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New trends in the preparation of artificial alveolar sockets in tooth autotransplantation

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Abstract: *The autotransplantation of teeth has been recognized in clinical practice as a proven method of restoring missing teeth. In patients with tooth loss, the socket must be created artificially by surgical means. In order to increase the success of the procedure, the preparation of the artificial socket is increasingly important, but the precise preparation of the socket often requires multiple surgical operations, which may prolong the procedure and affect the prognosis of the autologous dental implant.In recent years, digital technology has been innovated, and the use of computer-aided surgical simulation (CASS) in autodontic transplantation is becoming more and more frequent. The application of digital guides in the preparation of artificial alveolar sockets not only improves surgical precision but also shortens the surgical time and simplifies the procedure, making autodontic transplantation a controllable technique.*

Keywords: *tooth autotransplantation; digital guide; artificial alveolar socket*

1. Introduction

Autotransplantation of teeth (ATT) refers to the transplantation of healthy teeth without driving function into other alveolar sockets in the same oral cavity in the form of physiological function, and common indications are the transfer of additional, blocked, misplaced, or ectopic erupted teeth to other sites that require extraction of the teeth, or surgically artificially prepared sockets[1][2][3].ATT can be categorized into immediate transplantation: extraction of teeth that cannot be retained due to root stumps, severe caries, trauma, etc., and at the same time, autogenous tooth transplantation is performed in a fresh socket; early transplantation: transplantation is performed when a recently missing tooth is not completely healed in an alveolar socket within 4-8 weeks of the extraction of the affected tooth; delayed transplantation: artificial preparation of alveolar sockets is performed when congenitally missing teeth or teeth are missing for a period of time of no less than 3 months, and when a transplantation is required[4].

With the continuous development of digital technology, computer-assisted surgical simulation (CASS) applications are commonplace in oral and maxillofacial surgery, including autogenous dental implants. The extensive use of digital guides as an important technological tool in surgical procedures has confirmed its positive role in significantly improving surgical precision and shortening surgical time[5].Foreign reports mention that in order to more accurately prepare the artificial sockets needed for the donor teeth, in addition to 3D models of the teeth, clinicians have begun designing personalized surgical guides[6].Most domestic ATTs use 3D models alone, combined with digital guides for artificial alveolar socket preparation deserves further study.

2. Historical review and current status of artificial alveolar socket preparation in autogenous dental transplantation

2.1 Historical review of artificial alveolar socket preparation

It's been almost 70 years since ATT was first reported[7],but in the early days, the success rate was only about 50%[8].This is due to deficiencies in the surgical technique and the backwardness of the research and knowledge of the underlying mechanisms. The preparation of artificial sockets is an example: in the early ATT process, the donor tooth was used as the only guide to prepare the socket in the recipient's position, and in the preparation of artificial sockets, the donor tooth had to be extracted in advance and placed in the socket for repeated comparisons, so as to confirm the morphology and size of

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the sockets[9].However, the donor tooth left the alveolar bone for a long time, and the mechanical pressure on the root of the donor tooth during the comparative preparation of the alveolar socket reduced the activity of the periodontal membrane attached to the surface of the root, which led to the failure of the procedure[10].Then in the course of more than 50 years, autogenous tooth transplantation has also made great progress, the technique has become more mature and controllable, and the success rate of transplantation has risen to 80%~96% in clinical reports[11][12].ATT has progressed in part because of advances in digitization technology, such as cone-beam computed tomography (CBCT) and computer-aided design/computer-aided manufacturing (CAD/CAM) systems[13].Lee et al[14]Using spiral CT and computer-aided rapid prototyping (CARP), the procedure is guided by the creation of life-size resin jawbone models and actual-size dental models; Keightley et al[15]first use of CBCT and CARP to guide a case of ATT. The same year, Shahbazian et al[16]3D models and stereolithography models were produced using a 3-matic program to guide the ATT. These clinical trials have shown that 3D printing technology prints a prototype model of the recipient area, which is placed into the socket instead of the donor tooth for repeated fitting and preparation[17].The probability of root resorption is significantly reduced when the donor tooth is left in place for less than 15 minutes[18].The application of computer-aided design (CAD) and 3D printing technology in ATT can achieve good desired results.

