Simulation of postoperative occlusion and direction in autotransplantation of teeth: application of computer-aided design and digital surgical templates

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Abstract

Autotransplantation of teeth requires optimisation of both occlusion and direction to ensure minimal injury to the dental crown and the alveolar bone. We describe a method that could simulate postoperative occlusion and direction of the donor tooth by using CAD and digital surgical templates, and evaluate the postoperative effect in five patients who had teeth autotransplanted. Computed tomographic data were imported into ProPlan CMF 3.0 software, the donor tooth was simulated to replace the recipient site according to the position of the occlusion and alveolar bone, and a digital template was designed to guide preparation of the socket. A computer-aided, rapid prototyped, tooth was used to match the socket and, finally, an occlusal template was designed to ensure that the donor tooth was in the simulated position. We compared the position of the tooth in the simulation with its postoperative position using ProPlan CMF 3.0 software. In this way it was possible to simulate and guide the donor tooth accurately to the recipient site. At six-month follow up all teeth had survived successfully. Given the efficiency and precision of placement and the success, we conclude that CAD can successfully help to simulate occlusion and direction in autotransplantation of teeth while simplifying the procedure.

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Keywords: tooth autotransplantation; computer-aided design; digital surgical template

Introduction

Autotransplantation of teeth is used to replace teeth that are missing as a result of caries, periodontitis, endodontitis, or trauma. The procedure involves transfer of a donor tooth to a recipient site in the same patient, and the recipient area may be an extraction site or a surgically-prepared socket.[1] In the past procedures have involved measurement of the donor tooth, which was used as a template for the preparation of the socket.[2] However, the disadvantages of this are the long extraoral time taken for the transplant, and the pressure around the root, which can impair the vitality of the periodontal ligament attached to the donor tooth. This vitality is the most essential factor in the success of autotransplantation of teeth.

In recent years, digital templates have been widely used in autotransplantation, and Lee et al suggested the use of computer-aided design (CAD) rapid prototyping (RP) for transplantation of teeth.[3] Digital imaging of the donor tooth was obtained from a computed tomographic (CT) image and then exported to the RP machine for fabrication of the 3-dimensional model of the tooth. In their study, the extraoral time was about 7.7 minutes. However, there is still some

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uncertainty associated with the procedure. It is difficult for surgeons to predict a favourable postoperative occlusion and direction for the donor tooth. If it is in an unsuitable position it inevitably leads to overgrinding of the dental crown and alveolar bone. The distribution of the occlusion, which influences the long-term prognosis of the autotransplantation, is also uncertain.

Nowadays, CAD and RP technology have enabled the development of autotransplantation of teeth. Park et al used implant planning software to find the location of the donor tooth.[4] However, to our knowledge, the use of CAD to simulate the postoperative occlusion and direction of the donor tooth with a digital template as an operative guide has not been reported before.

We describe here how we simulated postoperative occlusion and fabricated a digital template to improve the accuracy of preparation of a socket for the donor tooth. We evaluated the accuracy of the technique and the template during and after the operation, and the survival and success rates were monitored for six months.

Patients and methods

We enrolled five patients aged between 21 and 41 years, who were all in good health, had no known systemic diseases, and were informed about the potential benefits and risks of autotransplantation of teeth and other restorative procedures, such as prosthodontics or implants. All patients chose the former, and informed consent was obtained in all cases. Each patient had cone-beam CT scanning (0.4 mm) of the skull, and the scanned data were imported into ProPlan CMF 3.0 software (Materialize) in DICOM format.

Choice of donor tooth

The donor tooth was traced and marked from the maxilla or mandible using ProPlan software. The donor tooth and recipient site were analysed, including the width and height of the tooth, the crown:root ratio, the width between the buccal and lingual alveolar ridge in the recipient area, and the distances from the adjacent teeth, to ensure that there was sufficient space in the recipient area to transplant the donor tooth. In one of these cases, we fitted the left lower third molar (no 38) into the right lower first molar socket (no 46) (Fig. 1). In two other cases the simulation stage indicated that the donor tooth root would be exposed as a result of the condition of the socket. In these cases, we augmented the bone.

