VeryPDF Software Demo Version (http://www.verypdf.com)

Submitted July 12, 2024;
accepted October 18, 2024.

Tiziano Testori, MD, DDS, MSc
Massimo Simion, MD, DDS
Francesco Giachi Carù, DDS, MSc
Stefano Corbella, DDS, PhD
Silvio Taschieri, MD, DDS
Giovanna Perrotti, DDS, MSc
Renato Cocconi, MD, DDS, MSc
Javier Calatrava, DDS, MSc
Ann Decker, DDS, PhD
Hom-Lay Wang, DDS, MSD, PhD

Immature Tooth Autotransplantation with Buccal Bone Fenestration Treated with GBR and Immature Tooth Autotransplantation in Regenerated Bone: Proof of Principles with Medium- (55 Months) to Long-Term (252 Months) Follow-ups

Tooth autotransplantation is a reliable procedure with high long-term success and survival rates and shows many advantages over dental implants, particularly for young patients in craniofacial development. Nonetheless, insufficient bone availability at the recipient site is a key limitation. This study aimed to establish the feasibility of tooth autotransplantation combined with staged or simultaneous bone regeneration to address complex cases. Two young patients with missing teeth due to hypodontia or trauma and who were deemed unsuitable for implants were treated. Both complex cases were addressed through autologous tooth autotransplantation, either in conjunction with simultaneous guided bone regeneration or into a previously regenerated crest. The 5-year follow-up for the autotransplanted canine and more than 20-year follow-up for the autotransplanted premolar revealed satisfactory results. These teeth played pivotal roles in restoring both function and esthetics in young patients. Additionally, tooth vitality was preserved throughout the follow-up period, with no complications noted. Tooth autotransplantation in combination with previous or simultaneous guided bone regeneration proved to be effective in restoring function and esthetics in complex situations in young patients. *Int J Periodontics Restorative Dent 2026;46:187–201. doi: 10.11607/prd.7356*

Keywords: *guided bone regeneration, impacted tooth, tooth autotransplantation*

Tooth autotransplantation is a complex but effective dental procedure that can offer numerous benefits, especially in cases where dental implants may not be feasible or indicated, such as in younger patients undergoing active craniofacial growth. It involves surgically moving a tooth from one site to another within the same patient, either into a postextraction surgical socket or into a surgically created socket designed to receive the transplanted tooth.[1] Various techniques of dental autotransplantation have been described, from more conventional procedures[2]

VeryPDF Software Demo Version (http://www.verypdf.com)

to modern digitally planned and executed autotransplantation protocols.[3,4] This procedure is well-documented in the scientific literature,[5] with success rates ranging from 84% to 94% and long-term follow-ups to 30 years,[6] and it is recently regaining popularity within the scientific community due to the incidence of implant complications.[7,8] Thus, especially in younger patients with cases of tooth loss due to injury or trauma, autotransplantation is preferred over implant placement.[9] Additionally, in cases involving esthetic concerns, these can be optimized through direct or indirect adhesive conservative techniques after complete healing.

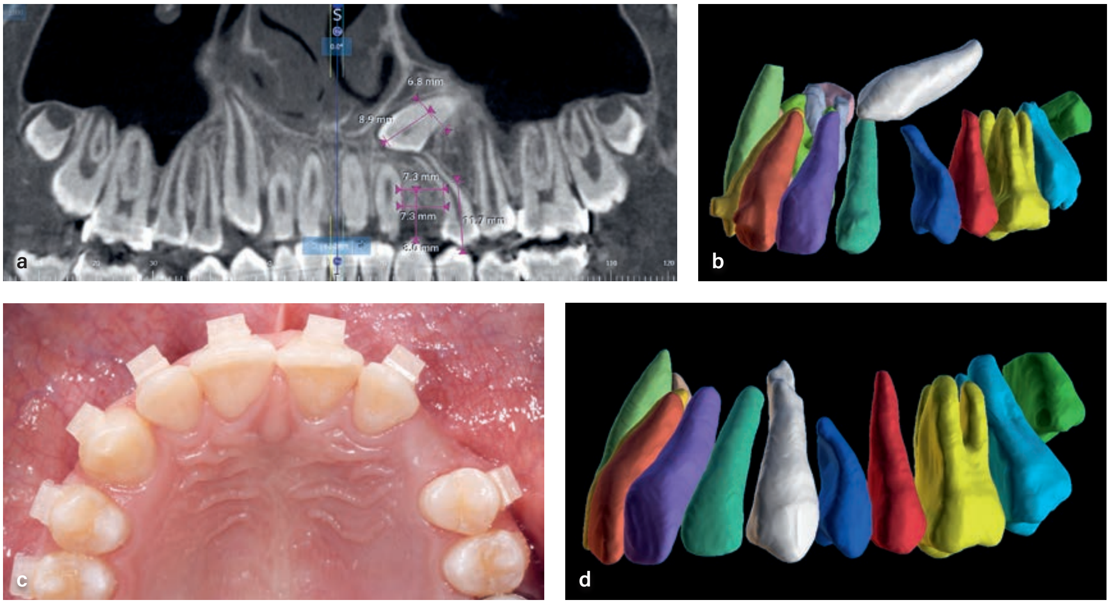
The success of this technique hinges upon preserving the periodontal ligament (PDL) during the extraction and manipulation of the donor tooth. This preservation is critical for fully matured teeth, but particularly for immature and/or impacted teeth that retain their follicle. Additionally, the degree of mechanical damage to the root surface during extraction significantly influences the healing of the PDL.[10] Thus, any damage to the root can compromise the PDL's ability to form new root cementum and PDL, potentially leading to complications such as root ankylosis or replacement root resorption, as well as pulp necrosis and acute periapical lesions.[11]

Tooth autotransplantation offers many advantages, including the preservation of proprioception, the potential for future orthodontic movement, as well as no interference with the growth of the alveolar process. Furthermore, it allows for the creation of a supracrestal tissue attachment, which maintains the attached gingiva and preserves the ridge width, interproximal bone, and interdental papillae.[12–15] Advocates of this procedure emphasize its ability to maintain and allow continued growth of the alveolar bone. In the event of transplant failure or complications[12] in a later stage, a well-preserved alveolar ridge could be used for future implant placement.[13]

During the planning stage of tooth autotransplantation, a comprehensive clinical and radiographic examination is imperative to identify a suitable vital donor tooth. The preferred candidates for this technique are teeth with simple root anatomy (uniradicular teeth, molars with fused roots), incomplete root formation (open apex), easily accessible for extraction, and with a mesiodistal and buccolingual size suitable for the recipient site.[6] Successful outcomes rely on meticulous case selection, precise planning, a careful surgical technique, and minimizing the extraoral time of the donor tooth.[14–16] In essence, achieving a stable, long-term functional and esthetic restoration necessitates interdisciplinary collaboration involving surgical, restorative, and sometimes orthodontic management.[17]

The surgical technique of dental autotransplantation involves the following steps:

