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Autotransplantation of teeth using computer-aided rapid prototyping of a three-dimensional replica of the donor tooth: a systematic literature review

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Abstract. This systematic review provides an overview of studies on autotransplantation techniques using rapid prototyping for preoperative fabrication of donor tooth replicas for preparation of the neo-alveolus. Different three-dimensional autotransplantation techniques and their treatment outcomes are discussed. The systematic literature search yielded 19 articles that satisfied the criteria for inclusion. These papers described one case–control study, four clinical observational studies, one study with a clinical and in vitro part, four in vitro studies, and nine case reports. The in vitro studies reported high accuracy for the printing and planning processes. The case reports all reported successful transplantation without any pathological signs. The clinical studies reported a short extraoral time of the donor tooth, with subsequent success and survival rates of 80.0–91.1% and 95.5–100%, respectively. The case–control study reported a significant decrease in extraoral time and high success rates with the use of donor tooth replicas. In conclusion, the use of a preoperatively designed surgical guide for autotransplantation enables accurate positional planning, increases the ease of surgery, and decreases the extraoral time. However, the quality of the existing body of evidence is low. Further research is therefore required to investigate the clinical advantages of this innovative autotransplantation technique.

Key words: tooth transplantation; autotransplantation; rapid prototyping; template; three-dimensional; 3D techniques.

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Autotransplantation of teeth refers to the surgical transposition of a donor tooth from a donor site to a surgically prepared artificial socket (recipient site) within the same individual. Several diverse indications favour physiological tooth replacement. Primary indications for autotransplantation include agenesis of teeth, premature and/or traumatic tooth loss, and heavily damaged teeth[1,2]. The most common procedure involving autotransplantation probably is the replacement of an absent mandibular premolar by a maxillary premolar in young patients[3]. This treatment option is particularly useful when orthodontic extraction therapy of maxillary premolars is indicated[4–6]. Ideally, autotransplantation of teeth should be performed when root formation is 50–75% of the expected complete root development[7–9]. This condition corresponds with a radiographically open apex of at least 1 mm, which allows revascularization of the pulp chamber and continued root growth[10]. The success and survival rates of transplanted teeth are generally high, with reported rates of 79–100% and 57–100%, respectively, after autotransplantation by conventional techniques[11,12]. Success is defined as autotransplantation with direct physiological implantation of the donor tooth, without any signs of pathology or need for additional procedures. Survival is defined as persistence of the transplanted tooth (despite possible compromised function, aesthetics, or development)[13].

The most important considerations for successful tooth transplantation are preservation of the healthy periodontal ligament cells and good tissue adaptation. These factors are influenced by surgical aspects such as the number of fitting attempts of the donor tooth, distance between the new alveolus and the root of the donor tooth, extra-alveolar time, skill of the surgeon, and level of trauma during donor tooth extraction[10,14,15].

In conventional autotransplantation techniques, the extracted donor tooth serves as a template for preparation of the new tooth socket at the recipient site. This involves manipulation of the vulnerable donor tooth. Multiple fitting attempts are usually required to achieve optimal adaptability between the recipient bone and the root surface of the transplanted tooth[14]. Every fitting attempt further increases the risk of trauma to the periodontal ligament and prolongs the extra-oral time[15]. In modern autotransplantation techniques, the risk of damage to the donor tooth is minimized by the use of a preoperatively designed surgical template instead of the donor tooth[16]. This replica can be fabricated based on preoperative cone beam computed tomography (CBCT) of the donor tooth. During surgery, the replica functions as a guide, enabling a quick and straightforward autotransplantation procedure[6,17–19].

This systematic review aims to provide an overview of studies involving autotransplantation with the use of a surgical guide for preparation of the neo-alveolus at the recipient site prior to donor tooth extraction. Different autotransplantation techniques are discussed, and the outcomes of this new procedure are assessed.

Methods

This literature review was conducted in accordance with the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)[20].

Identification of relevant studies

An electronic search of the PubMed, Embase, Web of Science, and Cochrane databases was conducted. Articles published from database inception to 24 March 2016 were retrieved, without any restrictions in terms of year or language of publication (Appendix 1). The reference and citation lists of relevant articles were subsequently scanned manually to identify any additional relevant studies. Duplicates were removed, and all articles were collected in an Endnote database.

Specific inclusion and exclusion criteria were set to identify relevant in vitro studies, case reports, and clinical retrospective/prospective studies. All studies involving autotransplantation with the aid of rapid prototyping for fabrication of individually designed replicas of donor teeth in humans were included. In vitro studies involving fabrication, planning, and surgical aspects of autotransplantation procedures were included. Studies that did not report on individual templates were excluded. Studies that reported on non-individualized or archetypal templates were thus excluded.

Prospective and retrospective randomized controlled trials, case–control studies, observational studies, case series, and case reports were all included in this review. Case reports and clinical studies were included only if the article described autotransplantation with the use of rapid prototyping techniques for fabrication of individual replicas of donor teeth in humans. There were no restrictions on the outcome parameters. However, the neo-alveolus at the recipient site had to have been prepared with the aid of an individual three-dimensional (3D) model of the donor tooth. Studies that used conventional autotransplantation techniques (i.e., preparation of neo-alveolus with the donor tooth itself as a guide) were excluded.

Data retrieval

The titles and abstracts of all identified reports were screened independently by two investigators (JV and FJ). If eligibility could not be determined on the basis of the title or abstract, the full text of the article was retrieved. In cases where eligibility of an article could not be determined in consensus, a third investigator (RM) was consulted.

Data were collected using predefined data retrieval forms and included information regarding the study design, participant characteristics, intervention, comparisons, and outcomes. The primary outcome of interest in this literature review was success after autotransplantation with the aid of a donor tooth replica. The advantages and disadvantages of 3D techniques for autotransplantation were also analyzed. Outcomes of in vitro studies included the accuracies of fabrication of the replica and planning/placement of the donor tooth.

Outcomes of case reports and clinical studies included success and survival rates, ankylosis, root resorption, clinical and/or radiographic abnormalities, healing stage, number of fitting attempts, and extra-alveolar time of the donor tooth.

Quality evaluation and risk of bias

The Checklist for Reporting In vitro Studies (CRIS guidelines) was used for the assessment of quality of in vitro studies[21]. The checklist recorded whether the in vitro study reported a sample size calculation, meaningful intergroup differences, sample preparation and handling, allocation sequence, randomization, blinding, and statistical analysis.

For case reports, the CAse REport (CARE) checklist was used for the assessment of compliance with the guidelines[22]. The criteria assessed by the CARE checklist were: inclusion of the words ‘case report’ in the title, two to five key words, abstract; introduction; patient information; clinical findings; timeline; diagnostic assessment; therapeutic intervention; follow-up; outcomes; discussion; patient perspective; and informed consent.

Non-randomized clinical studies were assessed using the methodological index

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