consent was obtained from each participant included in the study.

Ethical approval

All procedures performed involving human participants were in accordance with the ethical standards of the Institutional Review Board of the Faculty of Dentistry/Faculty of Pharmacy, Mahidol University (COA. No. MU-DT/PY-IRB 2012/128. 2607) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Declaration of competing interest

The authors declare that they have no conflict of interest.

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References

[1] Apfel H. Autoplasty of enucleated prefunctional third molars. J Oral Surg 1950;8:289–96.
[2] Lundberg T, Isaksson S. A clinical follow-up study of 278 autotransplanted teeth. Br J Oral Maxillofac Surg 1996;34:181–5.
[3] Bauss O, Engelke W, Fenske C, Schilke R, Schwestka-Polly R. Autotransplantation of immature third molars into edentulous and atrophied jaw sections. Int J Oral Maxillofac Surg 2004;33:558–63. https://doi.org/10.1016/j.ijom.2003.10.008.
[4] Osterne RL, Moreira Neto JJ, de Araujo Lima AD, Nogueira RL. Autotransplantation of immature third molars and orthodontic treatment after en bloc resection of conventional ameloblastoma. J Oral Maxillofac Surg 2015;73:1686–94. https://doi.org/10.1016/j.joms.2015.05.014.
[5] Gilijamse M, Baart JA, Wolff J, Sandor GK, Forouzanfar T. Tooth autotransplantation in the anterior maxilla and mandible: retrospective results in young patients. Oral Surg Oral Med Oral Pathol Oral Radiol 2016;122:187–92. https://doi.org/10.1016/j.oooo.2016.06.013.
[6] Plakwicz P, Fudalej P, Czochrowska EM. Transplant vs implant in a patient with agenesis of both maxillary lateral incisors: a 9-year follow-up. Am J Orthod Dentofacial Orthop 2016;149:751–6. https://doi.org/10.1016/j.ajodo.2015.12.008.
[7] Jang Y, Choi YJ, Lee SJ, Roh BD, Park SH, Kim E. Prognostic factors for clinical outcomes in autotransplantation of teeth with complete root formation: survival analysis for up to 12 years. J Endod 2016;42:198–205. https://doi.org/10.1016/j.joen.2015.10.021.
[8] Gerard E, Membre H, Gaudy JF, Mahler P, Bravetti P. Functional fixation of autotransplanted tooth germs by using bioresorbable membranes. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2002;94:667–72. https://doi.org/10.1067/moe.2002.128020.
[9] Yu HJ, Jia P, Lv Z, Qiu LX. Autotransplantation of third molars with completely formed roots into surgically created sockets and fresh extraction sockets: a 10-year comparative study. Int J Oral Maxillofac Surg 2017;46:531–8. https://doi.org/10.1016/j.ijom.2016.12.007.
[10] Waikakul A, Punwutikorn J, Kasetsuwan J, Korsuwannawong S. Alveolar bone changes in autogenous tooth transplantation. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011;111:1–7. https://doi.org/10.1016/j.tripleo.2010.11.003.
[11] Isa-Kara M, Sari F, Emre-Coskun M, Kustarci A, Burak-Polat H, Ozdemir H, et al. Stabilization of autotransplanted teeth using thermoplastic retainers. Med Oral Patol Oral Cir Bucal 2011;16:369–75.
[12] Andreasen JO, Paulsen HU, Yu Z, Bayer T, Schwartz O. A long-term study of 370 autotransplanted premolars. Part II. Tooth survival and pulp healing subsequent to transplantation. Eur J Orthod 1990;12:14–24.
[13] JO A. Atlas of replantation and transplantation of teeth. Mediglobe, Fribourg. 1992.
[14] Bae JH, Choi YH, Cho BH, Kim YK, Kim SG. Autotransplantation of teeth with complete root formation: a case series. J Endod 2010;36:1422–6. https://doi.org/10.1016/j.joen.2010.04.028.

