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Is there any complication in guided implant dentistry: A systematic review

Existe alguna complicacion en implantes dentales guiados: Una revisión sistemática

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ABSTRACT: The aim is to assess the clinical studies regarding the reported complications of implant placement with computer-guided surgery in partially/fully edentulous patients. The PubMed and Google Scholar databases were searched from 2000 to 2020 for pertinent clinical studies written in English. The PRISMA 2020 guidelines were followed. Two examiners conducted the quality assessment according to the methodological quality and synthesis of case series and case reports. At first, a total of 1057 papers were screened and 17 papers finally were included of which, one was the cohort, three were case series and 13 were case reports. Complications and errors of surgical guides were mostly three parts: 6 out of 17 articles reported preoperative complications, 9 articles reported complications during surgery that occurred for the patient or surgeon, and 11 articles reported postoperative complications. Computer-guided implantology is not flawless. So dentists should receive comprehensive training to prevent serious complications. Sufficient mastery to create a correct and accurate position for the implant and observing the important points of anatomical structures such as the alveolar nerve is one of the important points of this technique.

KEYWORDS: Dental implant, computer-assisted surgery, accuracy, complication guided surgery.

INTRODUCCIÓN

The Use of computed tomography and three-dimensional (3D) imaging technologies has brought notable progress in preoperative planning and intra-operative surgical guidance in the field of Implantology and oral rehabilitation (D' Haese *et al*., 2017; Kaewsiri *et al*., 2019). Precise placement of dental implants is critical to ensure the long-term success of treatment. Modern technology optimizes all steps of the implantation procedure, including the drilling and insertion of the implant (Albrektsson & Johansson 2001).

The use of patient-specific surgical templates, in different implant designs and bone preparation protocols, has shown high accuracy and fewer complications compared to the traditional freehand method. The two methods of computer-guided surgeries are (D' Haese *et al*., 2017) computer-aided designed and manufactured static guides and (Kaewsiri *et al*., 2019) dynamic navigation systems that use a stereo vision computer triangulation for real-time navigation (Farley *et al*., 2013; Laleman *et al*., 2016).

The surgical guide can be used for semi-edentulous/edentulous patients even in cases with moderate to severe bone loss (Garcia-Hammaker & George, 2019). These guides might be designed and manufactured weather manually or by computer-aided technologies in a dental laboratory. The dynamic navigation technology navigates the positions of the drills in the surgical site and constantly shows it on a monitor (Younes *et al*., 2018). The system allows for the actual transfer of the preoperative planning and visual feedback to the monitor (D' Haese *et al*., 2017). Surgical guides, as static techniques, have been considered the valid technique in most cases, although, in cases of inadequate access for the drills, limitation in mouth opening, and lack of bony reference point dynamic systems are preferred (Yeung *et al*., 2020). Zygomatic implant placement is an example of which surgical guides are inefficient and dynamic navigation is preferred (Ramezanzade *et al*., 2021).

Despite their advantages, computer-guided techniques are not flawless; They might be financially challenging to patients (Laleman *et al*., 2016). In addition to the increased cost of treatment, the treatment plan is longer, and more sessions are needed. Also, the successful use of computer-guided techniques requires advanced clinical expertise and includes a learning curve.

In dental implant surgeries, cold water while drilling into the surgical site plays a key role in temperature control while some studies found sight and proper irrigation debatable when using a surgical guide (Fauroux *et al*., 2018). The lack of proper irrigation results in rising temperatures followed by bone necrosis and implant failure (Liu *et al*., 2018).

In computer-guided surgery, several sleeves are placed on the surgical site to control the drilling process (both vertical and horizontal directions) and the depth of the osteotomy. Although, the use of sleeves and sleeve adaptors, causes limitations in mouth opening and impairs proper sight (Suriyan *et al*., 2019).

Computer Guided Surgery (CAS) is very widely used to achieve high accuracy in implantation. Despite the possibilities afforded by computer-assisted systems, this area faces several shortcomings which should be addressed for more reliable and safe clinical results.

This systematic review aims to assess the complications of computer-guided surgery in placing implants in totally or partially edentulous jaws alone or when compared with a free-hand technique. The secondary aim was to compare aesthetic results, occlusion, and loading between computer-guided surgery and free-hand technique.

MATERIAL AND METHOD

We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Page *et al*., 2021). This work was registered at PROSPERO (International prospective register of systematic reviews) with registration no. CRD42021245644, PICO Question

The PICO (P: population or patients: patients who have undergone dental implant placement using CAS, I: intervention: dental implant placement using CAS, C: comparator or control: conventional free-hand implant placement/none, O: outcomes: Implant failure rate, Complications, and errors of CAS).

