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Review

Accuracy of computer-assisted surgery in mandibular reconstruction: A systematic review

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ABSTRACT

Computer-assisted surgery (CAS) for mandibular reconstruction was developed to improve conventional treatment methods. In the past years, many different software programs have entered the market, offering numerous approaches for preoperative planning and postoperative evaluation of the CAS process of mandibular reconstruction. In this systematic review, we reviewed planning and evaluation methods in studies that quantitatively assessed accuracy of mandibular reconstruction performed with CAS. We included 42 studies describing 413 mandibular reconstructions planned and evaluated using CAS. The commonest software was Proplan/Surgicase CMF (55%). In most cases, the postoperative virtual 3-dimensional model was compared to the preoperative 3-dimensional model, revised to the virtual plan (64%). The commonest landmark for accuracy measurements was the condyle (54%). Accuracy deviations ranged between 0 mm and 12.5 mm and between 0.9° and 17.5°. Because of a lack of uniformity in planning (e.g., image acquisition, mandibular resection size) and evaluation methodologies, the ability to compare postoperative outcomes was limited; meta-analysis was not performed. A practical and simple guideline for standardizing planning and evaluation methods needs to be considered to allow valid comparisons of postoperative results and facilitate meta-analysis in the future.

Introduction

Mandibular defects after ablative tumor removal can lead to severe functional and aesthetic deficits, negatively affecting quality of life [1]. The gold standard for reconstruction of mandibular defects is osteocutaneous free tissue transfer with titanium plate fixation [2]. The fibula, iliac crest, and scapula are the three main donor sites for vascularized bone. Currently, the most common mandibular reconstruction approach is the fibular free flap (FFF) [2–4], which was introduced by Hidalgo in 1989 [5]. FFF has become the preferred bone flap because of its low donor site morbidity, good bone quality, lengthy bicortical bone segment, long vascular pedicle, large-diameter vessels, and ability to contour the neomandible with multiple osteotomies [6]. Alternatives are the deep circumflex iliac artery flap (DCIA) and the scapular osteocutaneous free flap (SOFF) [2]. All three bone flaps can be shaped by multiple osteotomies to reproduce an anatomical mandibular contour [7].

Computer-assisted surgery (CAS), also known as rapid prototyping or computer-aided design and computer-aided manufacturing, for mandibular reconstruction has gained popularity since its introduction by Hirsch in 2009 [7]. The process of CAS in mandibular reconstruction involves planning, modeling, surgical [7,8], and postoperative evaluation phases [9–11]; the evaluation phase is not performed in all studies. In the planning phase, a computed tomography (CT) scan of the craniofacial skeleton and a CT (with or without angiography) of the donor site is obtained and saved as Digital Imaging and Communications in Medicine (DICOM) files. These 2-dimensional (2D) DICOM images can be subsequently converted into 3-dimensional (3D) surface models in a Standard Tessellation Language (STL) file format. In the modeling phase, 3D models of the virtual planned components are manufactured [12]. In the postoperative evaluation phase, pre- and postoperative data sets are

Abbreviations: CAS, computer-assisted surgery; CT, computed tomography; MDCT, multiple detector computed tomography; CBCT, cone beam computed tomography; CTA, computed tomography angiography; FFF, fibular free flap; DCIA, deep circumflex iliac artery flap; SOFF, scapular osteocutaneous free flap; DICOM, Digital Imaging and Communications in Medicine; STL, Standard Tessellation Language; CAD, computer-aided design; PSRP, patient-specific reconstruction plate

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compared for discrepancies, most commonly by matching surfaces with an iterative closest-point algorithm, a tool in CAS software used to minimize the difference between two clouds of points [13].

The goals of mandibular reconstruction are to re-establish the aesthetics of the face, restore the patient's ability to eat in public, maintain intelligibility of speech, and achieve an accessible airway [2]. These reconstructive goals require a high standard of surgical precision. For this purpose, CAS offers the ability to plan osteotomies of both the resection and donor sites, mirror the unaffected mandible, evaluate the bone plate relationships for positioning of dental implants, create surgical resection guides, fabricate patient-specific reconstruction plates, and, most importantly, restore correct occlusion [7,14]. Superior aesthetic outcomes and dental rehabilitation can be achieved with CAS, compared with conventional surgery [9]. Furthermore, preoperative virtual planning shortens the operation time [15–22], including reducing flap ischemia duration [18,21,23], and appears to be cost-effective, despite the expensive technology [24,25].

CAS is relatively new, and because many different software programs have entered the market, numerous planning and evaluation approaches have been developed. In this systematic review, we review planning and evaluation methods in studies that quantitatively assessed the accuracy of mandibular reconstruction performed using CAS.

Materials and methods

A literature search was performed based on the preferred reporting items for systematic reviews and meta-analysis (PRISMA) statement [26]. To identify all relevant studies, we performed systematic searches in PubMed, EMBASE, and The Cochrane Library databases from inception to December 15, 2017. Search terms included MeSH terms for PubMed and EMtree terms for EMBASE, as well as free text terms. We used only free text terms for The Cochrane Library. Search terms expressing "mandibular reconstruction" were used in combination with search terms representing "computer-assisted surgery". Duplicate studies were excluded. The full search strategies for all databases can be found in Appendix 1.