[15] Andreasen JO, Kristerson L. The effect of extra-alveolar root filling with calcium hydroxide on periodontal healing after replantation of permanent incisors in monkeys. J Endod 1981;7:349–54. https://doi.org/10.1016/S0099-2399(81)80056-8.
[16] Moorrees CF, Fanning EA, Hunt Jr EE. Age variation of formation stages for ten permanent teeth. J Dent Res 1963;42:1490–502. https://doi.org/10.1177/00220345630420062701.
[17] Atwood DA. Reduction of residual ridges: a major oral disease entity. J Prosthet Dent 1971;26:266–79. https://doi.org/10.1016/0022-3913(71)90069-2.
[18] Luvizuto ER, Faco EF, Faco RS, Queiroz TP, Margonar R, Betoni-Junior W, et al. Bone augmentation and autogenous transplantation of premolar to the site of the fissure in a cleft palate patient. Dent Traumatol 2013;29:483–8. https://doi.org/10.1111/j.1600-9657.2012.01163.x.
[19] Miura K, Yoshida M, Asahina I. Secondary bone grafting with simultaneous auto-tooth transplantation to the alveolar cleft. J Oral Maxillofac Surg 2015;73:1050–7. https://doi.org/10.1016/j.joms.2015.01.004.
[20] Akiyama Y, Fukuda H, Hashimoto K. A clinical and radiographic study of 25 autotransplanted third molars. J Oral Rehabil 1998;25:640–4. https://doi.org/10.1046/j.1365-2842.1998.00215.x.
[21] Bauss O, Zonios I, Engelke W. Effect of additional surgical procedures on root development of transplanted immature third molars. Int J Oral Maxillofac Surg 2008;37:730–5. https://doi.org/10.1016/j.ijom.2008.05.003.
[22] Adell R, Lekholm U, Rockler B, Branemark PI. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 1981;10(6):387–416.
[23] Gargiulo AW, Wentz FM, Orban B. Dimensions and relations of the dentogingival junction in humans. J Periodontol 1961;32(3):261–7. https://doi.org/10.1902/jop.1961.32.3.261.
[24] Akter F, Ibanez J. Chapter 8 - bone and cartilage tissue engineering. In: Akter F, editor. Tissue engineering made easy. Academic Press; 2016. p. 77–97.
[25] Elsubeihi ES, Heersche JN. Quantitative assessment of post-extraction healing and alveolar ridge remodelling of the mandible in female rats. Arch Oral Biol 2004;49(5):401–12. https://doi.org/10.1016/j.archoralbio.2003.12.003.
[26] Araujo MG, Lindhe J. Dimensional ridge alterations following tooth extraction. An experimental study in the dog. J Clin Periodontol 2005;32:212–8. https://doi.org/10.1111/j.1600-051X.2005.00642.x.
[27] Alsulaimani M, Doschak M, Dederich D, Flores-Mir C. Effect of low-level laser therapy on dental root cementum remodeling in rats. Orthod Craniofac Res 2015;18:109–16. https://doi.org/10.1111/ocr.12064.
[28] Joe M, Marc Q, Wim T. Critical buccal bone dimensions along implants. Periodontol 2000 2014;66:97–105. https://doi.org/10.1111/prd.12042.
[29] Lieberman JR, Daluiski A, Einhorn TA. The role of growth factors in the repair of bone. Biology and clinical applications. J Bone Joint Surg Am 2002;84:1032–44.
[30] Robey PG. Cell sources for bone regeneration: the good, the bad, and the ugly (but promising). Tissue Eng B Rev 2011;17:423–30. https://doi.org/10.1089/ten.teb.2011.0199.
[31] Rybarczyk BJ, Lawrence SO, Simpson-Haidaris PJ. Matrix-fibrinogen enhances wound closure by increasing both cell proliferation and migration. Blood 2003;102:4035–43. https://doi.org/10.1182/blood-2003-03-0822.
[32] Nethander G. Autogenous free tooth transplantation by the two-stage operation technique. An analysis of treatment factors. Acta Odontol Scand 1998;56:110–5.
[33] Gupta S, Goel M, Sachdeva G, Sharma B, Malhotra D. Autotransplantation. J Conserv Dent 2015;18:500–3. https://doi.org/10.4103/0972-0707.168827.
[34] Nourshargh S, Alon R. Leukocyte migration into inflamed tissues. Immunity 2014;41:694–707. https://doi.org/10.1016/j.immuni.2014.10.008.
[35] Chamberlin JH, Goerig AC. Rationale for treatment and management of avulsed teeth. J Am Dent Assoc 1980;101(3):471–5.