Search strategy

We searched PubMed and Google Scholar databases for pertinent materials (from 2000 to 2020). The search strategy was as follows:

1) PubMed: (489)
((((((((guided surgery[Title/Abstract]) OR (navigational surgery[Title/Abstract])) OR (real-time navigation[Title/Abstract])) OR (dynamic guided surgery[Title/Abstract])) OR (static guided surgery[Title/Abstract])) OR (static computer guided surgery[Title/Abstract])) OR (computer guided surgery[Title/Abstract])) OR (surgical template[Title/Abstract])) AND (((((((((((complication[Title/Abstract]) OR (complications[Title/Abstract])) OR (implant failure[Title/Abstract])) OR (failure rate[Title/Abstract])) OR (surgical complication[Title/Abstract])) OR (prosthetic complication [Title/Abstract])) OR (marginal bone loss[Title/Abstract])) OR (iatrogenic[Title/Abstract])) OR (drilling[Title/Abstract])) OR (implant mis-positioning[Title/Abstract])) OR (bone preparation[Title/Abstract])).

2) Google Scholar:

Concept 1: complication OR complications OR "implant failure" OR "failure rate" OR "surgical complication" OR "prosthetic complication" OR "marginal bone loss" OR iatrogenic "computer-guided surgery" "dental implant" (604).

Concept 2: all in the title: complication OR complications OR "implant failure" OR "failure rate" OR "surgical complication"

OR "prosthetic complication" OR "marginal bone loss" OR iatrogenic OR drilling OR "implant mispositioning" OR "bone preparation" "guided surgery".

Concept 3: all in the title: guided implant complication OR complications OR "implant failure" OR "failure rate" OR "surgical complication" OR "prosthetic complication" OR "marginal bone loss" OR iatrogenic OR "implant mispositioning" OR "bone preparation".

Table I. Excluded studies with reasons.

Information	Reason for exclusion
Aghayan SH, Rokhshad R. The art of using computer-assisted navigation systems in guided implant surgery: A review. J Res Dent Maxillofac Sci. 2021; 6(2):51-62	Review
Boa K, Barrak I, Varga E Jr, Joob-Fancsaly A, Varga E, Piffko J. Intraosseous generation of heat during guided surgical drilling: an ex vivo study of the effect of the temperature of the irrigating fluid. Br J Oral Maxillofac Surg. 2016; 54(8):904-8.	Not clinical study
de Almeida EO, Pellizzer EP, Goiatto MC, Margonar R, Rocha EP, Freitas AC Jr, Anchieta RB. Computer-guided surgery in implantology: review of basic concepts. J Craniofac Surg. 2010; 21(6):1917-21.	Review
D' Haese J, Van De Velde T, Komiyama A, Hultin M, De Bruyn H. Accuracy and complications using computer-designed stereolithographic surgical guides for oral rehabilitation by means of dental implants: a review of the literature. Clin Implant Dent Relat Res. 2012; 14(3):321-35.	Review
D' Haese J, Ackhurst J, Wismeijer D, De Bruyn H, Tahmaseb A. Current state of the art of computer-guided implant surgery. Periodontol 2000. 2017; 73(1):121-33.	Review
dos Santos PL, Queiroz TP, Margonar R, de Souza Carvalho AC, Betoni W Jr, Rezende RR, dos Santos PH, Garcia IR Jr. Evaluation of bone heating, drill deformation, and drill roughness after implant osteotomy: guided surgery and classic drilling procedure. Int J Oral Maxillofac Implants. 2014; 29(1):51-8.	Animal study
Frösch L, Mukaddam K, Filippi A, Zitzmann NU, Kühl S. Comparison of heat generation between guided and conventional implant surgery for single and sequential drilling protocols-An in vitro study. Clin Oral Implants Res. 2019; 30(2):121-30.	Not clinical study
Gargallo-Albiol J, Barootchi S, Salomó-Coll O, Wang HL. Advantages and disadvantages of implant navigation surgery. A systematic review. Ann Anat. 2019; 225:1-10.	review
Kalaivani G, Balaji VR, Manikandan D, Rohini G. Expectation and reality of guided implant surgery protocol using computer-assisted static and dynamic navigation system at present scenario: Evidence-based literature review. J Indian Soc Periodontol. 2020; 24(5):398-408.	Review
Katsumata A. Computer assisted surgery and dental Cone Beam CT. Jpn J Oral Maxillofac. 2016; 62(12):602-7.	Study not in English
Markovi_ A, Lazi_ Z, Mi_i_ T, et al. Effect of surgical drill guide and irrigans temperature on thermal bone changes during drilling implant sites - thermographic analysis on bovine ribs. Vojnosanit Pregl. 2016; 73(8):744-50.	Animal study
Migliorati M, Amorfini L, Signori A, Barberis F, Silvestrini Biavati A, Benedicenti S. Internal bone temperature change during guided surgery preparations for dental implants: an in vitro study. Int J Oral Maxillofac Implants. 2013; 28(6):1464-9.	Animal study
Mili_i_-Lazi_ M, Proki_-Mari_ A, Todorovi_ A, Lazi_ V. Basics of navigation implant prosthetics planning. Serb Dent J. 2020; 67(4):193-200.	Review
Popescu SN, Ciochinda G, Burlibasa M, Tanase G, Mihai A, Perieanu VS, Perieanu MV, Donciu I, Andrei OC, Cristache CM. Guided surgery technique-review of accuracy and errors. Ro Med J. 2019; 66(4):313-7.	Review
Rodríguez R, Marques_Guasch J, Gargallo_Albiol J, Hernández_Alfaro F, Hosn_Centenero SA. Comparison of prosthetic and biological complications between guided surgery and free_hand surgery. Clin Oral Impl Res. 2018; 29(Suppl 17):362.	Not clinical study
Schneider D, Marquardt P, Zwahlen M, Jung RE. A systematic review on the accuracy and the clinical outcome of computer-guided template-based implant dentistry. Clin Oral Implants Res. 2009; b20 Suppl 4:73-86.	Review
Tatakis DN, Chien HH, Parashis AO. Guided implant surgery risks and their prevention. Periodontol 2000. 2019; 81(1):194-208.	Review
Unsal GS, Turkyilmaz I, Lakhia S. Advantages and limitations of implant surgery with CAD/CAM surgical guides: A literature review. J Clin Exp Dent. 2020; 12(4):e409-e417.	Review
Van Assche N, Quirynen M. Tolerance within a surgical guide. Clin Oral Implants Res. 2010; 21(4):455-8.	Not clinical study
Yong LT, Moy PK. Complications of computer-aided-design/computer-aided-machining-guided (Nobel Guide) surgical implant placement: an evaluation of early clinical results. Clin Implant Dent Relat Res. 2008; 10(3):123-7.	review