1. Donor tooth selection: An appropriate donor tooth is chosen based on size, shape, and compatibility with the recipient site and neighboring anatomical structures. The donor tooth can be (and typically is) an extruded and nonfunctional tooth, an impacted tooth, or a sound tooth that needs extraction for other reasons (eg, orthodontics) that matches the missing or damaged tooth. Digital tools and planning based on DICOM and STL files can facilitate this process.[3,4,18]
2. Extraction: Delicately and with as minimal trauma as possible, extract the donor tooth to maximize the preservation of the vital PDL.
3. Recipient site preparation: Extract the recipient's hopeless tooth (if needed) and create an osteotomy site into the recipient socket or a healed bone crest to receive the donor tooth.
4. Transplantation: Carefully transplant the donor tooth into the recipient site, ensuring an accurate fit, complete absence of occlusion, and stabilization of the donor tooth using composite reisn, wire splinting, or sutures.
5. Follow-up: Postoperative care involves instructions for proper oral hygiene habits, diet, and regular monitoring of the healing process to ensure the stability and integration of the transplanted tooth in the recipient site. In cases of fully mature donor teeth, root canal therapy will need to be performed due to the damage to the vascular supply. During this period, function can be recovered either by natural extrusion, an indirect minimally invasive restoration, or orthodontic treatment.



▲ **Fig 1** Patient 1. *(a and b)* Preoperative CBCT and artificial intelligence (AI) segmentation, respectively, reveal a morphologically altered root with an abnormal mesial curvature at the level of the maxillary left first premolar. *(c)* Preoperative intraoral occlusal view. *(d)* In the previsualization of the surgical procedure using AI, the mesially bent root of the premolar was virtually apicoectomized to accommodate the autotransplanted canine into the ridge.

An accurate diagnosis and comprehensive assessment by a qualified dentist are critical to ascertain whether tooth autotransplantation is the best treatment option, as it is not universally applicable to all clinical situations. Commonly recognized contraindications, such as insufficient ridge width or inadequate bone volume, may preclude the feasibility of autotransplantation. The need for a recipient site with a complete bony housing is still questioned throughout the literature. Andreasen et al demonstrated that transplanted teeth can achieve functional and esthetic success without a full bony housing as long as the PDL remains intact and undisturbed during the procedure.[9] However, in cases where there is a significant alveolar bone deficiency, ensuring optimal stability and esthetics can be challenging, potentially affecting the long-term prognosis of the transplanted tooth. Recent retrospective studies have demonstrated that when teeth were transplanted into sites with buccal dehiscences, they experienced greater clinical attachment loss than teeth completely surrounded by a bony housing,[19] which could hinder their long-term prognosis. Evidence in this field is scarce and limited to a couple of case reports and case series, which have shown favorable outcomes of autotransplanted teeth into previously or simultaneously augmented sites, although with a limited follow-up.[20,21]

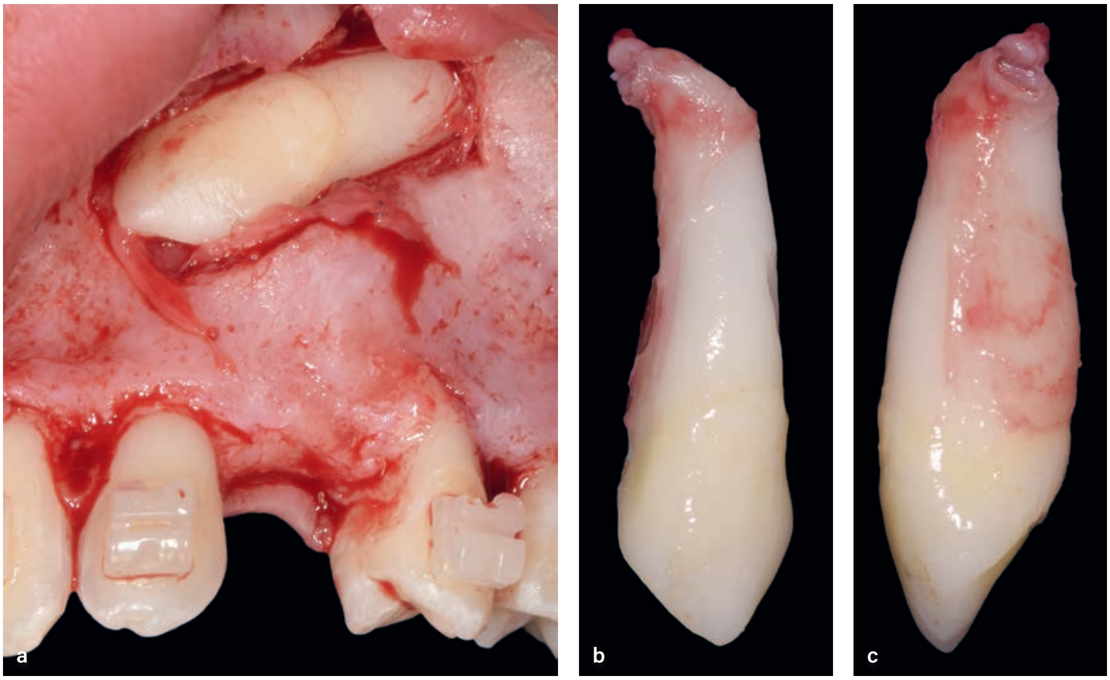
The purpose of this manuscript is to introduce two case reports showcasing the application of tooth autotransplantation in complex scenarios in young patients with limited bone availability. The first case illustrates the treatment of a transplanted tooth as if it were an implant accompanied by simultaneous horizontal guided bone regeneration (GBR). The second case describes the transplantation of a tooth into a site that had previously undergone bone augmentation through a GBR procedure.

Clinical Case Presentations

The manuscript adheres to the CARE guidelines for case reports.

Patient 1

A 16-year-old boy presented with a brachycephalic Angle Class II malocclusion and was undergoing orthodontic retreatment at the time of consultation. The patient was referred for the impacted maxillary left canine (Fig 1).



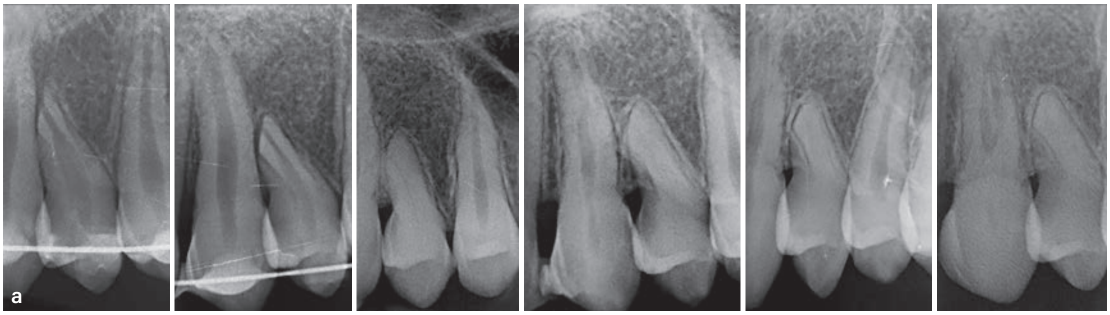
▲ **Figs 2a to 2c** *(a)* Extraction phase and unintentional PDL removal on the buccal side of the canine. *(b and c)* The extracted canine presents an immature apex and only mesiodistal and palatal preservation of the PDL.