Simulation of occlusion and position

The dental casts were scanned using a 3-dimensional scanner (Wiiboox Reeyee Pro), and the data were imported into ProPlan in STL format. The part of the dental arch in the maxilla or mandible was replaced by a dental cast model, and the occlusion was recorded. The recipient site was then replaced by the donor tooth. The position of the donor tooth
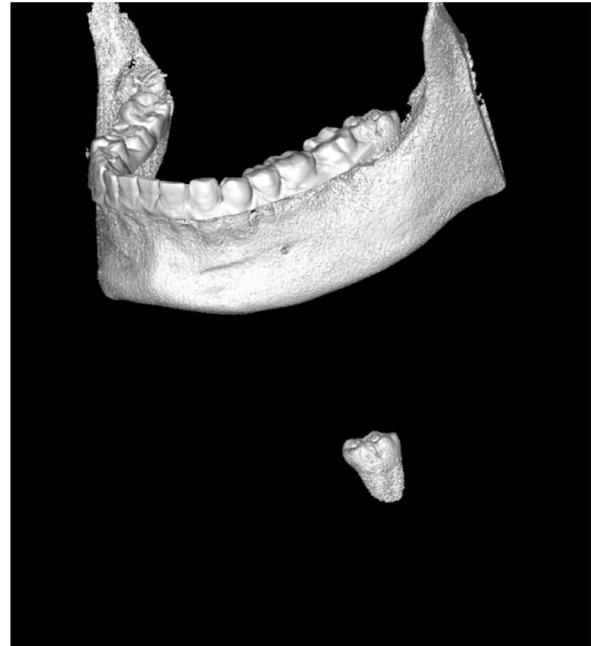

Fig. 1. Donor tooth (number 38) from the mandible was traced and marked.

was adjusted to match the occlusion and the socket (Fig. 2). The donor tooth was checked at this stage to find out whether it met our requirements.

Design of surgical template

The intersection of the donor tooth and recipient site was marked, as this helped to find out whether any areas in the socket needed to be resected. A cylinder shape was generated to simulate the dental burrs, the diameter and height of which were set. The number and direction of the shapes were adjusted to cover the entire intersection. To fix the cylinder shape, we created an occlusion splint in which the cylinder shape was set to ensure that it was in the correct position (Fig. 3). It was designed as a hollow tube to guide the direction and depth of the burrs. The data of the splint and cylinder were exported in STL format to the RP machine for the fabrication of the actual-sized resin template (Fig. 4).

Design of the location template

To ensure the donor tooth would fit in the simulated position, we designed a location template, which included the RP model donor tooth and the postoperative occlusion splint. If the RP tooth was in the projected position, the occlusion would fit into the template.