Concept 4: all in the title: complication OR complications OR "implant failure" OR "failure rate" OR "surgical complication" OR "prosthetic complication" OR "marginal bone loss" OR iatrogenic OR "implant mispositioning" OR "bone preparation" "flapless".

Inclusion and Exclusion Criteria: we included clinical studies (clinical trials, observational studies, case series, and case reports). Studies written in english and published between 2000 and 2020 were included.

Review papers, conference papers, and papers other than english were excluded from the study. Papers on surgical non-computer fabricated templates were also excluded. The articles that have been excluded from this study are listed in Table I with the reasons for exclusion.

Selection criteria: two writers reviewed the titles and abstracts of the included materials separately. If seemed pertinent, the full text was retrieved for further assessment.

Data extraction: the data from the selected articles were extracted by two authors (M.A and S.M) and supervised by a third author (Sh. R) based on a predefined checklist.

The following data were extracted (whenever applicable): the first author(s), year of publication, country of origin, study design, type of navigation system, number of participants, number of the implant site, implant positioning method, surgical approach(flapless/open-flap), type of edentulism, type of loading (immediate or delayed), reported complications and failure/success rate.

Risk of bias assessment: two examiners (M.A and S.M) conducted the quality assessment according to the methodological quality and synthesis of case series and case reports by Murad *et al*. (2018). There were 8 questions in the following domains: selection, ascertainment, causality, and reporting. Articles were classified into three groups: high, medium, and low quality. The points between 0 and 5 were considered as low quality, between 5 and 7 as medium quality, and a point of 8 was considered as high quality.

Data synthesis: since the quantitative analysis was not applicable, the data were reported qualitatively.

RESULTS

Study selection

The PRISMA flow chart of study selection is shown in Figure 1. In the initial search through PubMed and Google Scholar, 1137 articles were obtained. After duplication removal, a total of 1057 papers were left. After screening the articles based on the title and abstract, 37 articles reached the full-text evaluation. 20 papers were excluded after the full-text assessment. The reason for exclusion was as follows: 3 cadaver/ex-vivo studies, 4 studies without clinical data and 12 studies are review studies, and one paper in a language other than English. Finally, 17 were eligible to be included in the current study.

