Fully Guided Tooth Autotransplantation Using a Multidrilling Axis Surgical Stent: Proof of Concept

Ernest Lucas-Taulé, DDS, MSc,[*]
Marc Llaquet, DDS, MSc,[†]
Jesús Muñoz-Peñalver, DDS,[‡]
Jacobo Somoza, DDS,[§]
Marta Satorres-Nieto, DDS, MSc, PhD,[*] and
Federico Hernández-Alfaro, MD, DDS, PhD[*]

ABSTRACT

Introduction: Digital technology has been progressively introduced into tooth autotransplantation to enhance both treatment planning and surgery. The aim of this report was to describe a novel protocol for fully guided tooth autotransplantation. **Methods:** This report includes 10 consecutive patients treated with a complete virtual planning and a multidrilling axis surgical guide in combination with the computer-aided rapid prototyping model. **Results:** All transplanted teeth fulfilled the criteria for success over a mean follow-up duration of 13.1 months. No signs of progressive root resorption or pain were found during follow-up. One case required minimal adjustment of the surgical stent to allow correct seating, whereas a second case could not be performed fully guided because of limited mouth opening. **Conclusions:** Our protocol for fully guided tooth autotransplantation is a viable option that involves minimal bone preparation in a short surgical time. Future research should focus on further investigation of the benefits of this novel protocol in a larger sample. *(J Endod 2020;46:1515–1521.)*

KEY WORDS

Computer-aided rapid prototyping model; guided surgery; tooth autotransplantation; virtual planning

Tooth autotransplantation is an accepted and predictable procedure for the replacement of unrestorable teeth[1,2]. In contrast to dental implants, the transplant adapts to the eruption of adjacent teeth and developmental changes in the oral region and can be orthodontically moved.[3–6] Therefore, it is considered the ideal treatment for tooth replacement in growing patients[3,7,8]. Furthermore, given the regenerative potential of the periodontal ligament (PDL), the transplant itself stimulates regeneration of the attachment apparatus, leading to re-establishment of a normal alveolar process and preservation of the gingival architecture[9].

Since Slagsvold and Bjercke[10] established a tooth autotransplantation protocol at the University of Oslo in the 1960s, the predictability of this treatment has been confirmed by several long-term follow-up studies[11–15]. Predictors of survival of the transplanted tooth are chiefly related to preservation of the PDL cells in the donor tooth[4,9,11]. Tooth manipulation during surgery and its extraoral time may damage the PDL surface, leading to postoperative complications, such as root resorption and attachment loss[16]. Hence, this procedure requires gentle extraction and handling of the donor tooth during surgery.

Digital technology has been progressively introduced into this therapy to enhance both treatment planning and surgery. Lee et al[17] first described the use of computer-aided rapid prototyping (CARP) models in tooth autotransplantation, which allow the clinician to prepare the recipient site without the need of the donor tooth itself, thereby minimizing further complications. For its part, surgical planning software enables the design and manufacture of a 3-dimensional (3D)-printed surgical template for guided preparation of the recipient socket during surgery, as used in dental implants.

Some authors have proposed the use of multiple surgical templates for preparation of the recipient socket during tooth autotransplantation. However, to the best of our knowledge, no protocols include fully guided socket remodeling with a single and milled surgical template. The aim of this case series was to present a new protocol for tooth autotransplantation based on full virtual planning and a milled, sleeveless, multidrilling axis surgical guide in combination with the CARP model.

From the Departments of *Oral and Maxillofacial Surgery, †Endodontics, and ‡Periodontics, Universitat Internacional de Catalunya, Barcelona; and §Private Practice, Jacobo Somoza Institute, Madrid, Spain

Address requests for reprints to Dr Ernest Lucas-Taulé, Department of Oral and Maxillofacial Surgery, Universitat Internacional de Catalunya, C/Josep Trueta s/n 08195 St Cugat del Vallés, Barcelona, Spain.
E-mail address: ernest.lucas@uic.es

MATERIALS AND METHODS

Ten consecutive healthy patients were treated using a new protocol for tooth autotransplantation at a private dental office in Barcelona, Spain. A thorough oral and dental examination was performed after medical and dental history was obtained. All patients were informed about the potential benefits and risks before starting treatment. All patients provided informed consent before the surgery.