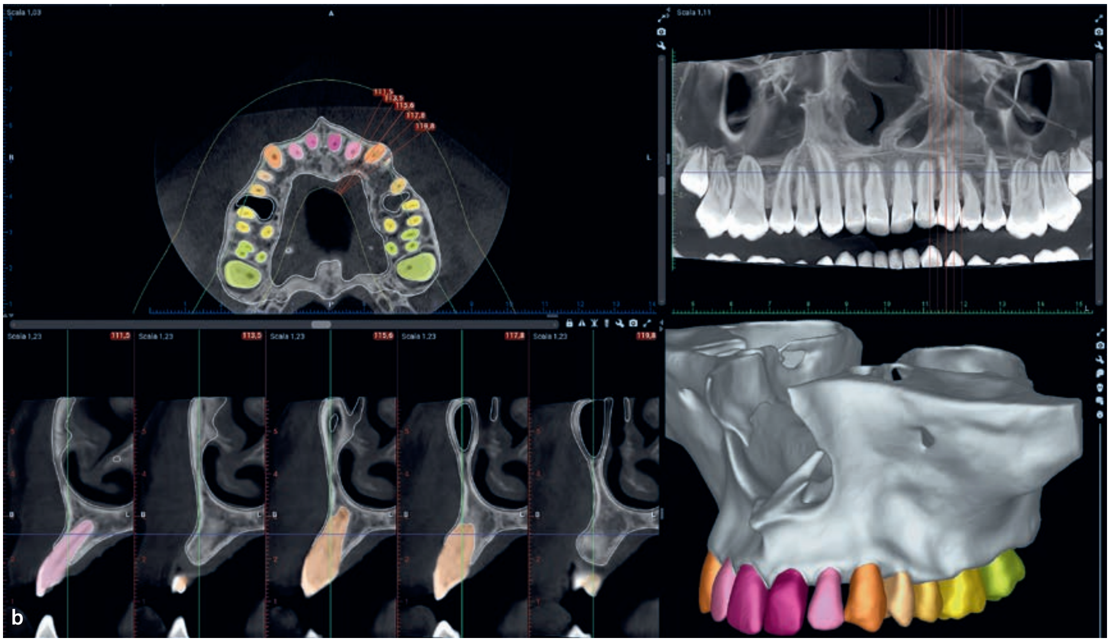
After evaluating different therapeutic alternatives, and in agreement with the orthodontist, it was determined that the orthodontic recovery of the impacted tooth was feasible but not acceptable to the parents and the young patient, due to the length of the treatment. The apical (deep) position, angulation of the impacted canine and the time required for its alignment into the arch would exceed 18 months of orthodontic treatment, with unpredictable results. Additionally, the root anatomy of the adjacent first premolar, which exhibits a mesial curvature in the middle and apical thirds of the root, made it impossible to orthodontically bring the canine into position without causing a collision between the canine and the root apex of the premolar. Proper CBCT analysis determined that the impacted canine was still immature and in Nolla Stage 9 development,[22] which means that the tooth was almost fully developed but the apex is still open, making it an ideal candidate for tooth autotrasplantation. Therefore, the extraction of the impacted canine and its autotransplantation into a surgically created socket was chosen as the therapeutic approach for this clinical case.

Space in the arch for the canine had been previously created through orthodontic alignment, so the canine could be autotransplanted into its final position. For the surgical extraction, a full-thickness flap was elevated to access the buccally displaced impacted canine. Once it was located, careful osteotomy and ostectomy by means of a piezoelectric device (Piezosurgery, Mectron) were performed to ensure the extraction of the canine in one piece and with minimal damage to the root surface, PDL, and follicle. Unfortunately, during the extraction, the buccal PDL was unintentionally removed (Figs 2a to 2c). Subsequently, a surgical slot for the canine was created by removing the buccal wall via piezoelectric surgery, as the residual ridge was only 6 mm wide and the donor canine was 7 mm wide. Furthermore, apicoectomy of the first premolar was performed without root canal treatment to allow for proper positioning of the donor canine (Figs 2d and 2e).

The transplanted tooth showed a complete dehiscence of the buccal root surface and an absence of PDL coverage in the buccal portion when placed into its new position. Therefore, it was decided to treat the tooth following the principles

▲ **Figs 2d to 2h** *(d)* Apicoectomy at the level of the premolar utilizing an OT12 insert (Piezosurgery, Mectron), which presents an unusual mesial bent root that prevents the correct positioning of the autotransplanted canine in the surgically prepared site. *(e)* The autotransplanted canine positioned in the surgical site, which presents good stability and no PDL in the buccal aspect. *(f and g)* A collagenated heterologous biomaterial (Gen-Os, OsteoBiol) was placed and covered with membranes of autologous platelet concentrates (L-PRF; IntraSpin system, BioHorizons), respectively. *(h)* Splinting of the autotransplanted canine with an orthodontic wire after suturing.





▲ **Fig 3** *(a)* Yearly periapical follow-ups from September 2019 to April 2024. *(b)* Five-year follow-up CBCT with 3D rendering and AI-driven segmentation of tooth–bone structures, showing the presence of a thin buccal bone plate around the maxillary left canine.

of implant dentistry, and a horizontal bone regeneration was performed using collagenated heterologous biomaterial (Gen-Os, OsteoBiol) covered with membranes of autologous platelet concentrates (leukocyte-platelet–rich fibrin [L-PRF]; IntraSpin system, BioHorizons). The flap was sutured, and the autotransplanted tooth was splinted and further secured by the orthodontic archwire to the adjacent teeth during the months following the procedure (Figs 2f to 2h).