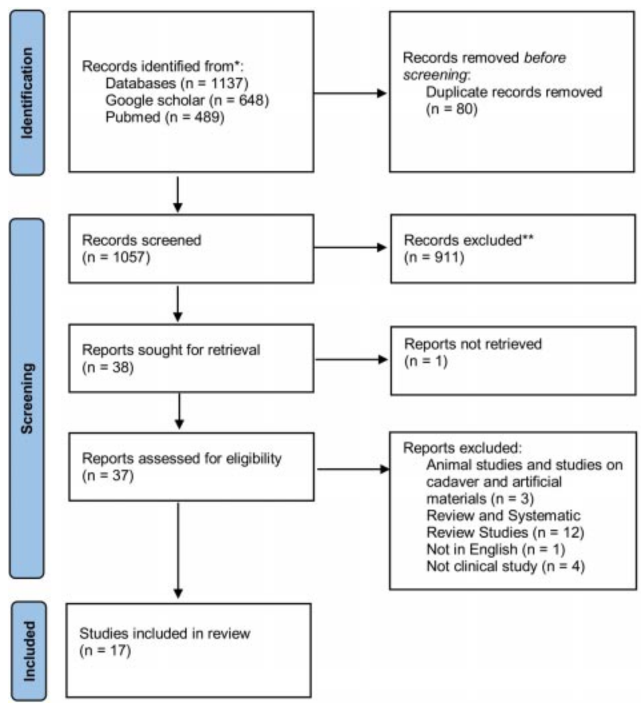

Fig. 1. The PRISMA flowchart of included studies.

Study characteristics

The characteristics of the included materials are shown in Table II. One was the cohort, 3 were case series and 13 were case reports. 237 patients with a total of 918 implants were included. 29 were female, 15 were male, and the rest (9 studies) (Beretta *et al*., 2014; Block, 2016; Jinmeng & Guomin, 2017; Happea *et al*., 2018; Schubert *et al*., 2019;

Table II. The characteristics of included studies.

