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CASE REPORT

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Tooth autotransplantation with 3D-printed replicas as part of interdisciplinary management of children and adolescents: Two case reports

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Abstract

The management of missing teeth as a result of dental trauma or associated with hypodontia in children and adolescents presents as a clinical challenge for the dental team. One of the options that is regaining popularity is dental autotransplantation. To improve autotransplantation outcomes, careful interdisciplinary planning, surgical simulation using cone beam computed tomography images and three-dimensional-printed teeth replicas should be undertaken for presurgical preparation. This case report showcases two applications of autotransplantation, with emphasis on interdisciplinary management, presurgical preparation and postsurgical orthodontic and aesthetic management to deliver a good long-term, sustainable, biological outcome, as a part of a comprehensive rehabilitation treatment plan in children.

KEYWORDS

adolescent, autologous, child, printing, three dimensional, tooth loss, tooth autotransplantation, transplantation

1 | INTRODUCTION

Dental autotransplantation refers to 'transplantation of an unerupted or erupted tooth in the same individual, from one site to another extraction site or a new surgically prepared socket'.[1] It has various advantages, such as conferring a satisfactory gingival outcome among patients,[2] facilitating the growth of alveolar bone[3] and potential for regeneration of normal periodontal ligament (PDL) that allows for proprioception and orthodontic movement.[4] The success and survival rate of autotransplantation is over 85%, with donor teeth with open apices having lower complication rates than those with complete root development.[5] As such, autotransplantation is considered a viable treatment option when applied within a comprehensive plan by an interdisciplinary dental team to replace missing teeth due to traumatic dental injury (TDI)[6] or manage hypodontia[7] among children and adolescents.

In recent years, methods to further improve the success and survival of autotransplants have been investigated. This involves presurgical preparation, such as using cone beam computed tomography (CBCT) for surgical simulation and developing three-dimensional (3D)-printed donor teeth replicas or surgical stents prior to the procedure.[8] The former allows clinicians to evaluate the adequacy of the prepared socket before carrying out the actual transplant, which minimises trauma and extra-alveolar time to the donor teeth while the latter allows for accurate preparation of the socket and positioning of donor teeth at the recipient site.

The aim of this case report was to present two cases of autotransplantation where 3D-printed replicas were used.

2 | CASE REPORTS

The reports were prepared in accordance with the PRICE 2020 guidelines.[9] The patients were both managed at the National University Centre for Oral Health Singapore (NUCOHS). Their characteristics, surgical factors (pre-, intra- and post-operative), follow-up duration and outcomes are presented in Table 1.

2.1 | Case 1

A fit and healthy 11-year-old boy was referred for the management of the maxillary permanent right (#11) and left (#21) central incisors with concerns regarding resorption and infra-occlusion following endodontic management after severe dental trauma (Figure 1). Seven months prior, #11 had an avulsion injury with an extraoral dry time of >60 min and #21 was severely intruded. Clinical and radiographic examination revealed a Class II Division 1 malocclusion on a Class I high-angle skeletal base. Both #11 and #21 showed reduction in physiological mobility, a high metallic tone on percussion and clinical infra-occlusion. Both #11 and #21 had previously initiated endodontic treatment but the prognosis of these teeth were considered to be poor because they were both diagnosed as ankylosed, with external root resorption. #11 demonstrated significant external replacement (ankylosis-related) resorption, while #21 showed external inflammatory (infection-related) resorption. However, due to the finding of ankyloses in both, they were considered to be at high risk of external replacement resorption and of poor long-term prognosis. The decision to intervene was made to prevent further restriction of vertical alveolar bone growth. His parents were also keen on orthodontic treatment to correct his crowding. A treatment plan of autotransplantation of the mandibular second premolars to the site of the maxillary central incisors, and extraction of the maxillary first premolars, followed by orthodontic treatment was decided upon by an interdisciplinary team consisting of a paediatric dentist, orthodontist and endodontist.

Two weeks before surgery, a CBCT was taken to assess the dimensions of the donor teeth, to allow the fabrication of the 3D donor tooth replicas and aid computer simulation of the procedure to ensure sufficient space for the placement of the donor teeth (Figure 2A–D). Due to the patient's apprehension towards the procedure, #11 and #21 were extracted under general anaesthesia and surgical preparation of the transplant sites was carried out immediately after. Prior to the extraction of the donor teeth, the donor tooth replicas were used to ensure sufficient preparation of the surgical sites. The autotransplantation of the mandibular second premolars to the site of the maxillary central incisors (#11T, #21T) was completed uneventfully with

TABLE 1 Patient characteristics, treatment factors and outcomes.