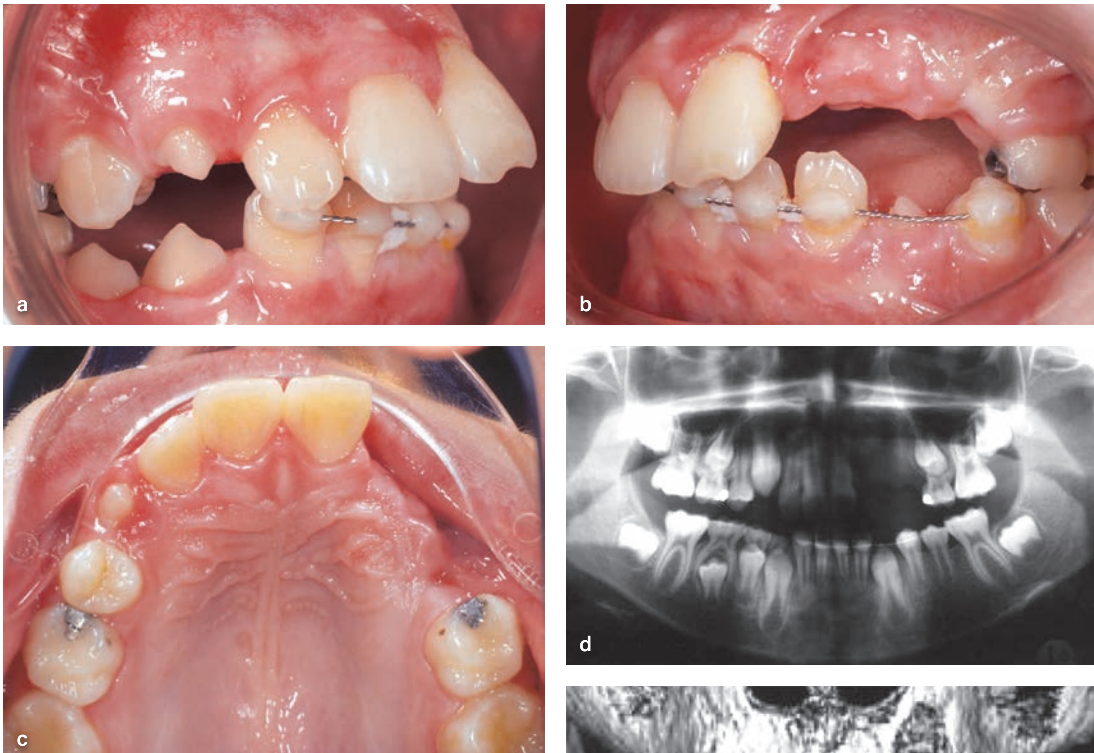
Follow-up periapical radiographs were taken immediately after the surgery, at 6 months, and yearly until the fifth year of follow-up. These radiographs showed early signs of apical root resorption and disappearance of the PDL space, as well as canal calcification of the first premolar (Fig 3a). A CBCT at the 5-year follow-up revealed the formation of a new vestibular bone surface, corresponding to cortical bone, covering the root (Fig 3b), combined with soft tissue stability and no recession around the buccal aspect of the canine (Fig 4). Throughout the observation period, sensitivity tests were conducted on both the canine and the first premolar, which had undergone an apicectomy, showing consistently positive results using electric methods (Digitest II pulp vitality tester, Parkell).

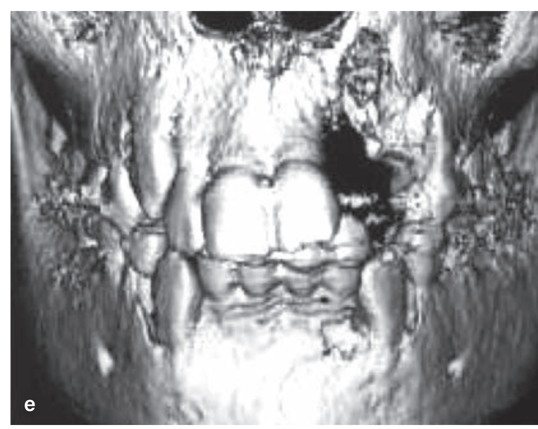
Five years later, the transplanted canine remains vital, presents a stable phenotype, has a clinical situation (probing pocket depths, recession, clinical attachment levels) compatible with good periodontal health, and it is aligned within the arch, providing favorable esthetics and correct occlusal function (Figs 4 to 6).

▲ **Fig 4** *(a)* Smiling, *(b)* intraoral lateral, and *(c)* occlusal views at the 5-year clinical follow-up.

▲ **Fig 5** Extraoral views *(a)* at the beginning of the multidisciplinary treatment, *(b)* during treatment, and *(c)* at 5 years. A natural-looking esthetic result was achieved.

▶ **Fig 6** Throughout the observation period, sensitivity tests were conducted on both the transplanted tooth in the canine site and the adjacent first molar, which had undergone an apicectomy, showing consistently positive results using electric methods (Digitest II, Pulp Vitality Tester, Parkell) at *(a)* 3 years and *(b)* 5 years.





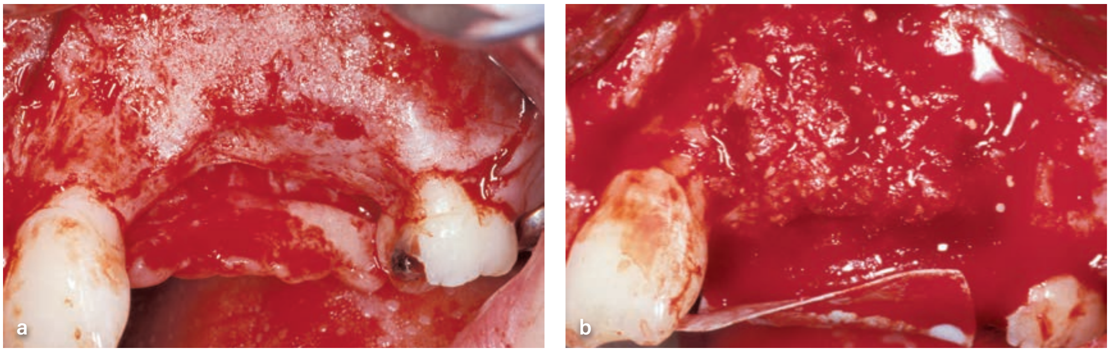
▲ **Fig 7** Patient 2. *(a to c)* Right lateral, left lateral, and occlusal views, respectively, of the initial clinical situation after traumatic avulsion of the maxillary left lateral incisor, canine, and first premolar in a 10-year-old patient. From the left lateral view, the gingival recession on the maxillary left central incisor and the atrophic edentulous ridge around the maxillary left lateral incisor, canine, and first premolar can be appreciated. *(d)* Panoramic radiograph showing the severe vertical defect in the areas of the left lateral incisor to the first premolar and the mixed dentition. *(e)* A 3D CBCT shows the bony defect and the development of the right hemimaxilla compared to the left.

Patient 2

A 10-year-old boy was kicked by a horse, resulting in the traumatic avulsion of the maxillary left lateral incisor, canine, and first premolar; gingival recession around the left central incisor; and severe bone loss in the left hemimaxilla (Figs 7a to 7c). The trauma also caused buccal flaring of the incisors and unbalanced growth of the maxilla, with the right hemimaxilla being more developed than the left, as shown in the radiographic and CBCT exams (Figs 7d and 7e). The treatment of growing patients with GBR techniques is always unpredictable because, while it is known that implant treatment should be performed only at the end of growth, there is no experience regarding the ideal period to undertake regenerative techniques. In this case, it was decided to perform bone regeneration immediately and postpone implant placement until the age of 18. The resolution of this complex case required a multidisciplinary approach in multiple stages, which lasted a total of 10 years and included specialists in orthodontics, dental hygiene, periodontics, and prosthodontics, as well as a laboratory technician.