Virtually Guided Planning

An intraoral scan of the recipient arch (Trios3; 3Shape, København, Denmark) and an 8×8 cm field of view cone-beam computed tomographic scan (Newtom 5GXL; Newtom, Verona, Italy) were acquired. Both registers included the full dental arch in order to allow a single radiation exposure and favor further file alignment.

Both STL and Digital Imaging and Communications in Medicine files were imported into the implant planning software (BlueskyPlan, Libertyville, IL). Files were aligned with the aid of the software alignment tool by selecting 3 common distant reference areas present in both files as tooth cusps and incisal edges. For selection of the donor tooth, 2-dimensional linear measurements of each possible donor tooth were obtained for a preliminary size assessment.

A donor tooth mesh was created by segmenting the Digital Imaging and Communications in Medicine file into an STL file. The donor tooth STL generated was then virtually displaced out of its original position into the recipient socket using the surface alignment tools (Fig. 1A). We carefully evaluated the final position of the donor tooth to estimate the size discrepancy between the transplant and recipient sites (Fig. 1C and D). At this stage, in the absence of an ideal candidate donor tooth, further surgical planning was aborted, and other treatment options were presented to the patient.

Surgical Stent Design and Manufacture

A sequential drilling axis was planned as follows: custom implants with an active length and diameter equal to that of the guided surgery burs were virtually orientated to cover the external outline of the digitally transplanted teeth (Fig. 1E). Two to 4 drillings were required depending on the tooth dimensions. The sleeve space diameter was set to be 100 μm wider than the one on the nonactive side of the burs.

The ideal insertion axis was set (Fig. 1B). When the drilling axis emergences were too close to each other, 2 guides were designed.

Subsequently, the surgical guide outline was determined, and a minimum guide thickness of 2 mm was chosen to ensure adequate resistance without compromising the comfort of the operator. Fitting check windows were then created in order to confirm an adequate seating of the guide in the patient's mouth.

Both the surgical guide and the donor tooth CARP model were exported as binary STL files. The CARP model file was reimported into the 3D printing software (Preform; Formlabs Inc, Somerville, MA) to generate adequate printing supports and export a sliced 3D printing file. The surgical guide file was reimported into computer-aided manufacturing software (Millbox Sum3D; CIMsystem, Milan, Italy) to generate a safe and efficient milling strategy. Biocompatible resins (Nextdent SG; Nextdent, Soesterberg, the Netherlands) were used for manufacturing on an SLA 3D printer (Formlabs 3, Formlabs Inc). A biocompatible clear poly(methyl methacrylate) (PMMA) disc (Polident, Volčja Draga, Slovenia) was used to manufacture the guide with a 5-axis milling machine (DWX-51D; Roland, Irvine, CA).

Finally, both the guide and the CARP model were sterilized using a low-temperature H_2O_2 plasma sterilizer (Plazmax; Tuttnauer, Breda, the Netherlands).

Surgical Technique

All patients were periodontally stable before the start of treatment. The patients received antibiotic prophylaxis (amoxicillin/clavulanic acid, 500/125 mg) 1 hour before surgery[18,19], which was performed under local anesthesia (lidocaine 2% with epinephrine 1:100,000) by the same experienced oral surgeon (E.L.T.).

In case of immediate tooth transplantation, the tooth at the recipient site was extracted without reflecting a mucoperiosteal flap (Fig. 2A). Instead, a mucoperiosteal flap was reflected when the transplantation was performed in a healed ridge. In both cases, the recipient socket was prepared using the previously milled surgical stent according to the implant drilling sequence (Alpha-Bio Guided Surgery Tool Kit; Alpha-Bio Tec, Petah Tikva, Israel) planned in the implant software (Fig. 2C). Additional alveoloplasty was performed using a tungsten round bur to smooth any irregularity in the alveolar socket when required (Fig. 2D). The suitability of the CARP model was then checked in the recipient site (Fig. 2B). Subsequently, the donor tooth was extracted atraumatically with forceps, minimizing the use of elevators to prevent any damage to the PDL.

After the final position and occlusion of the transplant were checked (Fig. 2E), it was splinted with a semirigid appliance, and sutures were placed for correct soft tissue adaptation. Donor teeth stability was successfully enhanced in all cases.