Patient characteristics		Presurgical factors		Surgical factors				Postsurgical and other factors			Pulp outcomes		Periodontal outcomes
Case	Age/gender	Reason for transplant	Donor tooth	Stage of root development (Moorrees)[25]	Recipient site	Extra-alveolar time of donor tooth	Splint type and duration	Aesthetic build-up; time of aesthetic build-up	Orthodontic treatment; time of tooth movement of transplanted teeth	Follow-up (months)	Pulp findings	Endodontic treatment	Stage of root development (Moorrees)[25]; C:R
1	11/M	Trauma	#35	Two-third root length developed with diverged ends	#21	<1 min	Twistflex 0.0175″ and composite; 4 weeks	4 weeks of post-transplant	11 months of post-transplant	35	PN	MTA apical plug; 3 months post-transplant	Completed; 1:1
			#45	Two-third root length developed with diverged ends	#11	<1 min					NAD	Nil	Arrested; 1:0.75
2	12/M	Hypodontia	#15	Half root formed, root equals crown length	#35	<1 min	Stainless steel wire 0.4 mm and composite; 2 weeks	Nil	24 months of post-transplant	42	PCO	Nil	Completed; 1:1.5
			#25	Half root formed, root equals crown length	#45	<1 min					PCO	Nil	Completed; 1:2

Abbreviations: C:R, crown:root ratio; M, Male; Min, minute; MTA, Mineral trioxide aggregate; NAD, No abnormalities detected; PCO, Pulp canal obliteration; PN, Pulp necrosis.

FIGURE 1 Baseline intraoral photograph and radiograph of the 11-year-old boy following dental trauma. (A) Frontal view of maxillary right and left central incisors (#11, #21) and dental crowding. (B) Periapical radiograph of #11 and #21.