Phase I

Phase I comprised bone augmentation surgery using GBR. Vertical GBR surgery was performed after patient education and oral hygiene preparation. A full-thickness flap was raised, the bony



▲ **Fig 8** *(a)* A full-thickness flap was elevated to expose the vertical bone defect. *(b)* A titanium-reinforced ePTFE membrane was fixed palatally, and an autologous particulate bone graft mixed with 30% DBBM was placed to fill the defect.

cortical surface was meticulously smoothened, and perforations were made to expose the medullar area and stimulate the bleeding and blood supply into the bone graft. Two support screws were then vertically positioned. First, a titanium-reinforced e-PTFE (expanded polytetrafluoroethylene) membrane was fixed palatally, and then a bone graft comprising 70% autologous particulate bone and 30% deproteinized bovine bone mineral (Bio-Oss, Geistlich) was inserted (Fig 8), to later be closed by primary intention and tension-free sutures.

Phase II

In this phase, membrane removal, placement of a palatal implant for orthodontic anchorage, and autotransplantation of the maxillary right second premolar to the position of the maxillary left canine were performed. After 6 months of submerged healing, the membrane was removed by means of a full-thickness flap, without including the adjacent teeth. Due to the young age of the patient and the resulting high regenerative potential, the membrane appeared partially covered by a thin layer of newly formed bone. The underlying bone was of excellent quality. To hinder the growth of the right hemimaxilla and to stimulate the left hemimaxilla, it was decided to extract the germ of the maxillary right second premolar, which had not yet erupted, and to reimplant it in the left hemimaxilla as a substitute for the canine. The deciduous tooth was then extracted to gain access to the definitive maxillary right first premolar, which was gently extracted with the entire follicle, and the root apex appeared still open and not fully formed. In the regenerated bone at the site of the maxillary left canine, a cavity large enough to accommodate the extracted right second premolar was created, and the immature tooth was immediately inserted and submerged beneath the soft tissue (Fig 9). Finally, a flat Onplant (Nobel Biocare) was placed through a narrow full-thickness tunnel in the center of the palate for orthodontic anchorage and allowed to heal in a submerged position.

Phase III

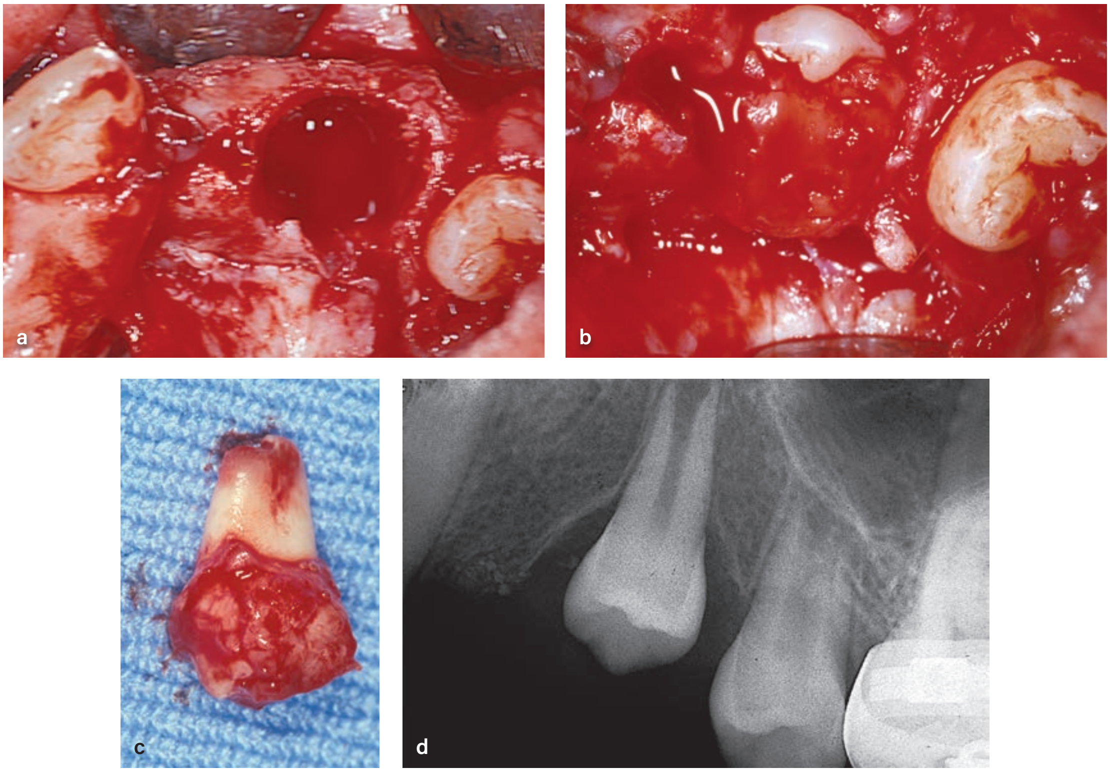
After 4 months of integration, the Onplant was uncovered and used as anchorage for an orthodontic appliance. Orthodontic treatment continued for the following 3 years, during which the transplanted tooth in the left canine position was brought into the arch, all the remaining teeth were aligned, and a stable occlusion was obtained.

Phase IV

At the age of 18, with skeletal growth finished, a 3.3 × 13-mm implant (Nobel Biocare) was placed in the maxillary left lateral incisor position. The tooth that had been transplanted to the left canine position was then prosthodontically prepared, and a crown with a canine shape was placed, maintaining the vitality of the pulp. The regenerated bone in the edentulous ridge continued to grow alongside the adjacent native bone, thanks to the stability provided by the left canine.

Phase V

After 4 months, once the implant was integrated, a provisional restoration was used during the



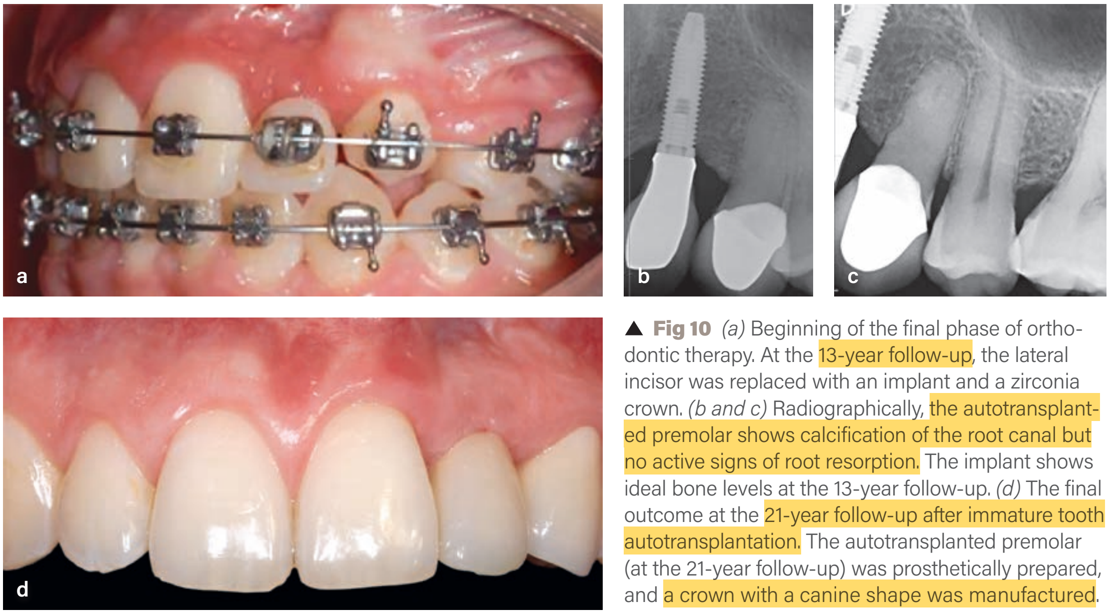
▲ **Fig 9** *(a)* Removal of the membrane after 6 months of submerged healing, which was covered by a thin layer of newly formed bone. *(b)* Osteotomy was carried out to create space for the autotransplanted premolar. *(c)* The extracted right second premolar with its follicle, with the root apex still open The primary tooth was extracted to access the follicle of the maxillary right second premolar to be transplanted to the site of the left canine. *(d)* A normal periodontal ligament can be seen around the implanted premolar.