Author (year), country of origin, language	Study type	Mean age /Sex	Number of cases, Primary/ Secondary/tertiary	complications	computed guided surgery	Number of Implants Placed/type of implants
Di Giacomo *et al.*, 2012. Brazil English	Retrospective cases study	60.3 years old / four males and eight females	12 cases	· Surgical complications · Restrictions on access to surgery · Breaking surgical guide · Infection · Possibility to change the size of the implant size to the predicted size · Decreased initial stability · Loss of soft tissue · Primary bone augmentation · Acute sinusitis · Marginal fistula and buccosinusal fistula · Prolonged pain · Misfit between suprastructure and the · Abutment · Speech problems, cheek biting · Occlusal wear · Limited access in the posterior areas	Static guided surgery	60 self-tapping external hex implants
da Silva Salomão *et al.,* 2021. Brazil, English	Case Report	29 years old /female	1 case	· The difference between the predicted position of the implant and the position of the implant in reality · Insufficient accuracy in intraoral scanning causes prosthetic problems · The surgical guide requires an experienced surgeon	Static guided surgery	1 implant Bone Level Tapered
Albiero *et al.,* 2015. Italy, English	Case study	55 years old /male	1 case	· There is an inevitable tolerance between the drills and the drilling guide, which is an inherent error of this method · The difference in the position of the implant in the design and reality · Lack of precise placement of the implant in the original position, especially in overloaded overloads, causes loose screws and incompatibility of the prosthesis and implant	Static guided surgery	6 regular implant Bone Level
Gulinelli *et al.,* 2016. Brazil, English	Clinical report	38 years old /female	1 case	· Due to the small space between the surgical guide and the sleeves, the irrigation process is not done well and to the required extent, and the temperature at the ossification site rises · Compromises visibility and senses compared to traditional methods · Incompatibility of keratinized gingival around the implant · Insufficient accuracy in preparing images and software and preparing surgical guides and occurrence of specialized problems · High cost · Limitation in mouth opening	Static guided surgery	6 implants with regular platform
Wang *et al.,* 2020. China, English	Research Article	-	-	· The cost is high and the preparation time is long · Due to dimensional tolerance as well as soft tissue and bone tissue of the patient causes looseness in the guide · Also, if the position of the implant is close to the adjacent tooth, the surgical process will be disrupted · Excess heat generation due to reduced irrigation in the surgical area	Static guided surgery	-
Jinmeng & Guomin, 2017. China, English	Research Article	-	-	· Due to the small space between the surgical guide and the sleeves, the irrigation process is not done well and to the required extent, and the temperature at the ossification site rises · Using a surgical guide compromises visibility and senses compared to traditional methods	Static guided surgery	-
Landázuri-Del Barrio *et al.,* 2013. Brazil, English	Prospective study	Average age 59 years /10 female, 6 males	16 cases	· Misfit between an abutment and implant occlusal adjustments · Screw loosening · Fracture of the prosthesis, and implant fracture · Fistula	Static guided surgery	64 regular implants
Puterman et al., 2012. USA, English	Clinical report	45-year-old female	1 case	Prosthetic misfit	-	12 regular implants
Schubert *et al.,* 2019. English	Experimental	-	-	Higher cost the need for special expertise	Digital implant planning and guided implant surgery	BL, Ø 4.1 mm RC, SLActive® 12 mm, Roxolid®, Loxim®
Park *et al.,* 2020). South Korea, English	Multiple regression analysis of a prospective cohort	(a) ≥18 years of age	72 cases	Errors of radiographic/clinical data, the clearance between the guiding hole and the drill, Geometry data can be inaccurate because of patient's moves, while inaccuracies in dental impression technique/materials and intraoral scanning increase transformational errors, and the drilling distance below the guided sleeve also influences accuracy. Placing a prefabricated metal sleeve within the template can induce an error during the fabrication of a surgical guide, and the clearance margins between the sleeve and the drill handle and between the drill handle and the drill can result in inaccuracies during surgery.	A three-dimensionally a printed template having nonmetal sleeves	187 implants
Peñarrocha *et al.*, 2012. Spain, English	A preliminary study	The mean age was 42 years (range 30-58) / (4 males and 8 females with a mean age of 38 years; range 26-53)	12 cases	Soft-tissue distribution is not possible	Guided surgery and mini flap technique	19 implants
Arisan *et al.*, 2013. Turkey, English	Prospective Studies	The similarity of the groups regarding the patient characteristics (age, gender, and presence of teeth in the antagonist jaw)	68 cases (34–35 cases per group)	Objective Bacteremia—the access of bacterium to the bloodstream—may yield life-threatening complications.	Template-guided surgery technique (flapless group)	A total of 377 implants were placed in 68 edentulous jaws using the conventional (conventional group) or a computer-assisted stereolithographic (SLA) template-guided surgery technique (flapless group).
Gillot *et al.*, 2010. France, English	Experimental study	Mean age: 60.6 for men, 61.4 for women	33 cases	· Fractures of resin · The distal implants could not be connected to the prosthesis. · Absence of primary stability of an implant in a type IV bone. · Major occlusal adjustments for one patient.	Nobelguide® (Nobel Biocare AB, Göteborg, Sweden)	211 implants
Beretta *et al.*, 2014. Italy, English	Prospective clinical study	-	2 cases	Deviation between the current position of the implant and the position	Static guided surgery	14 dental implants
Block, 2016. LA, English	Clinical report	-	-	Drills Irrigation District is faced with a problem. High cost	Static guided surgery	-
Block & Chandler, 2009. LA, English	Clinical study	-	-	Unstable Surgical Guide Inadequate Interocclusal Space for Implant Placement Implants Placed More Superficially Than Planned Need to Be Countersunk Lack of Integration from Burning/Heating of Bone	Static and dynamic guided	-
Happea *et al.,* 2018. Koln, English	Clinical report	-	-	Longer delivery time higher cost Loss of control over drilling guide design process	Static guided surgery	-

Wang *et al*., 2020;) did not specify their gender. The mean age of the patients was 45 years with an age range of 38-63, although, 8 studies did not report any data for age (Block & Chandler, 2009; Arisan *et al*., 2013; Beretta *et al*., 2014; Block, 2016; Jinmeng & Guomin, 2017; Happea *et al*., 2018; Schubert *et al*., 2019; Wang *et al*., 2020).

Based on the articles checked in this review, complications can be caused by the surgical techniques or the hardware used. The first included errors in the location and type of placement of the surgical guide and overheating during osteotomy while the latter includes errors in accuracy and strength of the surgical guide.

Results of risk of bias assessment

According to the risk of bias table (Table III), only one study obtained low quality (the number of cases and information related to the cases were not fully reported). 10 articles have the medium quality and 6 articles were considered high quality.

Results Among the reviewed articles, 6 out of 17 articles reported Preoperative complications, which occurred due to imaging and software errors, intraoral scans, and Patient movement resulting in the production of a surgical guide (Di Giacomo *et al*., 2012; Beretta *et al*., 2014; Albiero *et al*., 2015; Gulinelli *et al*., 2016; Park *et al*., 2020; da Silva Salomao *et al*., 2021). Nine articles reported complications and problems during surgery that occurred due to the surgical process, surgical instruments, location, and position of the surgical guide (Block & Chandler, 2009; Beretta *et al*., 2014; Block *et al*., 2016; Gulinelli *et al*., 2016; Jinmeng & Guomin, 2017; Happea *et al*., 2018; Park *et al*., 2020; Wang *et al*., 2020). Eleven articles reported postoperative complications occurring due to errors in prosthetic components in short-term and long-term follow-ups (Block & Chandler, 2009; Gillot *et al*., 2010; Di Giacomo *et al*., 2012; Peñarrocha *et al*., 2012; Puterman *et al*., 2012; Arisan *et al*., 2013; Landázuri-Del Barrio *et al*., 2013; Block, 2016; Happea *et al*., 2018; Schubert *et al*., 2019; Wang *et al*., 2020).