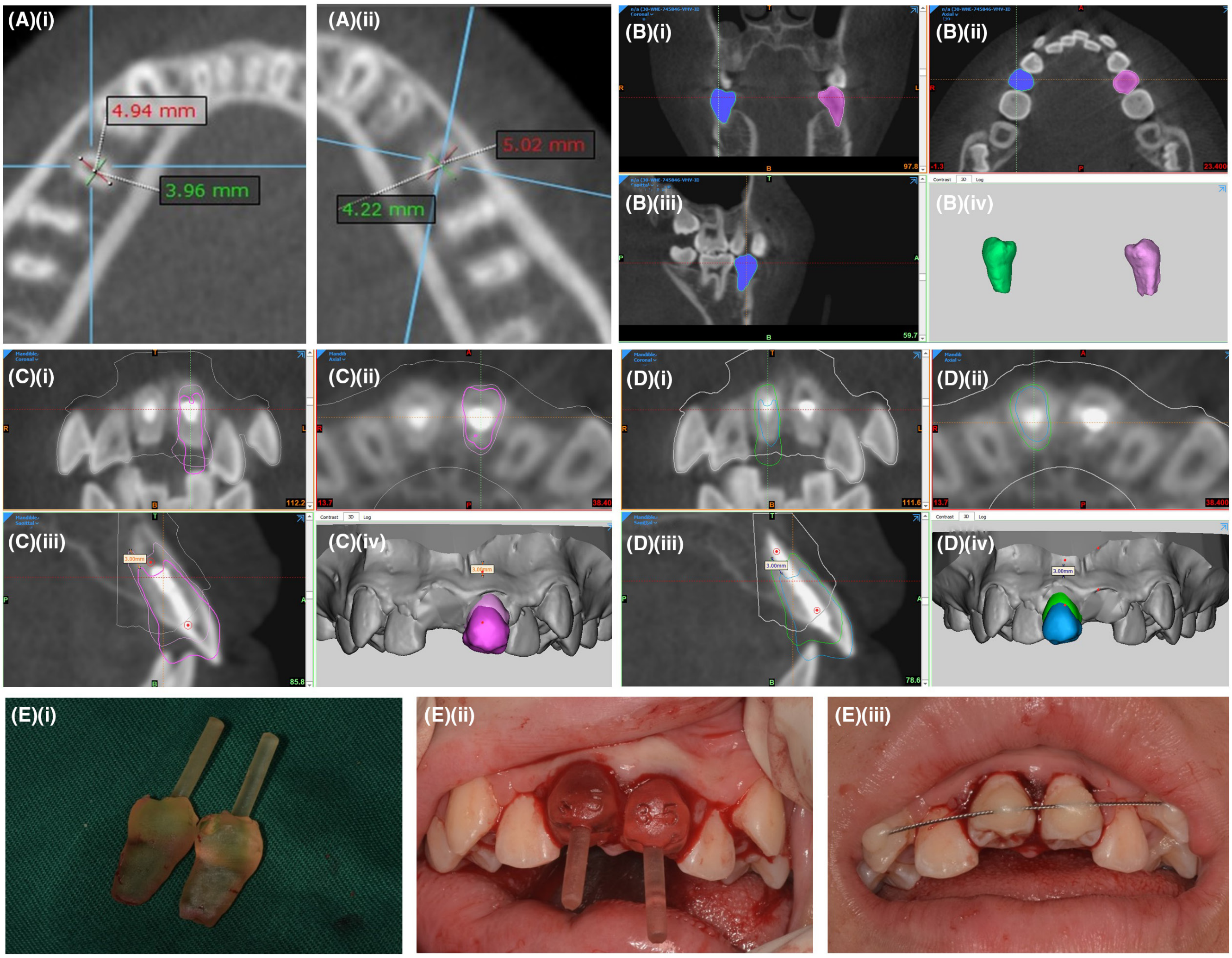

FIGURE 2 CBCT and surgical simulation. (A) (i–ii) CBCT images to determine the dimensions of the donor premolar teeth. (B) (i–iv) Donor premolar teeth from the CBCT. (C) (i–iv) and (D) (i–iv) Simulated removal of the ankylosed maxillary central incisors and simulation of the autotransplanted mandibular premolars in the transplant site. (E) (i) 3D-printed tooth replicas, (ii) 3D-printed tooth replicas at recipient sites and (iii) Donor teeth at recipient sites, splinted.

both donor teeth having an extra-alveolar time of less than 1 min, and a composite resin splint was placed (Figure 2Ei–iii). The splint was removed, and composite build-ups were performed at 4 weeks post-autotransplant (Figures 3 and 5A,B).

Orthodontic treatment for the mandibular arch commenced approximately 5 weeks post-autotransplant. Orthodontic treatment for the maxillary arch was deferred to allow for the healing of the autotransplants. 3 months post-autotransplant, #21T presented with a buccal sinus tract (Figure 4). Root canal treatment (RCT) with a mineral trioxide aggregate (MTA) apical plug was carried out on #21T (Figure 5C). Orthodontic movement of #11T and #21T was deferred until adequate healing of the pulp, and PDL tissues had occurred.

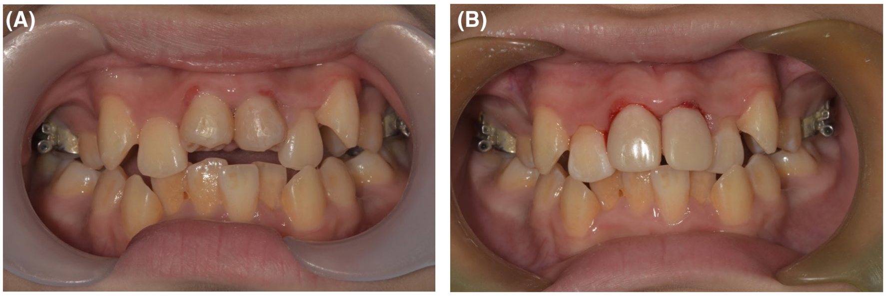

FIGURE 3 Donor premolar teeth at (A) 4 weeks of postautotransplant (B) following build-up at 4 weeks of postautotransplant.

FIGURE 4 Autotransplant (#21T) presented clinically with a sinus tract.

As an interim measure, fixed appliances from maxillary canines to second molars were placed to maintain the extraction space for subsequent anterior retraction. At 10 months post-autotransplant, no further root growth had been observed on both #11T and #21T. Orthodontic tooth movement of #11T and #21T commenced at 11 months post-autotransplant, and light continuous forces were used when engaging the autotransplants.

At 22 months post-autotransplant (19 months of post-RCT), hard tissue formation resembling a root tip was observed beyond the apical plug (Figure 5F,G). #11T had absence of continued root development and response to sensibility testing, but remained asymptomatic clinically. #11T and #21T subsequently continued to present with no periodontal anomalies, no tenderness on percussion and mobility within physiological limits.

At the later stages of orthodontic treatment, after proper positioning of the autotransplants was achieved, modifications were made to improve the aesthetics of #11T and #21T composite build-ups. Orthodontic treatment was completed 29 months after the autotransplant procedure (Figure 6). Both the patient and the parents were happy with the current aesthetic outcome, and due to the young age of the patient, permanent aesthetic restorative management was deferred.

2.2 | Case 2

A fit and healthy 12-year-old boy was referred for the management of hypodontia. Clinical and radiographic examination revealed a Class II Division 1 malocclusion on a mild Class II skeletal base and missing mandibular premolars (Figure 7). A treatment plan of autotransplantation of the maxillary second premolars to the sites of mandibular premolars, followed by orthodontic treatment was decided upon.