Postoperatively, all patients were prescribed 500 mg amoxicillin every 8 hours
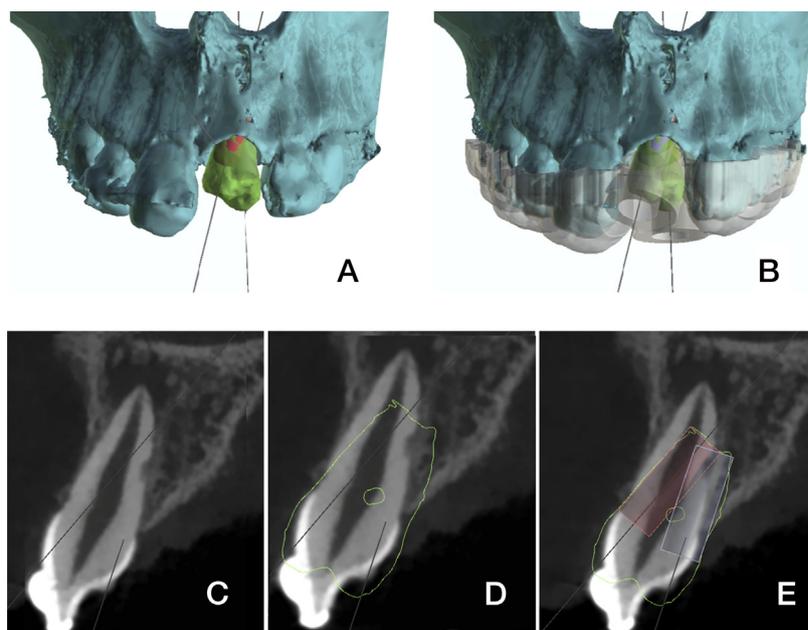

FIGURE 1 – The digital protocol. (A) The donor tooth virtually placed into the recipient socket. (B) The sleeveless surgical guide design according to the ideal 3D position of the donor tooth. Note the implant drilling axis. (C) Initial radiographic examination reveals the replacement resorption and the apical lesion of the recipient site (sagittal view). (D) The donor tooth virtually placed into the recipient socket (sagittal view). (E) The implant drilling sequence virtually planned for the osteotomy of the alveolar socket (sagittal view).
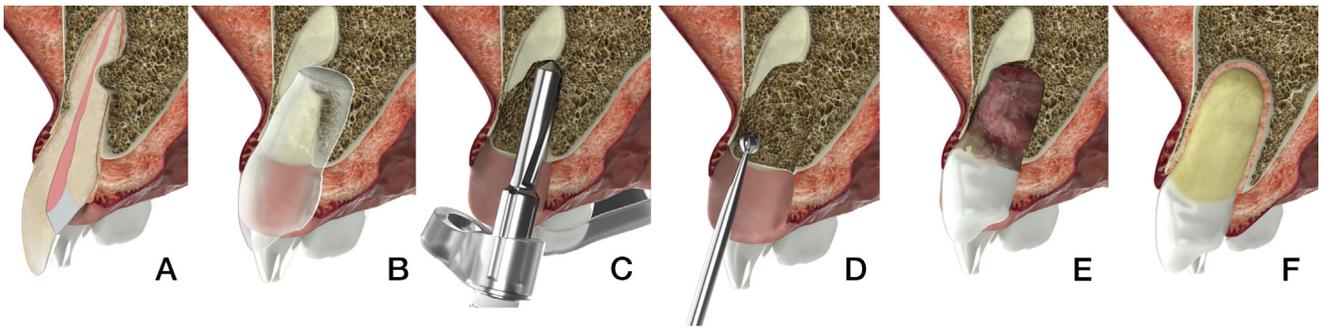
FIGURE 2 – The surgical protocol. (*A*) The initial situation. Note the replacement root resorption in the buccal and palatal aspects of the recipient tooth. (*B*) The ideal 3D position of the CARP model. Note the anatomic discrepancy between the alveolar socket and the CARP model. (*C*) The implant drilling sequence through a multiaxis milled PMMA surgical guide. (*D*) Additional alveoloplasty and bone reshaping using a tungsten round bur. (*E*) The definitive position of the donor tooth. Note the same position between the donor tooth and CARP model in Figure 1*B*. (*F*) After 2 years of follow-up. Note the root development, no signs of root resorption, and healing of the periodontal ligament.

for a week and 600 mg ibuprofen every 8 hours for 3 days. A soft diet for 2 weeks was recommended.