1-Pre-surgical errors/complications (during the preoperative planning process)

In 2021, da Silva Salomão *et al*. found that the placement of the implant during surgery on a patient with a surgical guide was different from that predicted, due to the inaccuracy of intraoral scans, images, and software, which later caused the prosthesis to deviate. In a study of twelve patients treated with the Static Surgery Guide and evaluated for 30 months, one of the errors that occurred in surgery was the difference in the predicted size of the implants used before surgery and the size of the surgery, which led to a change in the size of the implants (Puterman *et al*., 2012).

In a study of 72 patients, Park *et al*. (2020) found that errors in radiography resulted in a difference in distance between the surgical guide and the surgical drill. This error was attributed to the patient moving during the imaging process. In addition, errors in hardware used for internal scans had caused looseness and gaps between the surgical guide and the sleeves.

2-Peri-surgical errors/complications

Di Giacomo *et al*. (2012) assessed a total of 60 implants in 12 patients with alveolar defects and reported restrictions in surgical access. The reported complications were; breaking the surgical guide during surgery, lack of proper access to the posterior part of the patient's mouth (4 cases), lack of coordination, and looseness of the prosthesis (2 cases). Happea *et al*. (2018) compared computer-guided surgery with the traditional method and found that the latter has a longer preparation time for the surgery.

Gulinelli *et al*. (2016) found that the drilling process with the surgical guide sleeves compromises the visibility of the surgeon when compared to traditional methods. Likewise, the irrigation of the surgical site is not done well and causes temperature rise and bone necrosis at the drilling site. Also due to the instability of the surgical guide on the patient's jaw, it is difficult to control the drill during osteotomy (Happea *et al*., 2018). Other complications reported by the authors include an increase in patient seat time as well as an increase in the number of treatment sessions (Happea *et al*., 2018; Wang *et al*., 2020), increased time to reduce the bone temperature (Albiero *et al*., 2015; Block, 2016; Happea *et al*., 2018; Park *et al*., 2020), the high cost to purchase the surgical guide hardware and software and the learning curve (Gulinelli *et al*., 2016), limited access in the posterior areas (Di Giacomo *et al*., 2012), drill overuse and wear; increased tolerance between components, and others (Puterman *et al*., 2012).

3-Post surgical complications

Complications of late postoperative surgical complications were reported in a long-term study of 13 patients; the complications were loose prosthesis in one case, speech problems in one case, Persistent pain in one the case, a

Table III. The risk of bias assessment for included studies.

First author (year of publication)	1. Does the patient(s) represent(s) the whole experience of the investigator (centre) or is the selection method unclear to the extent that other patients with similar presentation may not have been reported?	2. Was the exposure adequately ascertained?	3. Was the outcome adequately ascertained?	4. Were other alternative causes that may explain the observation ruled out?	5. Was there a challenge/rechallenge phenomenon?	6. Was there a dose–response effect?	7. Was follow-up long enough for outcomes to occur?	8. Is the case(s) described with sufficient details to allow other investigators to replicate the research or to allow practitioners to make inferences related to their own practice?	Overall appraisal quality
Di Giacomo *et al*., 2012	Y	Y	Y	Y	Y	N	Y	Y	7/8 Medium quality
da Silva Salomão *et al*., 2021	N	Y	Y	Y	Y	Y	Y	N	6/8 Medium quality
Albiero *et al*., 2015	Y	Y	Y	Y	Y	Y	Y	Y	8/8 High quality
Gulinelli *et al*., 2016	Y	Y	Y	Y	Y	Y	Y	Y	8/8 High quality
Wang *et al*., 2020	N	Y	Y	Y	Y	Y	Y	Y	7/8 Medium quality
Jinmeng & Guomin, 2017	N	Y	Y	Y	Y	Y	Y	Y	7/8 Medium quality
Landázuri-Del Barrio *et al*., 2013	Y	Y	Y	Y	Y	Y	Y	Y	8/8 High quality
Puterman et al., 2012	Y	Y	Y	Y	N	Y	N	Y	6/8 Medium quality
Schubert *et al*., 2019	N	Y	N	Y	N	Y	Y	Y	5/8 Low quality
Park *et al*., 2020	Y	y	Y	y	y	y	y	y	8/8 High quality
Peñarrocha *et al*., 2012	Y	Y	Y	Y	Y	N	Y	Y	7/8 Medium quality
Arisan *et al*., 2013	Y	Y	Y	Y	Y	Y	Y	Y	8/8 High quality
Gillot *et al*., 2010	Y	Y	Y	Y	Y	Y	Y	Y	8/8 High quality
Beretta *et al*., 2014	Y	Y	Y	Y	N	Y	Y	Y	7/8 Medium quality
Block, 2016	Y	Y	N	Y	N	Y	Y	Y	6/8 Medium quality
Block & Chandler, 2009	Y	N	Y	Y	Y	Y	Y	Y	7/8 Medium quality
Happea *et al*., 2018	Y	Y	Y	Y	N	Y	Y	Y	7/8 Medium quality