One month before surgery, a CBCT was taken to determine the suitability of the surgical sites and location of vital structures (Figure 8Ai–iv). This was performed in conjunction with an intra-oral impression to ensure accurate dimensions of the surgical sites and donor teeth. Computer simulation of the procedure was performed to determine the position of the donor teeth in relation to vital structures at the recipient sites (Figure 8B,C). Based on the simulation, a surgical stent and tooth replicas were 3D-printed (Figure 8Di,ii). Under general anaesthesia, surgical preparation of the transplant sites was carried out immediately following the extraction of the mandibular second primary molars (#75 and #85) with the aid of the surgical stent (Figure 7Ei). Once the 3D-printed replicas were deemed to fit comfortably in the surgically prepared sockets, the autotransplant procedure was completed uneventfully, with both donor teeth having an extra-alveolar time of less than 1 min (Figure 8Eii–iii). The maxillary right (#15) and left (#25) second premolars were transplanted to sites of mandibular left (#35T) and right (#45T) second premolars, respectively. The autotransplants were splinted for 2 weeks.

Orthodontic treatment for the other teeth, not including the transplanted teeth, commenced 1 month post-autotransplant. Continued root development and positive response to sensibility testing were recorded from 6 months post-autotransplant onwards (Figure 9A–C,E–G). #35T and #45T remained clinically asymptomatic, with no periodontal anomalies, no tenderness on percussion and having mobility within physiological limits. Orthodontic tooth movement on the autotransplanted teeth commenced when the roots were ¾ formed as the donor teeth were transplanted when the roots were premature. Orthodontic forces on the transplanted teeth were kept light and continuous with movements performed in one plane at a time: mesialising tooth movements were followed by rotational movements (Figure 10A) to avoid excessive apical pressures that could impair blood supply to the developing roots. Further root development on #35T and #45T was noted at 3.5 years post-autotransplant (Figure 9D,H).

3 | DISCUSSION

Tooth loss from TDI and hypodontia in children and young adolescents often present as a clinical challenge for the dental team

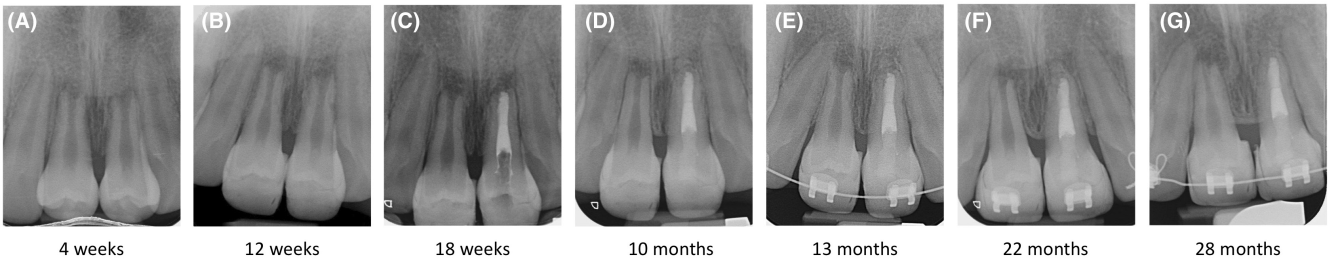

FIGURE 5 Radiographs (A-G) of autotransplants (#11T, #21T).