soft tissue contouring period until an ideal position of the gingival margin and emergence profile were obtained, and the final implant-supported restoration was delivered. Clinically, the autotransplanted tooth and implant show stable soft tissue and radiographic situations. The 21-year follow-up of the autotransplanted premolar presents calcification of the root canal but no active signs of root resorption, and the 13-year implant follow-up shows ideal bone levels (Fig 10). Furthermore, an extraoral view of the patient shows an ideal esthetic result maintained 21 years after the autotransplantation (Fig 11).

Discussion

These two clinical cases demonstrate the success of autotransplantation in young patients with teeth that had an immature apex and how it can be a useful tool to solve complex clinical cases, even when bone availability is limited. Both cases emphasize the importance of meticulous planning, careful execution, and long-term follow-up to ensure successful outcomes, and they show the possible role of GBR in these treatment plans, either in a simultaneous or a staged approach.

Autotransplantation has been well-established and widely used for over 40 years.[6,23,24] High survival rates have been consistently reported for autotransplanted teeth, particularly in the anterior maxilla, especially when transplantation occurs during root development.[5,25] The favorable esthetic outcomes and high levels of patient satisfaction reported further validate the efficacy of this technique.[26] Autotransplantation offers distinct advantages, particularly in patients undergoing craniofacial growth, as it allows for proprioception during function, physiologic growth of the



▲ **Fig 10** *(a)* Beginning of the final phase of orthodontic therapy. At the 13-year follow-up, the lateral incisor was replaced with an implant and a zirconia crown. *(b and c)* Radiographically, the autotransplanted premolar shows calcification of the root canal but no active signs of root resorption. The implant shows ideal bone levels at the 13-year follow-up. *(d)* The final outcome at the 21-year follow-up after immature tooth autotransplantation. The autotransplanted premolar (at the 21-year follow-up) was prosthetically prepared, and a crown with a canine shape was manufactured.

▲ **Fig 11** Extraoral views *(a)* at the beginning of the multidisciplinary treatment (age 10 years) and *(b and c)* at ages 18 and 31 years, respectively. A natural-looking esthetic result was achieved.

alveolar bone, preservation of the alveolar ridge, and restoration of the normal alveolar process.[27]

Successfully transplanted teeth demonstrate complete restoration of the functional PDL after healing, facilitating orthodontic movement and achieving an esthetically pleasing outcome with a normal gingival contour.[28] A crucial aspect for a successful outcome is the preservation or regeneration of periodontal tissues and pulp.[29] Because the donor tooth extraction will interrupt the vascular supply, pulp healing can only be expected in cases of transplantation of developing teeth. In these cases, sensitivity tests and radiographic follow-ups must be performed every 6 months postsurgery to monitor for inflammatory resorption (external resorption related to infection) and periapical lesions due to root canal infection. Sensitivity tests should become positive within the first 6 months following surgery. In cases of pulp devitalization or infection, root canal treatment should be initiated as early as possible. Pulp canal obliteration is common and should be considered a positive sign of pulp health.[6]

The extraoral duration of the avulsed tooth significantly affects the prognosis of dental autotransplantation,[10] with the underlying rationale for endodontic healing in such procedures grounded in a series of crucial steps. The phenomenon of replacement resorption, witnessed in some instances of autotransplantation, is strongly associated with the tooth's dry storage and the length of extraoral time. Success rates plummet to below 10% when the tooth remains outside the oral environment for longer than 60 minutes. In the two cases featured in this study, the extra-alveolar time was under 15 minutes, with the teeth preserved in an isotonic solution (Dentosafe, Medice Arzneimittel Pütter). The literature indicates that teeth with closed apices should undergo root canal therapy prior to transplantation or within a 7- to 14-day window posttransplantation, as necrotic pulp can trigger inflammatory resorption and compromise the tooth's longevity.[30,31]

On the other hand, transplanted teeth with open apices that have not completed root formation have a pulp survival rate of 96% compared to 15% for fully formed root teeth. In the first patient reported herein, it was decided not to perform endodontic treatment on the tooth but to replant it while keeping it vital. This technique has been described in the literature before.[32,33] The tooth underwent periodic vitality checks using thermal and electrometric pulp tests. Even though the maxillary left first premolar underwent apicectomy to create space for the tooth insertion at the adjacent canine site, it had regained its vitality at the end of the follow-up period due to the process of pulp revasculatization. Nakakura-Ohshima et al emphasized that root resection favorably influenced the preservation of native pulp cells, fostering their differentiation into odontoblasts.[34]

Long-term periodontal stability is evident in cases where alveolar tissues remain healthy, minimizing the loss of periodontal attachment.[19] In the first case, the stability of the periodontal tissues could be attributed to two different and concomitant processes. On the lingual side of the transplanted canine, the preservation of the PDL fibers on the root surface may have triggered and promoted periodontal healing, highlighting the importance of an extraction technique that preserves the residual fibers of the PDL.[35] The PDL fibers were unintentionally removed due to surgical trauma during tooth extraction. Thus, the stability of the periodontal tissue at this site was a result of the possible underlying bone regeneration. It is noteworthy that the extent of new bone formation on the buccal site stabilized the establishment of the supracrestal tissue attachment, limiting not only the periodontal probing depth but also the gingival recession, which was minimal. Regarding the formation of new periodontal attachment, hypotheses can be made about the nature and histologic characteristics of the tissue after healing under the described conditions. In 1995, Sander and Karring demonstrated that when GBR leads to the formation of new alveolar bone, the formation of a new and healthy periodontal attachment apparatus consisting of both connective and epithelial tissue can also be observed.[36] Furthermore, it can be hypothesized that autologous platelet concentrates (such as L-PRF, in this case) may have had an additional effect in promoting bone and soft tissue regeneration, further improving the stability of the gingival tissue.[37] These favorable findings were also obtained in the only recently published and available case series about bone augmentation previous to tooth autotrasplantation, which had a survival rate of 91% with an average follow-up of 6 years.[20] In the that case, both in 3D reconstruction and in some of the sections, the bundle bone is slightly visible in the apical and middle positions of the roots, supporting the gingival tissues and leading to the clinical outcomes that are described in the text (no pathologic periodontal probing depths [PPDs] and minimal gingival recession). However, it should be considered that, in any case, regardless of whether there is bundle bone covering buccal surface of the replanted tooth, the absence of pathologic PPDs is the most important positive predictive outcome about tooth prognosis from the periodontal point of view, although this can be the result (and, in the opinion of the authors, this is not the case) of a reparative (rather than regenerative) healing process. Unfortunately, just histologic analysis may allow us to reach a definitive conclusion. The automatic segmentation shows the presence of bone on the vestibular side of both the maxillary right and left canines. The segmentation was performed using Romexis software (Planmeca), and this process is fully automated guided by artificial intelligence, with no operator-dependent component or the possibility to alter or modify the final result.