The sutures and splint were removed after 15 days. An endodontic specialist (M.L.) completed the endodontic treatment within 1 month of the surgery in closed apex transplants. Restorative treatment was performed 2–6 months after the surgical appointment. Appointments were scheduled 1 week, 2 weeks, 4 weeks, 8 weeks, 6 months, and 1 year after tooth autotransplantation (Fig. 2*F*).

RESULTS

Ten consecutive patients (Fig. 3*A–J*) with a mean age of 16.6 years (range, 9–37 years) were treated from January 2018 to October 2019. Seven patients were female. The mean follow-up duration was 13.1 months (range, 6–27 months). Six premolars and 4 wisdom teeth were used as donors, half of which had an open apex. Eight cases were treated at the same time as tooth extraction (Fig. 4*A–L*), and

the other 2 cases were treated in a healed ridge (Fig. 5*A–I*).

The success of the transplants was assessed based on the absence of pathologic mobility and inflammation at the recipient site and a lack of continuous radiolucency or root resorption around the transplanted tooth.

All transplants fulfilled the criteria for success. No signs of inflammation or pain were found during follow-up. Moreover, no signs of ankylosis or progressive inflammatory root resorption were found in the controls, except for 1 instance of inflammatory root resorption that was arrested after endodontic treatment in a closed apex case. None of the open apex transplanted teeth showed loss of vitality. Pulp obliteration was observed in all open apex cases. All patients were periodontally healthy with no probing pockets deeper than 3 mm.

Complications

The proposed protocol was not free of complications. One case required minimal adjustment of the inner aspect of the surgical stent to allow correct seating and was

probably caused by movement of teeth in a patient who had received orthodontic treatment. A second case could not be performed in a fully guided manner because of limited mouth opening, which impeded access for distally tilted drilling of a first lower molar. No other complications were noted.

DISCUSSION

This investigation aimed to validate our fully guided protocol for tooth autotransplantation. The current evidence underlines the importance of CARP models for the reduction of the number of complications associated with damage to the PDL[20]. Several studies have focused on reducing the extraoral time of the donor tooth[17,20,21]; however, accurate osteotomy and minimal surgical trauma to the recipient socket should also be achieved. The severity of this trauma is directly related to overheating of bone during the osteotomy, which may lead to cell death, preventing the formation of new bone[22,23]. Furthermore, an excessive alveoloplasty in the recipient socket increases the discrepancy between the donor
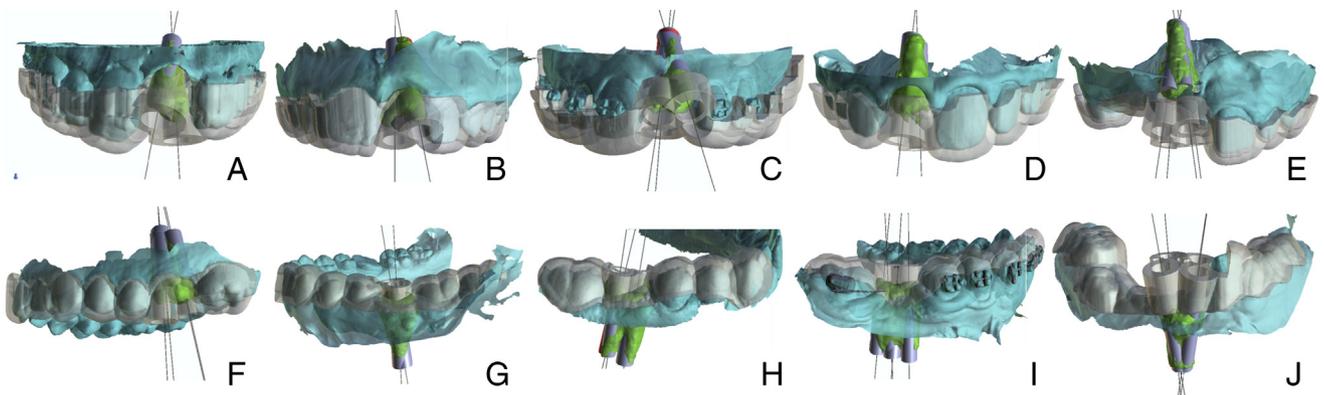