Surgical technique

The procedure was done under local anaesthesia and, in cases of immediate transplantation, the tooth from the recipient site was extracted first. The surgical template was fixed to the dental arch of the recipient area, and the socket was prepared
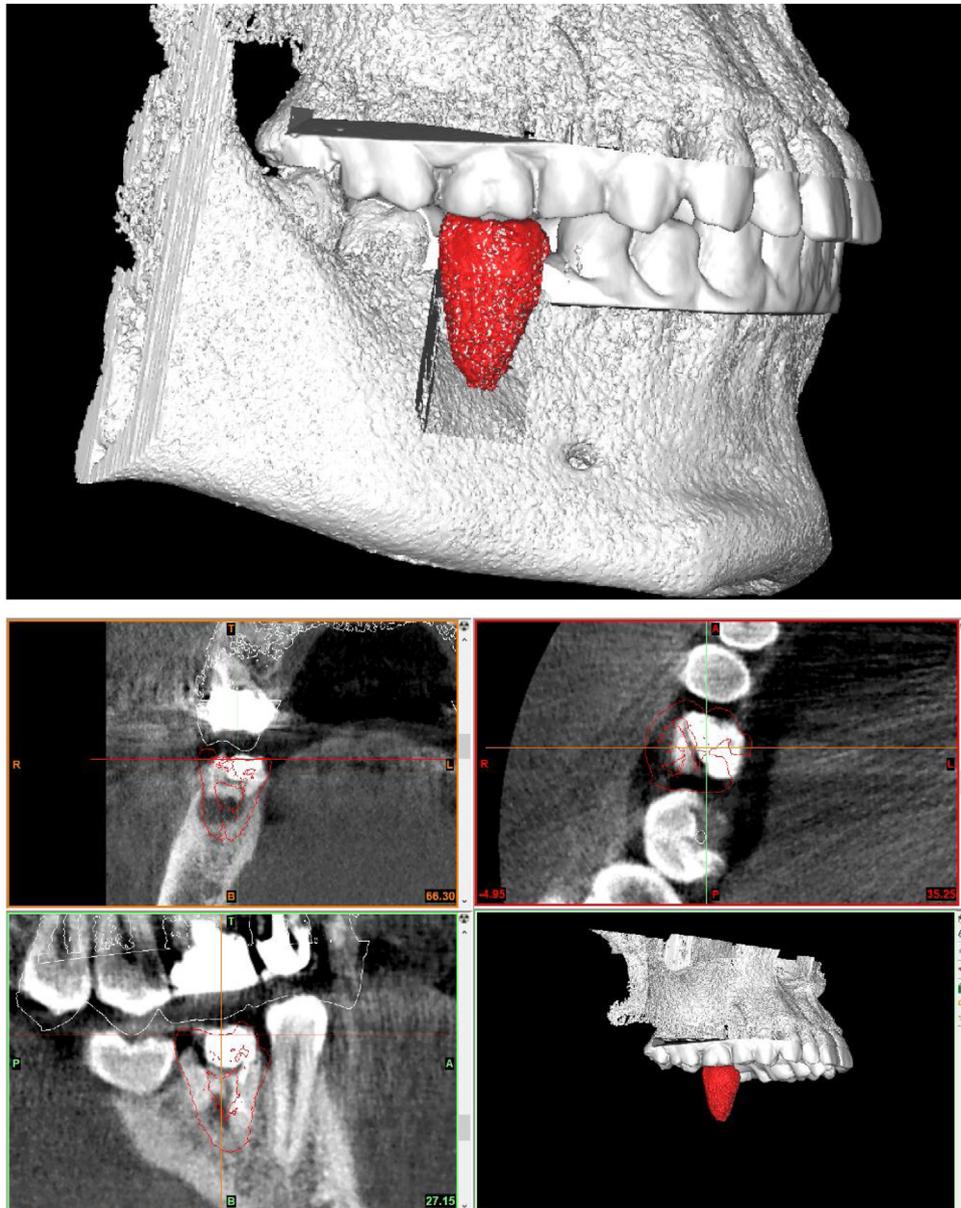
Fig. 2. The recipient site (number 46) was replaced by the donor tooth (number 38, in red) and its position was adjusted to match the occlusion and the socket.

according to the template with a round implant burr. Adjustments were then made to the socket to match the RP tooth. The position of the tooth was checked by fixing the location template after preparation of the socket (Fig. 5). The donor tooth was then extracted with minimal injury and transferred to the prepared socket, with splinting of the donor tooth with wire and resin if necessary. Finally, the occlusion was checked to ensure to make sure that there was no occlusal interference.

In two cases, bony augmentation was needed. Autogenous bone blocks were harvested by piezosurgery from the mandibular ramus, and the autogenous corticocancellous bone milled into particulate bone. The exposed surface of the root of the donor tooth was filled with autogenous particulate bone, and a platelet-rich fibrin membrane placed over the autogenous bone.

Postoperative management

All five patients had panoramic radiographs and cone-beam CT images taken immediately postoperatively, and at three and six months later. The splint was removed after 4–6 weeks, and a clinical examination made that included mobility, condition of the pulp, resorption of the root, and periodontal state. The root canal was treated in donor teeth that had roots. All five patients had endodontic treatment two weeks after transplantation. Restorative treatment was not usually necessary because of the accuracy of the preoperative occlusion design, which reduced the cost for patients.