2.2 Digital guides in the preparation of artificial alveolar sockets

Digital guides are used as a core technology in surgical procedures and are valued so highly because of the significant increase in precision and reduction in operative time[19]**.**Digital guides used earlier for oral implants[20][21],Complex maxillofacial fracture repositioning[22],malignant tumor[23],extraction of implanted teeth[24] .There have been recent cases of[25]When clinicians use 3D model teeth only to assist in the preparation of artificial sockets, they are unable to confirm the position of the previously computer-designed donor teeth. As a result, the position and occlusion of the 3D model teeth were difficult to match the original design, and some of the printed model teeth with a 1:1 volume ratio to the computer-simulated donor teeth were different from the actual donor teeth. As a result, some donor teeth could not be successfully placed. This is especially true for artificial socket preparation, which often requires multiple geodesic socket preparations, which may prolong the duration of the procedure and affect the prognosis of autogenous tooth grafts.In particular, the lack of guidance aids in the preparation of artificial sockets means that the clinician can only utilize CBCT and clinical experience to prepare artificial sockets. This is usually done by drilling the socket with several consecutive turning pins of increasing diameter. However, the shape of the implant root is never a perfect cylinder with parallel borders, so there is inevitably a trial-and-error phase, which increases the risk of a prolonged procedure or a mismatch between the implant and the socket. And the optimal time for autografting is when the root has reached its maximum length and width, but the walls of the apical foramen of the grafted tooth are inverted or at least parallel. For this reason, the dimensions of the artificial socket should be only slightly wider and longer than those of the donor tooth to prevent pressure and subsequent damage to the periodontal cells (PDLc) and the epithelial root sheath (HERS), while ensuring a continuous blood supply to the PDLc and the pulp of the grafted tooth. In addition to size and depth, the most overlooked key factor is angulation, i.e., achieving the optimal position of the artificial alveolar socket i.e., in relation to three planes: in relation to the alveolar bone border to minimize the risk of penetration of the buccal lateral bone plate (especially in the case of alveolar bone resorption); in relation to the adjacent tooth roots to prevent damage during preparation; and in relation to the occlusal plane.This raises the requirements for the preparation of the artificial alveolar sockets. Therefore, foreign reports mention that in order to more accurately prepare the artificial sockets required for donor teeth, clinicians tend to design personalized surgical guides in addition to 3D model teeth.Production of computerized surgical guides by virtual preoperative planning proposed by Malka Ashkenazi. The safety of the procedure can be improved by accurately and optimally sizing and orienting the artificial alveolar sockets. Advantages of the current surgical method over previously proposed methods include more accurate preparation of the size and shape of the artificial alveolar socket by using four guide holes instead of one. In addition, the drilling holes were positioned 1 mm wider and longer than the donor teeth, ensuring that the periodontium and the epithelial root sheaths of the developing young grafts were preserved during the procedure[26-29].

2.3 Domestic and international research status

Zhao Jihong et al [10]forty-one cases of dental autografts assisted by 3D-printed donor models and surgical guides were included and divided into two groups based on the successful placement of donor teeth after alveolar socket preparation under the guidance of model teeth. Alveolar socket preparation time, extra-alveolar time, and number of donor tooth positioning trials were then compared and analyzed between the two groups. The incidence of complications was also included in the prognostic assessment.

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Results The mean alveolar socket preparation time, mean extra-alveolar time of the donor tooth and mean number of positioning tests of the donor tooth in 41 cases were 12.73 ± 6.18 min, 5.56 ± 3.11 min and 2.61 ± 1.00, respectively. The group that could not successfully place the donor tooth (15.57 ± 6.14 min and 7.29 ± 2.57 min) was more likely to have a complication than the group that could successfully place the donor tooth (9.75 ± 4.73 minutes, 3.75 ± 2.57 minutes) spent more time on alveolar preparation and extra-alveolar time. The group that could not successfully place donor teeth had a higher number of donor tooth positioning trials (3.19 ± 0.75) than the other group (2.00 ± 0.86). There was no significant difference in survival rates between the two groups. ATT was performed on 8 wisdom teeth with fully developed roots in 8 adult patients at the Affiliated Stomatological Hospital of Peking University. Personalized guides with local splints, surgical templates, and arch bars for the donor teeth were virtually designed and fabricated using three-dimensional printing, and then applied to the ATT. Clinical and radiological results were observed, and extra-alveolar time, success and 1-year survival rates were analyzed to assess the accuracy and stability of the procedure. Ten patients requiring ATT surgery were selected, and their imaging data were imported into the appropriate specialized software, and digital guides and 3D models (grafted teeth) were designed to guide alveolar socket preparation.