FIGURE 3 – Virtual 3D planning for 10 consecutive patients following the proposed protocol; 6 open apex premolars and 4 closed apex wisdom teeth were used in this proof of concept (*A–J*).
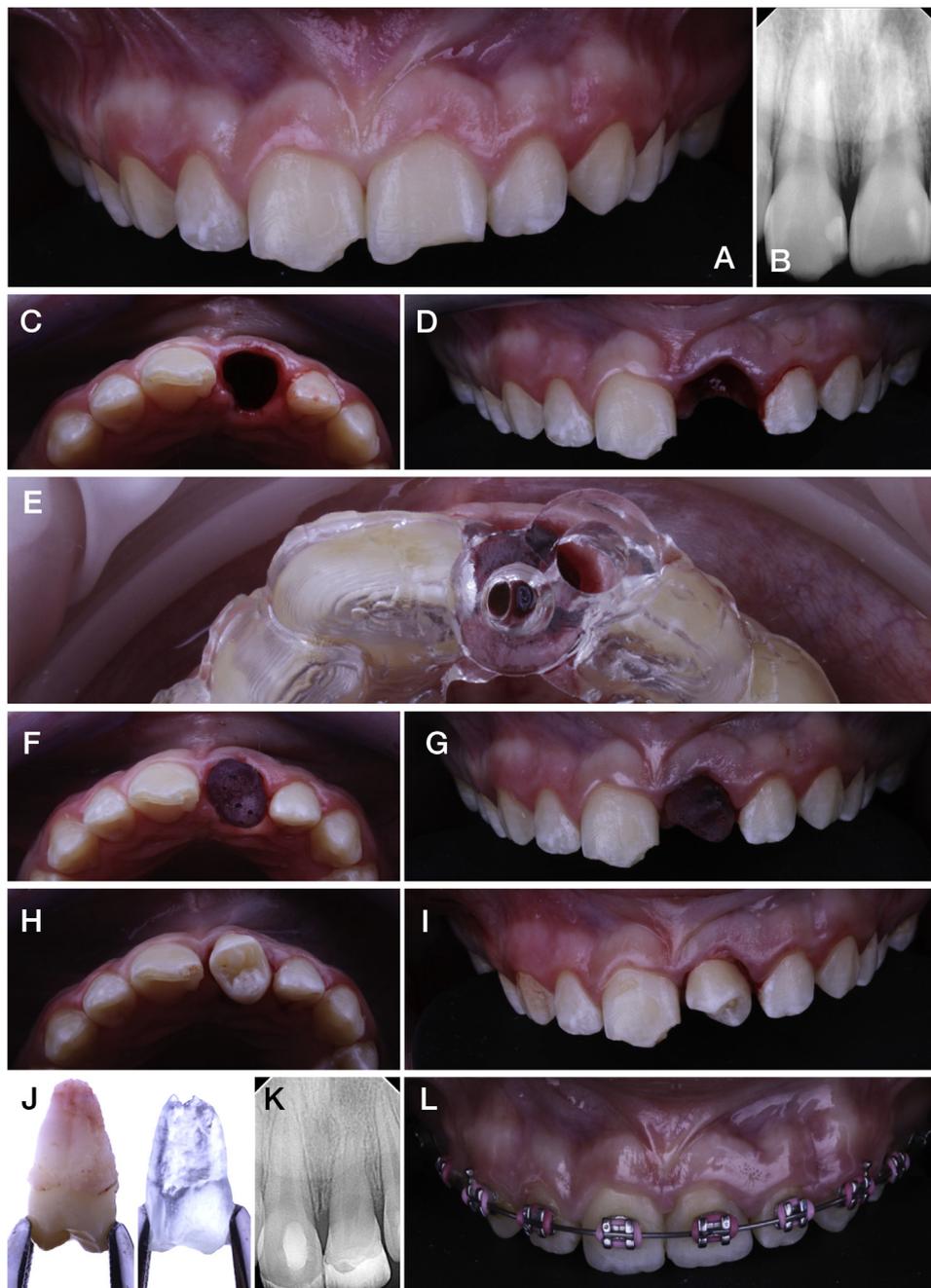
FIGURE 4 – The clinical sequence: immediate premolar autotransplantation. A 9-year-old girl was referred to the clinic for evaluation of the anterior teeth after a traumatic injury 9 weeks earlier. The trauma involved concussion of the upper right central incisor and avulsion of the upper left central incisor, which had been replanted and subsequently splinted 2 days later. Clinical examination revealed signs of reversible pulpitis at the upper right central incisor and a high metallic percussion sound at the upper left central incisor, which was 1 mm infrapositioned (*A*). Ankylosis of this tooth was confirmed after radiographic examination revealed loss of the periodontal ligament space (*B*). Given that the patient was diagnosed with Angle class II division 1, the patient was considered a good candidate for premolar extractions (*C–L*).

tooth and the recipient area, preventing stability of the blood clot and consequently periodontal regeneration[24].