residual buccal soft-tissue defect around one implant in one case, and seven implant failures (7/78 implants). In another study (Yong & Moy, 2008), with a one year follow up, the most common complication observed was postoperative pain (4/23 patients), signs of post-surgical inflammation or hyperplasia in 4/23 patients, marginal fistula in 1/23 patients, occlusal material fracture of the prosthesis 2/23 patients, loosening of retaining screws 1/23 patients, slight discrepancies between the abutments and implants 1/23 patients, and midline deviation of the prosthetic rehabilitations 1/23 patients (van Steenberghe *et al*., 2005).

In, another study with 6 to 21month follow-up, 23 patients treated with a surgical guide was evaluated for postoperative complications. The most common complication was fracture of the prosthesis (observed in 8 out of 23 patients). In two cases, abutment screw loosening was observed. In soft tissue complications, pre-implant symptoms with pocket formation, bleeding on probing, and mucosa inflammation around implants can be mentioned, these occurred in two patients. Marginal bone loss has been reported in one case after 1 year, with a rate of bone resorption of more than 2 mm (Malo *et al*., 2007).

A study reported decreased initial stability, Loss of soft tissue, acute sinusitis, the misfit between the superstructure and the abutment, speech problems, cheek biting, and occlusal wear. Some complications were rooted in the difference between the actual size of the implant size and the predicted size (Di Giacomo *et al*., 2012).

DISCUSSION

The use of computer-guided techniques in dental implant surgery has increased rapidly in recent years. This trend allows for the involvement of all dental practiotionaires from the beginning of treatment, which ensures a comprehensive diagnosis and treatment planning, and satisfactory outcomes. The computer-guided surgery increases the accuracy and the possibility of determining the exact position of the implant (Gargallo-Albiol *et al*., 2019). Despite the advantages of this method, some complications caused by the surgical technique or the hardware used have been reported. This review elucidates the disadvantages of the different computer-guided surgery methods.

Proper implant placement is very important to achieve a proper restoration with sufficient beauty and function (Tatakis *et al*., 2019). Navigation surgery was first presented in neurosurgery for leading to safer brain surgery in a minimally invasive matter (Mezger *et al*., 2013); computer-aided surgery or image-guided surgery has been used to provide that Implants' position is correct. Using a computer-assisted surgical approach, two methods of dynamic and static navigation were introduced. Dynamic navigation is a method in which 3D software is used to control and monitor the osteotomy and drilling protocol and correct placement of the implant while performing the work (Block *et al*., 2017). While the static navigation approach uses static prefabricated patterns to guide bone drilling and implant placement. In the static navigation approach, two methods the full-guided (FG) and half-guided (HG) approaches are the most widely used. Although similar to other methods, the use of full-guided static or dynamic navigation has limitations and errors, including reduction of accuracy in fully-edentulous arches compared to partially edentulous jaw (Farley *et al*., 2013; Younes *et al*., 2018); reduced accuracy in bone-supported templates when compared with mucosal-supported or tooth-supported templates (Arisan *et al*., 2010; Laleman *et al*., 2016); the inaccuracy of temporary prostheses prepared in advance for immediate loading protocols (Amorfini *et al*., 2017); and mouth-opening limitations, particularly in posterior areas. when using static surgical guides may interact with The limitations in mouth opening and the specially designed surgical drills. In addition, the flap reflection is essential for bone augmentation procedures which limits their use in the flapless approach.

1- Pre-surgical errors/complications (during the preoperative planning process).