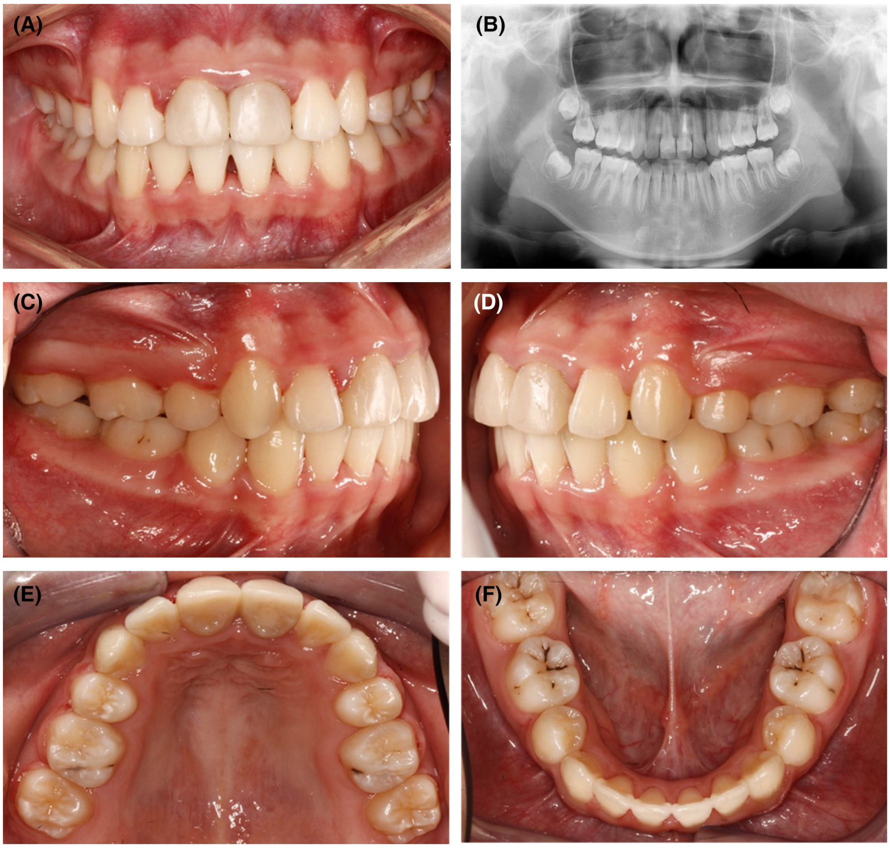

FIGURE 6 Intraoral photographs and radiograph taken at postorthodontic treatment 29 months of postautotransplant (A) Frontal view; (B) Panoramic radiograph; (C) Right buccal view; (D) Left buccal view; (E) Maxillary occlusal view; (F) Mandibular occlusal view.

due to the multifaceted clinical presentation requiring input from several specialties. Prompt referral and management frequently result in an improvement in quality of life for these patients.[10] The management of these cases usually requires an interdisciplinary care team, comprising a paediatric dentist, orthodontist and at times an oral surgeon or prosthodontist, to collaborate, communicate and formulate a comprehensive treatment plan.[11,12] Autotransplantation is one of the multiple treatment options (amongst orthodontic substitution and prosthodontic replacement) to manage tooth loss from TDI or hypodontia. It allows for strategic redistribution of teeth from a crowded arch to one with missing teeth.[13] Autotransplantation provides a more biological outcome than prosthetic replacement of traumatically involved teeth with poor prognosis (e.g. progressive replacement resorption) or missing teeth.[1] Preservation of the periodontal ligament around the transplanted teeth allows for the continued growth of the alveolar process. The autotransplants would have intact proprioception and can function like natural teeth. Comparatively, orthodontic substitution may not always be a viable option for the patient depending on the space requirements of the arch, the morphology of the adjacent teeth and the patient's aesthetic requirements. Implant treatment is contraindicated in the children and adolescents due to the risk of infra-occlusion of both the implant and the crown during the growth phase.[14]

The two patients in our case report were referred to the interdisciplinary team at NUCOHS for complications associated with TDI and hypodontia, respectively. The various treatment options, such as orthodontic substitution of maxillary central incisors with the lateral incisors or prosthodontic replacement in Case 1, were presented and discussed. Ultimately, the families in both Cases 1 and 2 decided on autotransplantation with comprehensive orthodontic treatment.

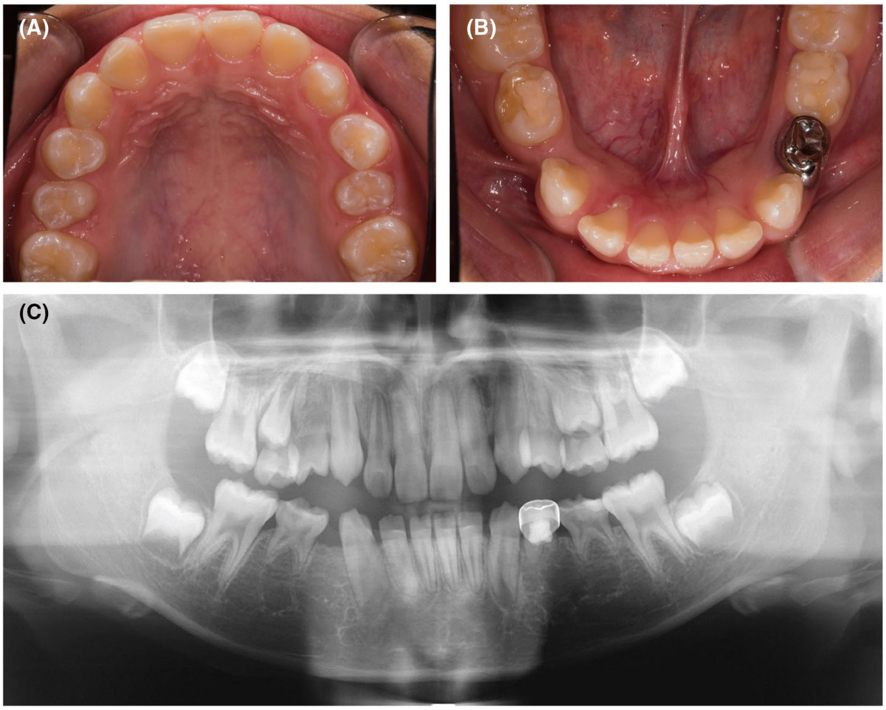

FIGURE 7 Baseline intraoral photographs and radiograph of the 12-year-old boy with hypodontia. (A) Maxillary arch (B) Mandibular arch (C) Panoramic radiograph.