VeryPDF Software Demo Version (http://www.verypdf.com)

Common complications noted after dental autotransplantation include ankylosis, root resorption, and pulp necrosis with infection.[38] Partial obliteration of the pulp canal is a physiologic mechanism observed in 96% of the cases requiring regular follow-up. This calcific metamorphosis of the pulp represents the natural pulp response to trauma.[39] The only clinical relevance that pulp canal obliteration may present is related to the difficulty of performing endodontic treatment in cases of apical lesions, although the literature reports that only 1% to 16% of teeth with calcific metamorphosis may progress to pulp necrosis.[40] Periapical rarefaction is observed in 7.3% to 26.4% of these teeth within 4 years of trauma, especially in cases of total obliteration of the pulp space.[41]

Regarding the optimal duration for splinting reimplanted teeth, available evidence suggests a period of 1 to 2 weeks. Prolonged or rigid splinting beyond this timeframe can significantly increase the risk of ankylosis and other complications such as root resorption and issues with pulpal vitality. Therefore, to minimize the risk of ankylosis, splinting should be removed within 1 to 2 weeks after reimplantation.[42] However, the clinical situation in the first presented case is different due to the presence of buccal bone dehiscence, making the splinting period recommended for an intact surgical socket inapplicable. Thus, it was decided to extend the splinting period, prioritizing one of the fundamental principles for success in GBR: blood clot and wound stability.[43] To the authors' knowledge, there are no papers addressing this specific issue in this particular situation. Further, the canine from the first clinical case was splinted for months after September 2019 due to the COVID-19 outbreak, which prevented the authors from performing elective procedures, and might have been a contributing factor for the development the radiographic images compatible with root ankylosis.

Overall, successfully autotransplanted teeth can function similarly to natural teeth, preserving alveolar bone volume and warranting consideration as a therapeutic option when appropriate clinical criteria are met.[4]

Conclusions

To the best of the present authors' knowledge, the cases presented herein constitute the first reports in the dental literature that detail tooth autotransplantation concurrent with GBR to address buccal bone dehiscences, as well as autotransplantation into areas that have undergone previous vertical regeneration. While these two case reports have their inherent limitations, the clinical outcomes offer preliminary evidence supporting the concept. Nonetheless, the technique has shown encouraging predictability in both medium- and long-term follow-up observations. Future clinical research, comprising larger cohorts and longer follow-up periods, is required to substantiate this technique's efficacy and safety before it can be widely recommended for standard clinical practice. The favorable results noted in these clinical cases can be credited, in part, to the meticulous interdisciplinary coordination throughout the diagnostic and surgical stages.

Acknowledgments

This study was self-funded. The authors declare no conflicts of interest.

Author contributions: T.T. and M.S. performed the surgery, wrote the preliminary draft, and approved the final version; F.G.C. helped in writing the preliminary draft; S.C., A.D., and J.C. researched the literature and wrote the periodontal and surgical rationale; S.T. researched the literature and wrote the endodontic rationale; G.P. and R.C. performed the orthodontic treatment and contributed to the writing of the manuscript; and H.L.W. finalized the paper with the CARE checklist and did the editing.

References

1. Apfel H. Autoplasty of enucleated prefunctional third molars. J Oral Surg (Chic) 1950;8:289–296.
2. Czochrowska EM, Stenvik A, Bjercke B, Zachrisson BU. Outcome of tooth transplantation: Survival and success rates 17–41 years posttreatment. Am J Orthod Dentofacial Orthop 2002;121:110–119.
3. Lucas-Taule E, Llaquet M, Munoz-Penalver J, Somoza J, Satorres-Nieto M, Hernandez-Alfaro F. Fully guided tooth autotransplantation using a multidrilling axis surgical stent: Proof of concept. J Endod 2020;46:1515–1521.