Different protocols have been described for socket remodeling. Some authors reported shorter surgical times and fewer failures using both CARP models and implantation of surgical stents[25,26]. In a cadaveric study, Anssari Moin et al[27] proposed a custom-printed osteotome as an alternative to implant drills, which reduced the number of CARP model fitting attempts. Those authors reported results similar to those achieved by implant-guided surgery when comparing superimposed images of the preoperatively planning and the final donor tooth position[28]. Nevertheless, given that osteotomes have been associated with impaired bone healing when used in mandibular bone[29], this approach can only have a relevant role in cases with low bone density[30]. Clinical validation of this technique still awaits.

Other authors have described similar outcomes using prefabricated templates based on the most common sizes of wisdom teeth
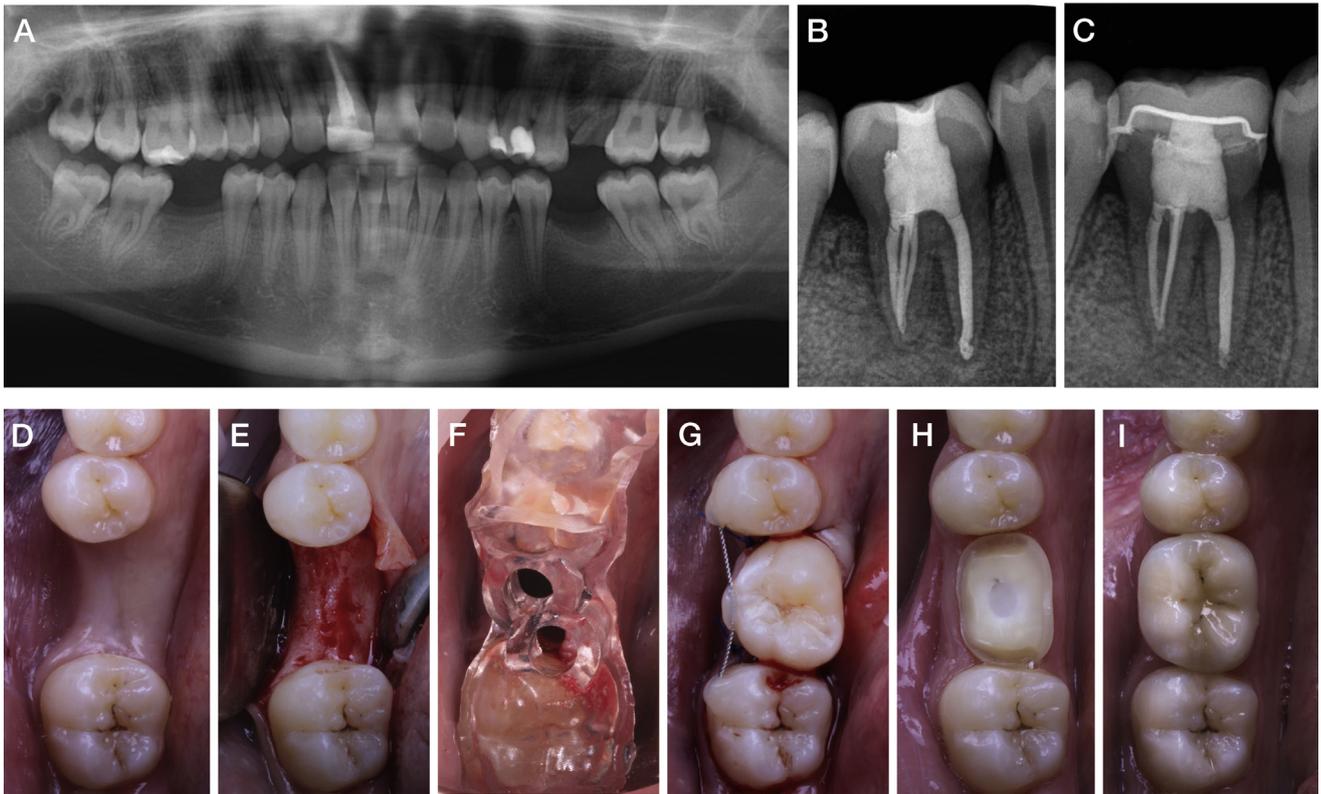
FIGURE 5 – The clinical sequence: wisdom tooth autotransplantation in a surgically created socket (*A–I*). A 17-year-old girl was referred to the clinic for replacement of a missing lower right molar. An artificial socket was created using a milled and sleeveless surgical guide. The upper right wisdom tooth was used as a donor tooth according to the proposed protocol. Root canal treatment was performed within a month, and prosthetic treatment was completed 8 weeks after the surgical appointment.