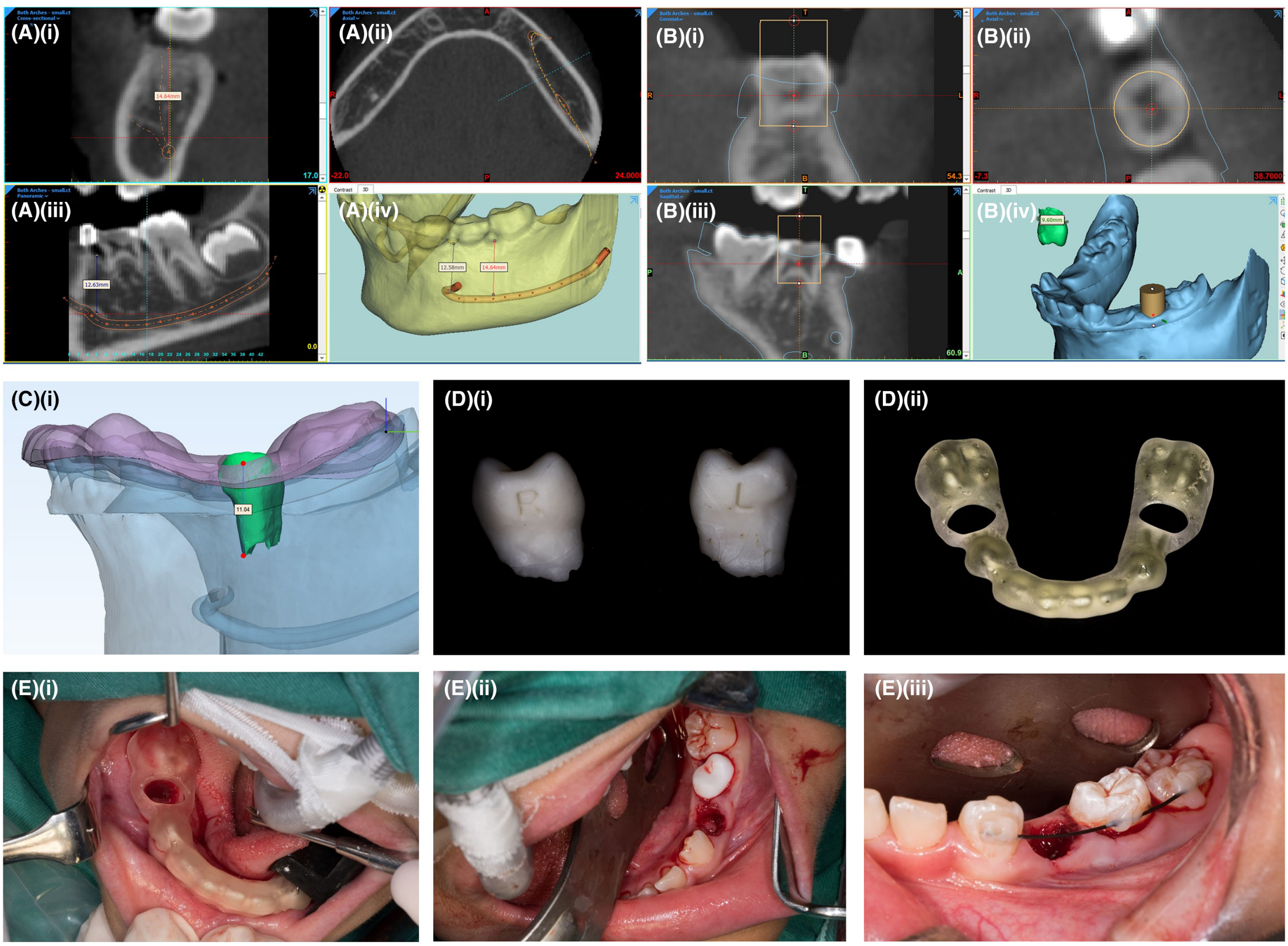

FIGURE 8 CBCT and surgical simulation. (A) (i–iv) Identification of inferior alveolar nerve relative to dentition. (B) (i–iv) Measurement of donor tooth diameter and determination of recipient site location. (C) Final image render of location of maxillary right donor tooth in recipient site, in relation to left inferior alveolar nerve and surgical stent. (D) (i) Three-dimensional (3D)-printed tooth replica (ii) Surgical stent. (E) (i) Preparation of surgical site with surgical stent (ii) 3D-printed tooth replica at recipient site and (iii) Donor tooth at recipient site and splinted.