A study of 10 partially edentulous human mandibular cadavers was conducted abroad in 2016. The 3D data from these cadavers were imported into specialized software for analyzing the recipient site area and selecting donor teeth. Subsequently, in line with the donor teeth, customized surgical tools and surgical guide templates were designed and 3D printed. Alveolar socket preparation was performed under the guidance of the surgical guide template and the donor tooth was transplanted. To evaluate the planned donor tooth position compared to the transplanted donor tooth position, the mandible was scanned again with a CBCT system and a software match was applied to measure the accuracy of the procedure. The surgical technique is also described for a 42-year-old man with an ATT on a maxillary cusp. after flap turning, a surgical guide for guided osteotomy and apicoectomy was inserted. This 3D-printed guide allowed the clinician to quickly and accurately resect the curved apex, providing a non-invasive extraction of the entire affected cusp within the cyst. Three additional 3D surgical guides for placement of turning pins and a 3D replica of the tooth were printed to prepare the socket. After final positioning, a dental semi-rigid splint was secured to the adjacent teeth. An 18-year-old male patient received an autograft of the right mandibular third molar to replace the included right second molar. The procedure was based on a guided implant surgical approach through the superimposition of DICOM files and 3D datasets of the jawbone. In order to design a 3D printed template with the help of a fully digital workflow; 3D replicas and digital guides were used to prepare the alveolar sockets in order to prevent artificial damage to the donor teeth during the procedure. A further report mentions the treatment of 10 consecutive patients using complete virtual planning and multidrill axial surgery combined with computer-assisted rapid prototyping modeling. At an average follow-up time of 13.1 months, all transplanted teeth met the criteria for success.The technique is based on computerized 3D simulation and guidance that can accurately determine the dimensions of the artificial socket and its optimal position in relation to the alveolar bone border and the roots of neighboring teeth, reports a multidisciplinary head of dentistry in Israel. This could greatly simplify the autogenous dental implant procedure and potentially increase its success rate and benefit more young patients.

3. Analysis of current situation

Comparison of domestic and international studies shows that there are not many reports on the use of digital guides for the preparation of artificial sockets in ATT, and most of the case reports on this technique come from abroad. With the continuous development of digital guides in dentistry in China, the feasibility of this technique has been improved, and there are too few guiding aids for the preparation of artificial sockets in ATT, which is not enough to prepare perfect sockets with the clinician's experience and limited technical means. Most of the research evidence only emphasizes the importance of 3D printed donor tooth replicas in socket preparation. However, it is difficult to match the position and occlusion of the 3D modeled teeth with the original design in the clinical preparation of artificial sockets, which increases the uncontrollability of the clinician in the preparation of sockets. The application of digital guides compensates and enriches the clinician's aids in socket preparation, and can improve the safety of the procedure by accurately and optimally sizing and orienting the artificial sockets.

However, it should be noted that this technology still has some drawbacks, namely that it is a time-consuming process during the planning phase. In addition to the time required for 3D printing, performing virtual surgeries and designing individual digitized guides for each patient takes a significant amount of time and requires a high level of digitized equipment. And it increases the cost to the patient and requires a high level of patient compliance. And the outcome of treatment in individual patients may be unpredictable, with possible complications such as inflammatory root resorption, alternative root resorption, or loss of clinical attachment level, which need to be analyzed on a problem-by-problem basis.

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4. Conclusions

ATT is a rigorous and delicate surgery, the precision and minimally invasiveness of the surgery is reflected in all aspects, and every detail has a bearing on the success or failure of the surgery. The emergence and innovation of digital technology has enabled digital guides to help clinicians better control the details and play a more optimal role in positioning and guiding during surgery. With the continuous development of digital technology in recent years, computer-assisted surgical simulation (CASS) has been applied to the field of oral and maxillofacial surgery, including autogenous dental implants. The preparation of artificial alveolar sockets has been a gray area for many years, with uncontrollable factors, such as the size and shape of the prepared sockets can only be determined by a single reference to a 3D donor tooth replica and the anatomical and morphological structures obtained from CBCT by the clinician through clinical experience. The combination of digital guides and 3D donor tooth replicas for the preparation of artificial sockets will greatly improve the efficiency and accuracy of socket preparation, reduce the number of donor tooth fits, and improve the safety of the procedure.

In conclusion, although there are still some shortcomings in the preoperative design and planning of this technique, the efficiency of the preoperative evaluation needs to be improved, and more experts and scholars need to devote their efforts to continuous improvement. However, the digital guide, which assists in guiding the preparation of artificial sockets by predicting the position of the donor teeth after surgery, greatly improves the efficiency and accuracy of socket preparation and simplifies the entire surgical procedure. Most importantly, it improves the controllability and safety of ATT socket preparation, providing a new possibility and a new choice for clinical restoration of missing teeth.

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