Two reviewers (GvB and FL) independently screened all potentially relevant titles and abstracts for eligibility, and the full text was subsequently evaluated for eligibility criteria. Studies were included if they met the following criteria: (1) mandibular reconstruction; (2) CAS; and (3) accuracy measurement data presented in the Results. The exclusion criteria were as follows: (1) animal or cadaver studies; (2) use of computer stereo models; (3) no English translation available; (4) not original research articles (e.g. editorials, letters, oral papers, posters, interviews); and (5) presentation of both maxillary and mandibular reconstruction accuracy data, with no ability to filter data pertaining to just the mandibular reconstruction.

Results

The initial literature searches yielded a total of 1114 references: 518 in PubMed, 553 in EMBASE, and 43 in The Cochrane Library. A PRISMA flowchart of the literature search and study selection process is shown in Fig. 1. After removing 401 duplicate references retrieved from more than one database, 713 studies remained. Their titles and abstracts were screened according to the eligibility criteria; 557 studies

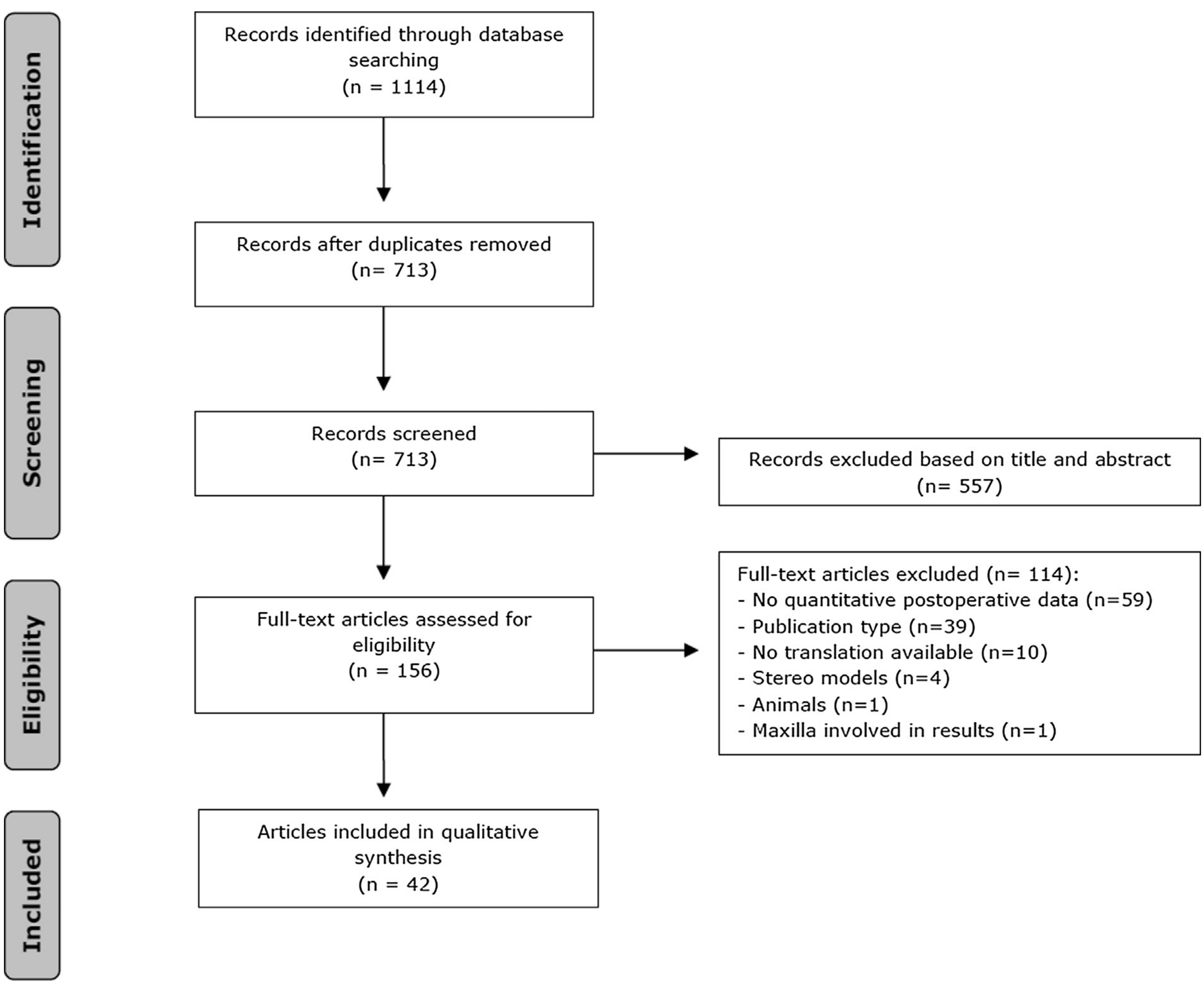

Fig. 1. Flowchart methodology for the study selection process.