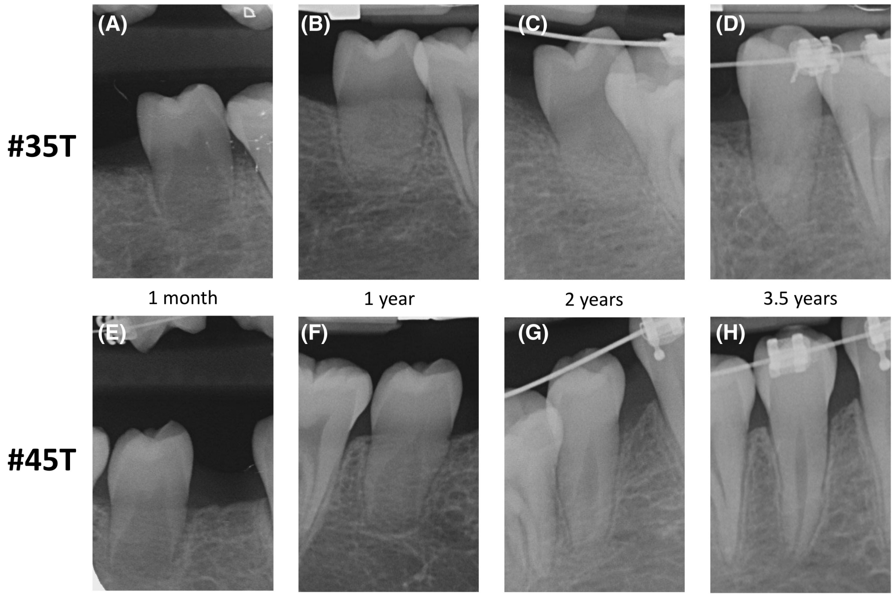

FIGURE 9 Root development of autotransplants at recipient sites #35T and #45T (A, E) 1 month, (B, F) 1 year, (C, G) 2 years, (D, H) 3.5 years.

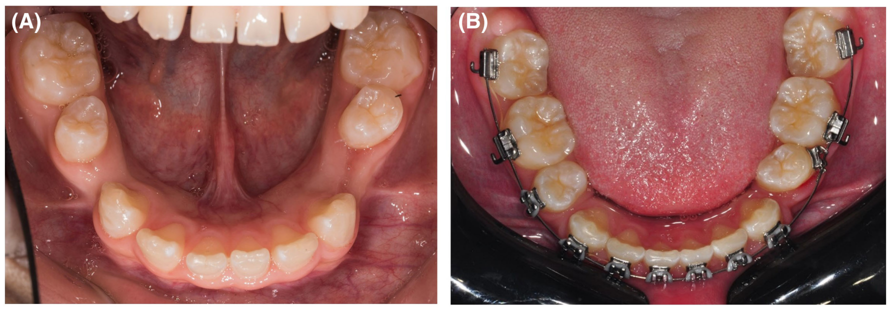

FIGURE 10 Orthodontic movement on the transplanted teeth. (A) Teeth before orthodontic treatment. (B) Mesialisation of #35T and #45T took place before rotational movements.

As part of the presurgical preparation, a CBCT was taken for visualisation of the surgical site and surgical simulation, and 3D-printed tooth replicas and surgical stents were prepared. Knowledge of the surgical sites allows the oral surgeon to confidently prepare the sockets under general anaesthesia, which can reduce total surgery time. Specifically for Case 2, it allowed the identification of the location of the inferior dental nerves and thickness of alveolar bone at the recipient sites. In Case 1, simulation was carried out to determine whether there was sufficient space at the recipient sites for transplantation of the donor teeth. If there had been insufficient space, orthodontic treatment would have commenced prior to autotransplantation to create space for the placement of the donor teeth.[15]

When preparing the socket to receive the donor tooth, it is preferable that the socket is as accurate as, or slightly larger than the dimensions of the donor tooth root to prevent forceful or multiple attempts to insert the donor tooth into the socket, which will compromise PDL healing.[16] 3D-printed tooth replicas can address these considerations. Replicas are slightly larger than the actual donor tooth, therefore allowing the creation of a slightly larger socket, thereby reducing the number of tries to insert the donor tooth.[8,17] Clinicians can even customise the replica to be slightly bigger prior to printing or extending the root length of the donor tooth to account for possible root growth should the surgery be delayed. The recipient sites in our cases were slightly overprepared, which allowed immediate transplantation and comfortable sitting of the donor teeth.