To evaluate the accuracy of the position of the donor tooth we compared the simulated preoperative position of the tooth with its postoperative position by calculating the
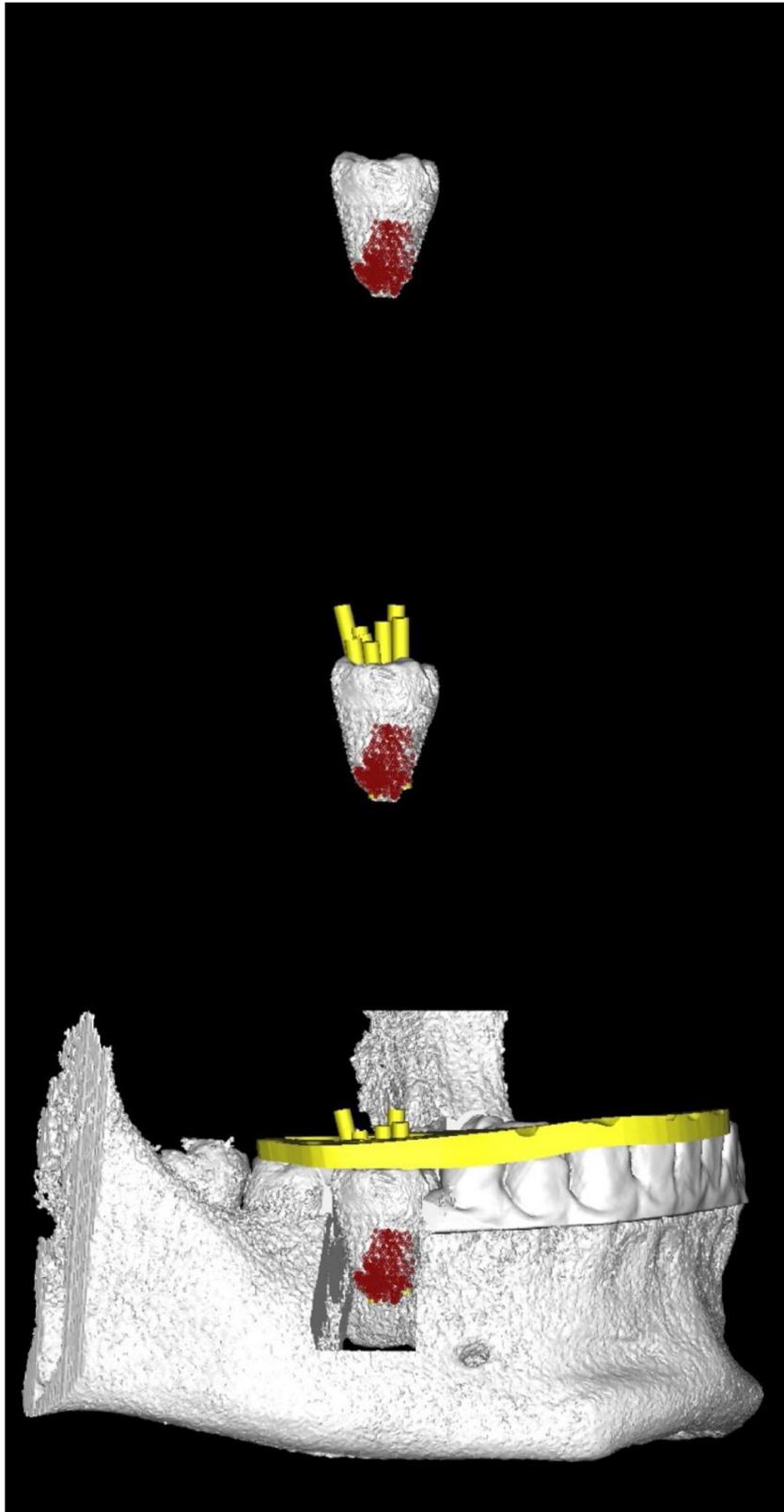
Fig. 3. A cylinder shape was set to cover the entire intersection (in red) and was fixed to the occlusion splint.

Fig. 4. The surgical template fixed in the dental arch.

Fig. 5. The location template fitted well, indication that the donor tooth was in the simulated position.

Table 1
Prognosis of the donor tooth six months postoperatively.