4. Pedrinaci I, Calatrava J, Couso-Queiruga E, et al. Tooth autotransplantation with adjunctive application of enamel matrix derivatives using a digital workflow: A prospective case series. J Dent 2024;148:105131.
5. Barendregt D, Andreasen JO, Leunisse M, et al. An evaluation of 1654 premolars transplanted in the posterior region—A retrospective analysis of survival, success and complications. Dent Traumatol 2023;39(suppl 1):50–62.
6. Tsukiboshi M. Autotransplantation of teeth: Requirements for predictable success. Dent Traumatol 2002;18:157–180.
7. Derks J, Tomasi C. Peri-implant health and disease. A systematic review of current epidemiology. J Clin Periodontol 2015;42(suppl 16):s158–s171.
8. Rodrigo D, Sanz-Sanchez I, Figuero E, et al. Prevalence and risk indicators of peri-implant diseases in Spain. J Clin Periodontol 2018;45:1510–1520.
9. 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.
10. Andreasen JO. Relationship between cell damage in the periodontal ligament after replantation and subsequent development of root resorption. A time-related study in monkeys. Acta Odontol Scand 1981;39:15–25.
11. Kvint S, Lindsten R, Magnusson A, Nilsson P, Bjerklin K. Autotransplantation of teeth in 215 patients. A follow-up study. Angle Orthod 2010;80:446–451.
12. Schwartz O, Bergmann P, Klausen B. Resorption of autotransplanted human teeth: A retrospective study of 291 transplantations over a period of 25 years. Int Endod J 1985;18:119–131.
13. Ong D, Itskovich Y, Dance G. Autotransplantation: A viable treatment option for adolescent patients with significantly compromised teeth. Aust Dent J 2016;61:396–407.
14. Lundberg T, Isaksson S. A clinical follow-up study of 278 autotransplanted teeth. Br J Oral Maxillofac Surg 1996;34:181–185.
15. Mejare B, Wannfors K, Jansson L. A prospective study on transplantation of third molars with complete root formation. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2004;97:231–238.
16. Keightley AJ, Cross DL, McKerlie RA, Brocklebank L. Autotransplantation of an immature premolar, with the aid of cone beam CT and computer-aided prototyping: A case report. Dent Traumatol 2010;26:195–199.
17. Zachrisson BU. Planning esthetic treatment after avulsion of maxillary incisors. J Am Dent Assoc 2008;139:1484–1490.
18. Gomez Meda R, Abella Sans F, Esquivel J, Zufia J. Impacted maxillary canine with curved apex: Three-dimensional guided protocol for autotransplantation. J Endod 2022;48:379–387.
19. Lucas-Taule E, Llaquet M, Munoz-Penalver J, Nart J, Hernandez-Alfaro F, Gargallo-Albiol J. Mid-term outcomes and periodontal prognostic factors of autotransplanted third molars: A retrospective cohort study. J Periodontol 2021;92:1776–1787.
20. Verweij JP, Wes JT, van Teeseling RA, Becking AG. Pre-autotransplantation alveolar process augmentation and premolar autotransplantation as a treatment method for single tooth replacement in adolescents. Int J Oral Maxillofac Surg 2021;50:1632–1637.
21. Yu HJ, Qiu LX, Wang XZ. Long-term follow-up of autogenous canine transplants with application of guided bone regeneration. Int J Oral Maxillofac Surg 2014;43:355–361.
22. Nolla C. The develpoment of permanent teeth J Dent Child 1960;27:254–266.
23. Park YS, Jung MH, Shon WJ. Autotransplantion of a displaced mandibular second premolar to its normal position. Am J Orthod Dentofacial Orthop 2013;143:274–280.
24. Cunha DL, Masioli MA, Intra JB, Roldi A, Dardengo Cde S, Miguel JA. Premolar transplantation to replace a missing central incisor. Am J Orthod Dentofacial Orthop 2015;147:394–401.
25. Lucas-Taule E, Bofarull-Ballus A, Llaquet M, Mercade M, Hernandez-Alfaro F, Gargallo-Albiol J. Does root development status affect the outcome of tooth autotransplantation? A systematic review and meta-analysis. Materials (Basel) 2022;15:3379.
26. Akhlef Y, Schwartz O, Andreasen JO, Jensen SS. Autotransplantation of teeth to the anterior maxilla: A systematic review of survival and success, aesthetic presentation and patient-reported outcome. Dent Traumatol 2018;34:20–27.
27. Anitua E, Mendinueva-Urkia M, Galan-Bringas S, Murias-Freijo A, Alkhraisat MH. Tooth autotransplantation as a pillar for 3D regeneration of the alveolar process after severe traumatic injury: A case report. Dent Traumatol 2017;33:414–419.
28. Day PF, Kindelan SA, Spencer JR, Kindelan JD, Duggal MS. Dental trauma: Part 2. Managing poor prognosis anterior teeth—Treatment options for the subsequent space in a growing patient. J Orthod 2008;35:143–155.
29. Jakse N, Ruckenstuhl M, Rugani P, Kirnbauer B, Sokolowski A, Ebeleseder K. Influence of extraoral apicoectomy on revascularization of an autotransplanted tooth: A case report. J Endod 2018;44:1298–1302.
30. Kristerson L, Andreasen JO. Influence of root development on periodontal and pulpal healing after replantation of incisors in monkeys. Int J Oral Surg 1984;13:313–323.
31. Cohen AS, Shen TC, Pogrel MA. Transplanting teeth successfully: Autografts and allografts that work. J Am Dent Assoc 1995;126:481–485.
32. 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;46:531–538.
33. Suwanapong T, Waikakul A, Boonsiriseth K, Ruangsawasdi N. Pre- and peri-operative factors influence autogenous tooth transplantation healing in insufficient bone sites. BMC Oral Health 2021;21:325.
34. Nakakura-Ohshima K, Quispe-Salcedo A, Sano H, Hayasaki H, Ohshima H. The effects of reducing the root length by apicoectomy on dental pulp revascularization following tooth replantation in mice. Dent Traumatol 2021;37:677–690.
35. Plotino G, Abella Sans F, Duggal MS, et al. Present status and future directions: Surgical extrusion, intentional replantation and tooth autotransplantation. Int Endod J 2022;55(suppl 3):827–842.
36. Sander L, Karring T. New attachment and bone formation in periodontal defects following treatment of submerged roots with guided tissue regeneration. J Clin Periodontol 1995;22:295–299.
37. Kornsuthisopon C, Pirarat N, Osathanon T, Kalpravidh C. Autologous platelet-rich fibrin stimulates canine periodontal regeneration. Sci Rep 2020;10:1850.
38. Rohof ECM, Kerdijk W, Jansma J, Livas C, Ren Y. Autotransplantation of teeth with incomplete root formation: A systematic review and meta-analysis. Clin Oral Investig 2018;22:1613–1624.
39. Abd-Elmeguid A, ElSalhy M, Yu DC. Pulp canal obliteration after replantation of avulsed immature teeth: A systematic review. Dent Traumatol 2015;31:437–441.
40. Kristerson L. Autotransplantation of human premolars. A clinical and radiographic study of 100 teeth. Int J Oral Surg 1985;14:200–213.
41. Assuncao LR, Ferelle A, Iwakura ML, Nascimento LS, Cunha RF. Luxation injuries in primary teeth: A retrospective study in children assisted at an emergency service. Braz Oral Res 2011;25:150–156.

42. Gul A, Lauridsen E, Gerds TA, Andersson L. Risk of ankylosis of avulsed teeth immediately replanted or stored under favorable storage conditions before replantation: A long-term clinical study. Dent Traumatol 2024;40:137–143.
43. Wang HL, Boyapati L. "PASS" principles for predictable bone regeneration. Implant Dent 2006;15:8–17.

Tiziano Testori, MD, DDS, MSc
Section of Implant Dentistry and Oral Rehabilitation, Dental Clinic, IRCCS Galeazzi Sant'Ambrogio Hospital, Milan, Italy; Department of Biomedical, Surgical and Dental Sciences, University of Milan, Milan, Italy; Department of Periodontics & Oral Medicine, University of Michigan School of Dentistry, Ann Arbor, Michigan, USA.

Massimo Simion, MD, DDS
Department of Periodontology, Maxillofacial and Odontostomatology Unit, Fondazione Cà Granda IRCCS, Ospedale Maggior Policlinico, University of Milan, Milan, Italy.

Francesco Giachi Carù, DDS, MSc
Lake Como Institute, Advanced Implant Training Center, Como, Italy.

Stefano Corbella, DDS, PhD
Silvio Taschieri, MD, DDS
Department of Biomedical, Surgical, and Dental Sciences, University of Milan, Milan, Italy; Department of Oral Surgery, Institute of Dentistry, I. M. Sechenov First, Moscow State Medical University, Moscow, Russia.

Giovanna Perrotti, DDS, MSc
Lake Como Institute, Advanced Implant Training Center, Como, Italy.

Renato Cocconi, MD, DDS, MSc
Private practice, Parma, Italy.

Javier Calatrava, DDS, MSc
Department of Periodontics & Oral Medicine, University of Michigan School of Dentistry, Ann Arbor, Michigan, USA; Section of Graduate Periodontology, Faculty of Odontology, Complutense University, Madrid, Spain.

Ann Decker, DDS, PhD
Hom-Lay Wang, DDS, MSD, PhD
Department of Periodontics & Oral Medicine, University of Michigan School of Dentistry, Ann Arbor, Michigan, USA.

Correspondence to:
Dr Tiziano Testori, tiziano.testori@unimi.it