After autotransplantation, it is recommended that PDL and pulp healing, and continued root development are observed before light orthodontic forces are applied on the transplanted teeth, minimally 6 months after transplantation.[18] In addition to the timing to commence orthodontic treatment, the direction and magnitude of orthodontic forces applied are essential to the success of an autotransplant and should be discussed within the interdisciplinary team. For Case 2, translational movement followed by rotational forces was performed prior to root-end closure to prevent pulp strangulation.[19] For Case 1, treatment and resolution of any pulp or periodontal pathosis were ensured before commencing orthodontic treatment.[20] In addition, in view of arrested root development of both autotransplants, modifications to the orthodontic treatment were undertaken to minimise further resorption to their roots. #11T and #21T were engaged only after adequate space was created. This minimised round-tripping during alignment, and reduced the magnitude and duration of orthodontic forces on #11T and #21T.

When the recipient site of the autotransplant is in the aesthetic zone, the autotransplant should be restored as soon as is practical to match the morphology and aesthetics of the adjacent teeth, so as to restore the patient's self-esteem. In Case 1, #11T and #21T were restored 4 weeks of postautotransplant. In the interim period, the patient expressed feeling extremely self-conscious and being unwilling to smile and was significantly more confident immediately following the placement of the composite restorations to restore the form of the autotransplanted teeth. Close communication amongst the paediatric dentist, orthodontist and prosthodontist regarding the space required for restorative build-up and type of final restoration is imperative. Regular revision of the anterior restorations may be required as orthodontic treatment progresses. In Case 1, there was initially inadequate space to build #11T and #21T to the ideal mesiodistal widths and contours given the moderate crowding. Orthodontic positioning of the autotransplants was performed to facilitate build-ups with ideal contours that better resembled central incisors. The build-ups were modified during later stages of orthodontic treatment for better aesthetics. Following the completion of orthodontic treatment and growth of the patient, if indicated, definitive restorative treatment such as veneers or crowns can be performed on the autotransplanted teeth by the prosthodontist, to achieve a long-term optimal aesthetic outcome.

While there is no consensus on the criteria for evaluating the success of an autotransplant, the most frequently reported success criteria are the absence of progressive internal or external root resorption, ankylosis, hypermobility, pathologically increased probing depths, crown-to-root ratio greater than one and pulp or apical inflammation.[6,21] Self-limiting complications such as arrested root development and endodontic treatment that result in resolution of apical inflammation should not preclude an outcome from being considered successful.[6] In Case 1, despite #11T having arrested root development and #21T requiring endodontic treatment, overall, both cases can be considered successful with all autotransplants presenting with normal PDL and pulp findings (#11T in Case 1 being clinically asymptomatic). All autotransplanted teeth were also amenable to orthodontic movement with good final aesthetic outcomes. The successful outcomes in both cases can be attributed to correct donor tooth selection (i.e. teeth with close to ⅔ root formation),[6] thorough presurgical preparation (i.e. use of CBCT-guided computer simulation and 3D-printed tooth replicas and surgical stents)[8] and a short extra-oral time during the autotransplant procedures.[22]

An interesting finding in this case report is the development of root-like structure beyond the MTA plug in autotransplant #21T in Case 1. To the authors' knowledge, this is the first known autotransplanted tooth with this finding. Similar radiographic findings had been previously reported after replantation and MTA plug of an immature avulsed tooth.[23] This was attributed to the vitality of the Hertwig's epithelial root sheath (HERS) even after pulp necrosis.[24] Case 1 showcased the resilience of HERS whereby continued root-like development beyond the MTA plug was observed despite 'trauma' from autotransplantation, followed by pulp necrosis and root canal treatment.

4 | CONCLUSION

This case report showcased two successful applications of autotransplantation with presurgical preparation in two paediatric patients with TDI and hypodontia by an interdisciplinary dental team, particularly with the use of 3D-printed tooth replicas to aid the autotransplant procedure. Favourable outcomes were achieved after a follow-up duration of at least 35 months. Case 1 also highlights an interesting outcome after endodontic therapy of the autotransplant, and the importance of recognising patient-related outcomes (patient's aesthetics) in addition to treatment-related outcomes.

AUTHOR CONTRIBUTIONS

MMYK and IKD should be considered joint first authors. BLT, IKD, MMYK, RCWW, SHS and WWL participated in data collection. MMYK and IKD led the writing. BLT, IKD, MD, MMYK, RCWW, SHS and WWL revised the manuscript for important intellectual content.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest. All authors have made substantial contributions to this study and/or manuscript, and all have reviewed the final paper prior to its submission. The authors declare no financial conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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