instead of CARP models or surgical guides[31,32]. Their protocol included preparation of the alveolar socket using the corresponding prefabricated template according to the dimensions of the donor tooth. Even though this option is simpler, the exact shape and size of the alveolar socket can be compromised, increasing the extraoral time of the donor tooth.

Our protocol concurs with the recent developments in personalized medicine applied to tooth autotransplantation because virtual planning, the CARP model, and guided surgery are included[25,33]. Furthermore, the milled PMMA multidrilling axis surgical stent provides benefits over and above the previously described guided approaches[32]. On the one hand, plastic sleeves have been shown to minimize frictional heating when compared with metal sleeves[34]. On the other

hand, Park et al[35] showed that the precision of the milled surgical guides was significantly higher than that of 3D-printed ones. Stiffness provided by milled PMMA enables the manufacture of multiple-drilling axis surgical guides with closer drilling whole emergences than conventional guided surgery stents. As a consequence of the employment of a single surgical guide, the clinician is able to prepare a greater osteotomy in a shorter period of time compared with single-drilling axis surgical guides. In those cases in which sleeves are used, the multidrilling axis approach would not be possible with a single surgical guide because overlap and a collision between sleeves would occur. Nevertheless, an ongoing paucity of evidence prevents the formulation of strong recommendations.

Within the limitation of the present results, we conclude that our protocol for fully guided tooth autotransplantation is a viable option that allows less invasive bone preparation in a short surgical time. Future research should focus on further investigation of the plausible benefits of this novel protocol in a larger sample.

REFERENCES

1. 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.

2. Watanabe Y, Mohri T, Takeyama M, et al. Long-term observation of autotransplanted teeth with complete root formation in orthodontic patients. Am J Orthod Dentofacial Orthop 2010;138:720–6.

3. Zachrisson BU, Stenvik A, Haanaes HR. Management of missing maxillary anterior teeth with emphasis on autotransplantation. Am J Orthod Dentofacial Orthop 2004;126:284–8.

4. Plakwicz P, Wojtowicz A, Czochrowska EM. Survival and success rates of autotransplanted premolars: a prospective study of the protocol for developing teeth. Am J Orthod Dentofacial Orthop 2013;144:229–37.

5. Czochrowska EM, Stenvik A, Album B, et al. Autotransplantation of premolars to replace maxillary incisors: a comparison with natural incisors. Am J Orthod Dentofacial Orthop 2000;118:592–600.

6. Czochrowska EM, Stenvik A, Zachrisson BU. The esthetic outcome of autotransplanted premolars replacing maxillary incisors. Dent Traumatol 2002;18:237–45.

7. Andreasen JO, Paulsen HU, Yu Z, et al. A long-term study of 370 autotransplanted premolars. Part I. Surgical procedures and standardized techniques for monitoring healing. Eur J Orthod 1990;12:3–13.

8. Slagsvold O, Bjercke B. Applicability of autotransplantation in cases of missing upper anterior teeth. Am J Orthod 1978;74:410–21.

9. Tsukiboshi M. Autotransplantation of teeth: requirements for predictable success. Dent Traumatol 2002;18:157–80.

10. Slagsvold O, Bjercke B. Autotransplantation of premolars with partly formed roots: a radiographic study of root growth. Am J Orthod 1974;66:355–66.

11. Andreasen JO, Paulsen HU, Yu Z, et al. 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.

12. Czochrowska EM, Stenvik A, Bjercke B, et al. Outcome of tooth transplantation: survival and success rates 17-41 years posttreatment. Am J Orthod Dentofacial Orthop 2002;121:110–9.

13. Jonsson T, Sigurdsson TJ. Autotransplantation of premolars to premolar sites. A long-term follow-up study of 40 consecutive patients. Am J Orthod Dentofacial Orthop 2004;125:668–75.