Case No.	Degree of mobility	Peridontal space on radiographs
1	None	Normal
2	None	Normal
3	1°	Slightly wide
4	None	Normal
5	None	Normal

There were no signs of resorption of the root, or inflammation of the pulp.

volume using ProPlan. We used a postoperative dental cast to replace the simulated one and calculated the volume of the overlap. A larger intersection necessitates greater accuracy in the position of the donor tooth.

Results

Five patients were studied. The surgical templates fitted well on all dental arches, and the location templates matched the occlusion after preparation of the socket. In all cases, the donor tooth could be inserted into the recipient site immediately after extraction. The preparation of the socket took about eight minutes, the proportion of overlap volume to preoperative simulation tooth volume was roughly 99.4 %, and the proportion of overlap volume to postoperative tooth volume was 99.2%.

Details of prognosis are shown in Table 1. There were no signs of pain or inflammation during the two weeks postoperatively, and no root resorption or periapical radiolucence on radiographs six months postoperatively. In four cases the

donor tooth was not mobile, and the periodontal space in the radiographs was continuous and intact. However, in one case, the tooth had 1° mobility, and the periodontal space was slightly wider at six months postoperatively.

Discussion

Previously, if teeth were missing, most dentists chose restoration with an implant,[5] but did not consider autotransplantation despite its many advantages including its high success rate, shorter treatment period, and better function. The main reason for this hesitation was probably the difficulty in predicting the direction of the donor tooth in the recipient site, although the complicated operation also had a role.[6] In addition, there are not yet any effective ways to match the occlusion and to avoid excessive grinding of dental tissue and alveolar bone.

To predict the postoperative position and occlusion of the tooth and to simplify the procedure, we adopted the following method: we designed the direction and occlusion of the donor tooth by computer simulation, designed a surgical template to prepare the guide socket, and used the location template to ensure that the donor tooth was in the simulated position. The main advantage of this method was that the procedure was more predictable and controllable.

The success of autotransplantation of teeth depends on the healing of tissue after operation.[7] Favourable healing of the periodontal ligament of the donor tooth is critical in governing the success rate,[8] and depends on the number of viable cells preserved on the surface of the root.[9] The cells of the periodontal ligament could be damaged during mechanical extraction or biochemically as a result of many extraoral conditions such as variable pH, osmotic pressure, and dehydration.[10] The periodontal ligament can be successfully preserved if donor teeth are extracted with minimal mechanical damage to the periodontal ligament, and if the extraoral time is reduced during the operation.[11]

An increasing number of studies have concentrated on reducing the extraoral time of the donor tooth and preventing extensive production of heat during preparation of the socket. Lee et al[3] used RP tooth models to prepare the socket, and the proportion of extraoral time was 7.4 minutes. We found that the donor tooth could be inserted into the recipient site immediately after extraction. There were two reasons for this – first, the accuracy of the tooth model, which was traced and marked using ProPlan, and secondly the use of the location template to ensure that the donor tooth was in the simulated position.

Tsukiboshi et al considered that the most important factor in bone formation was the cervical approximation of the donor tooth and socket in the recipient area.[2] The bony tissue under the cervical portion is a closed wound, and there is less chance of infection if the cervical approximation is optimal, as it increases the chance of obtaining satisfactory healing. If the surgical template is applied effectively it does not require

extensive preparation of the socket. It also decreases the difficulty of the operation, and shortens the time needed to adjust the occlusion.

The digital simulation of autotransplantation of teeth included the design of the occlusion and position of the donor tooth, with the available digital templates guiding the procedure. Although these steps take some time, they greatly simplify the procedure and can predict the postoperative direction of the tooth and improve the accuracy of the preparation of the socket. Above all, our findings show that autotransplantation of a tooth is controllable technology.

Conclusion

Given the efficiency of precision and placement, and the success rates, we conclude that CAD with surgical templates can successfully help simulate occlusion and direction in the autotransplantation of a tooth while simplifying the procedure.

Ethics statement/confirmation of patients' permission

The Ethics Committee gave approval, and we obtained the patients' permission for publication.

Conflict of interest

We have no conflicts of interest.

Acknowledgements

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