ORIGINAL ARTICLE

CLINICAL FACTORS AFFECTING THE ACCURACY OF GUIDED IMPLANT SURGERY–A SYSTEMATIC REVIEW AND META-ANALYSIS

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ABSTRACT

Objectives
To systematically review the current dental literature regarding clinical accuracy of guided implant surgery and to analyze the involved clinical factors.

Material and Methods
PubMed and Cochrane Central Register of Controlled Trials were searched. Meta-analysis and meta-regression analysis were performed. Clinical studies with the following outcome measurements were included: (1) angle deviation, (2) deviation at the entry point, and (3) deviation at the apex. The involved clinical factors were further evaluated.

Results
Fourteen clinical studies from 1951 articles initially identified met the inclusion criteria. Meta-regression analysis revealed a mean deviation at the entry point of 1.25 mm (95% confidence interval [CI]: 1.22-1.29), 1.57 mm (95% CI: 1.53-1.62) at the apex, and 4.1° in angle (95% CI: 3.97-4.23). A statistically significant difference ($P < .001$) was observed in angular deviations between the maxilla and mandible. Partially guided surgery showed a statistically significant greater deviation in angle ($P < .001$), at the entry point ($P < .001$), and at the apex ($P < .001$) compared with totally guided surgery. The outcome of guided surgery with flapless approach indicated significantly more accuracy in angle ($P < .001$), at the entry point ($P < .001$), and at apex ($P < .001$). Significant differences were observed in angular deviation based on the use of fixation screw ($P < .001$).

Conclusions
The position of guide, guide fixation, type of guide, and flap approach could influence the accuracy of computer-aided implant surgery. A totally guided system using fixation screws with a flapless protocol demonstrated the greatest accuracy. Future clinical research should use a standardized measurement technique for improved accuracy.

INTRODUCTION

Digital technology has been playing a more and more important role in dentistry for number of years, one of the most common used digitalized

dental technique is digital radiography, which provides dental professionals potentially a better way of diagnosis and treatment for dental desease.[1-3] In the past several years, with the introduction of computed tomography (CT) and 3-dimensional (3D) printing into the field of implant dentistry, computer-aided design and computer-aided manufacturing (CAD/CAM) technology brought a great evolution of novel treatment concepts to dental implant treatment.[4] CT and 3D implant planning software can not only provide clinicians with 3D information of patient's anatomic structures, but also data regarding the patient's final prosthesis, these digital data can be combined with the CAD/CAM technology and further lead to a digital workflow ending with the production of stereolithographic (STL) template via a prototyping system.[5,6] The STL template can then be used to guide the position and direction of certain implants during surgery. By which, the whole surgical procedure is so called "guided dental implant surgery."

According to the consensus statement published in 2009,[7] the term "computer-guided surgery" is defined as the use of a static surgical guide that reproduces the virtual implant position directly from CT data and does not allow for intraoperative modification of the implant position. It has been demonstrated to be an established treatment,[6] which reduces the probability of damage to the adjacent critical structures such as bones, nerves, adjacent tooth roots, and sinus cavities. The main advantage of guided surgery is the ability to plan and optimize the implant position in a restoration-driven placement manner. Moreover, computer-guided technique can help to decrease postoperative discomfort and allows for immediate function, as they enable implant placement with minimal surgical trauma. In addition, this technique offers an alternative to bone augmentation in situation of severely resorbed alveolar ridges, as they facilitate optimal position of implants in available bones.[8-10] However, with the generalization of this technique, many doubts have risen on its usefulness and especially the accuracy.[11-15]

Accuracy in guided implant surgery is defined as matching the planned position of the implant in the software with the actual position of the implant in the patient's mouth.[13] It reflects the accumulation of all deviations from imaging over the transformation of data into a guide, to the improper positioning of the latter during surgery,[14] and the different types of errors include error during image acquisition and data processing, error during surgical template production, error during template positioning and movement of the template during drilling, and mechanical error caused by tolerance of surgical instruments. All errors, although seldom occurring, can be cumulative.

In recent years, several studies have been performed on different factors affecting the accuracy of guided surgery,[16,17] and systematic reviews[6,18-20] have evaluated these studies very well, focusing on the accuracy, clinical advantages, survival rates, complications of computer-guided surgery, and the influence of using different types of guide. However, only limited and incomplete data were provided in clinical trials regarding the accuracy and influence of relevant clinical factors except for tissue of support.[18] There are still no concerted standard parameters for the evaluation of deviation, which leads to diversity in results and, therefore, can hardly provide an effective indication for the clinical application of guided surgery.

In the present study, we tried to review the current dental literature, focusing on the clinical accuracy of guided dental implant surgery, to analyze the involved clinical factors affecting the accuracy, and tried to find the most appropriate method for the evaluation of accuracy.

MATERIALS AND METHODS

Protocol and Registration

This review was registered at the International Prospective Register of Systematic Reviews (https://www.crd.york.ac.uk/PROSPERO, registration number 42016050127). It was conducted in accordance with the guidelines of "Preferred Reporting Items for Systematic Review and Meta-analysis Protocols 2015 Statement."[21]

Search Strategy for Identification of Studies

Two Internet sources of MEDLINE-PubMed and Cochrane Central Register of Controlled Trials (CENTRAL) were used to search for eligible articles (published and online preview) in English, and this was complemented by a manual search of the references of all selected full-text articles. Publications from January 1, 1990, to October 31, 2016, were searched using the following search strategy: PubMed: ((((((((((("Dental Implantation"[Mesh]) OR "Dental Implants"[Mesh]) AND "Surgery, Computer-Assisted"[Mesh]) OR "Computer-Aided Design"[Mesh]) OR dental implant navigation) OR digital dentistry) OR guided dental implant surgery) OR image-guided dental implant surgery) OR computer-guided dental implant surgery) OR dental stereo lithography) AND "Dimensional Measurement Accuracy"[Mesh]) OR dental implant deviation) OR dental implant precision) OR dental implant accuracy); Cochrane Central Register of Controlled Trials: dental implantation OR dental implant and dental navigation OR computer aided dental implant OR three-dimensional (3D) dental planning OR 3D dental planning OR computer-assisted dental implant OR dental stereo lithography OR guided dental implant placement OR dental surgical template OR dental guided surgery OR dental surgical guide AND dimensional