14. Schwartz O, Bergmann P, Klausen B. Autotransplantation of human teeth: a life-table analysis of prognostic factors. Int J Oral Surg 1985;14:245–58.

15. van Westerveld KJH, Verweij JP, Toxopeus EE, et al. Long-term outcomes 1–20 years after autotransplantation of teeth: clinical and radiographic evaluation of 66 premolars and 8 molars. Br J Oral Maxillofac Surg 2019;57:666–71.

16. Andreasen JO, Paulsen HU, Yu Z, et al. A long-term study of 370 autotransplanted premolars. Part III. Periodontal healing subsequent to transplantation. Eur J Orthod 1990;12:25–37.

17. Lee SJ, Jung IY, Lee CY, et al. Clinical application of computer-aided rapid prototyping for tooth transplantation. Dent Traumatol 2001;17:114–9.

18. Chung W, Tu Y, Lin Y, Lu H. Outcomes of autotransplanted teeth with complete root formation: a systematic review and meta-analysis. J Clin Periodontol 2014;41:412–23.

19. Romandini M, Tullio ID, Congedi F, et al. Antibiotic prophylaxis at dental implant placement: which is the best protocol? A systematic review and network meta-analysis. J Clin Periodontol 2019;46:382–95.

20. Verweij JP, Moin DA, Mensink G, et al. Autotransplantation of premolars with a 3-dimensional printed titanium replica of the donor tooth functioning as a surgical guide: proof of concept. J Oral Maxillofac Surg 2016;74:1114–9.

21. Kim E, Jung J, Cha I, et al. Evaluation of the prognosis and causes of failure in 182 cases of autogenous tooth transplantation. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2005;100:112–9.

22. Flanagan D. Osteotomy irrigation: is it necessary? Implant Dent 2010;19:241–9.

23. Gaspar J, Borrecho G, Oliveira P, et al. Osteotomy at low-speed drilling without irrigation versus high-speed drilling with irrigation: an experimental study. Acta Med Port 2013;26:231–6.

24. Wikesjo UM, Nilveus R. Periodontal repair in dogs: effect of wound stabilization on healing. J Periodontol 1990;61:719–24.

25. Shahbazian M, Jacobs R, Wyatt J, et al. Validation of the cone beam computed tomography–based stereolithographic surgical guide aiding autotransplantation of teeth: clinical case–control study. Oral Surg Oral Med Oral Pathol Oral Radiol 2013;115:667–75.

26. Strbac GD, Schnappauf A, Giannis K, et al. Guided autotransplantation of teeth: a novel method using virtually planned 3-dimensional templates. J Endod 2016;42:1844–50.

27. Anssari Moin D, Derksen W, Verweij JP, et al. A novel approach for computer-assisted template-guided autotransplantation of teeth with custom 3D designed/printed surgical tooling. An ex vivo proof of concept. J Oral Maxillofac Surg 2016;74:895–902.

28. Tahmaseb A, Wismeijer D, Coucke W, et al. Computer technology applications in surgical implant dentistry: a systematic review. Int J Oral Maxillofac Implants 2014;29(Suppl):25–42.

29. Stavropoulos A, Nyengaard JR, Lang NP, Karring T. Immediate loading of single SLA implants: drilling vs. osteotomes for the preparation of the implant site. Clin Oral Implants Res 2008;19:55–65.

30. Al-Ekrish AA, Widmann G, Alfadda SA. Revised, computed tomography-based Lekholm and Zarb jawbone quality classification. Int J Prosthodont 2018;31:342–5.

31. Day PF, Lewis BR, Spencer RJ, et al. The design and development of surgical templates for premolar transplants in adolescents. Int Endod J 2012;45:1042–52.

32. Ashkenazi M, Levin L. Metal tooth-like surgical templates for tooth autotransplantation in adolescents. Dent Traumatol 2014;30:81–4.

33. Verweij JP, Jongkees FA, Anssari Moin D, et al. Autotransplantation of teeth using computer-aided rapid prototyping of a three-dimensional replica of the donor tooth: a systematic literature review. Int J Oral Maxillofac Surg 2017;46:1466–74.

34. Sannino G, Gherlone EF. Thermal changes during guided flapless implant site preparation: a comparative study. Int J Oral Maxillofac Implants 2018;33:671–7.

35. Park J, Yi T, Koak J, et al. Comparison of five-axis milling and rapid prototyping for implant surgical templates. Int J Oral Maxillofac Implants 2014;29:374–83.