1-1 Cone-beam computed tomography (CBCT) imaging and intraoral scans

Errors in the system can be caused by inaccuracies and problems in cone-beam computed tomography data sets such as image quality and resolution, reliability, metal artifacts, or motion of patient during cone-beam computed tomography examination (Vercruyssen *et al*., 2015; D´ Haese *et al*., 2017). At present, cone-beam tomography is more commonly used when compared to the computed tomography due to the increased radiation dose and cost, and acquisition time as well as higher image resolution (Liang *et al*., 2010). Arisan *et al*. (2013) reported that several interference and noise in cone-beam computed tomography images could be seen in most cases. To eliminate these problems, it is necessary to adjust manually on the gray intensity thresholds and eliminate noise and scattering. Metal artifacts during imaging can have a great impact on image quality and cause errors during implant surgery. Metal artifacts can reveal the alveolar outline and anatomical boundaries, but there is currently no effective way to reduce these interactions and noise from artifacts in cone-beam computed tomography.

1-2 software

After imaging and obtaining multislice cone-beam computed tomography information, the images are extracted as a "digital imaging and communications in medicine" (DICOM) file. This imaging template is designed to be compatible with all business treatment planning software packages on the market (Tatakis *et al*., 2019). Implant surgery errors with the surgical guide can occur from various stages of work in the software, including conversion, segmentation, volume and manual removal of artifacts, and improper position of the simulated implant in the software (Arisan *et al*., 2010; Vercruyssen *et al*., 2015). In a review article, by examining the various commercial software available in the market, they found that it could not be done due to the large heterogeneity in the design of the study (Van Assche *et al*., 2012). A study has assessed three software found that there is no significant difference between the level of error of this three software (Ruppin *et al*., 2008).

Specifically, when working with dynamic navigation systems, an error in the system might affect the spatial relationship between the reference points and the case. This leads to mistakes in the drilling procedure and implant placement (Brief *et al*., 2005).

To reduce software errors, clinicians should consider the differences in implant planning software features and system inaccuracies so that they can perform surgery with the highest degree of accuracy.

1-3 patient movement

During imaging with cone-beam computed tomography scanning, the patient's movement can lead to errors during imaging as well as errors in the output data of the imaging. In a randomized controlled trial, Vercruyssen *et al*. (2014; 2015) performed special care for patients during the scan to minimize the effects of motion-induced movement. And obtained the correct position of the prosthesis. They found that using the occlusal bite index to stabilize the mandible and scan the prosthesis was especially useful in completely edentulous patients. To reduce the patient's movement during the scan, the operator in charge of the cone-beam computed tomography scan during the scanning process should always be careful so that the patient has minimal movement. After the scan, the obtained cone-beam computed tomography images should be carefully checked for signs of possible movement, Otherwise, the scan must be repeated.

2- Peri-surgical errors/complications

2-1 surgical process and surgeon experience

Misalignment and inadequate design of the virtual model of teeth taken from intraoral or external stone cast scan data and cone-beam computed tomography model could be an effective source of errors in the design of surgical guides. These deviations due to incorrect registration are transferred to the surgical process and lead to unacceptable complications and differences during surgery for the planned position of the implant and the actual position. Also, the type of surgical guide (tooth supported, bone supported, soft tissue supported) used can affect the accuracy of the surgery. Clinical studies show that the use of tooth support stereolithographic guides is more accurate than those that bone- and mucosa-supported ones (Ozan *et al*., 2009; Geng *et al*., 2015). In a meta-analysis of four studies including 599 implants, clinical studies were reviewed and compared the accuracy of different types of the surgical guide. It was concluded that the bone-supported guides have a significant deviation in angle, point of entry, and apex compared to the other two models (tooth-supported and mucosa-supported guides) (Raico Gallardo *et al*., 2017). The physical and mechanical properties of the surgical guide and handling by the surgeon are other factors that can lead to complications during implant surgery. It was reported by Arisan *et al*. (2010) that in two out of 16 surgeries with the surgical guide approach, the surgical guides were fractured during surgery. In studies on complications of the surgical guide, surgical guide fractures (incidence rate: 6.7%-9.7%) have been identified as an important complication during surgery (Voulgarakis *et al*., 2014); therefore, careful design and handling of the guides is essential to prevent such problems.

For a surgeon, using a surgical guide to achieve the correct position of the implant is the most important factor. Also, during surgery, the surgical guide should be in place without movement and distortion (Hämmerle *et al*., 2009). These factors indicate that unforeseen complications occur during surgery with a surgical guide. The more experience and skill, the faster and better the solving of these problems. In a clinical study, a comparison was made between surgery by 10 experienced surgeons and 10 inexperienced surgeons (Rungcharassaeng *et al*., 2015); The vertical deviation of implants implanted by inexperienced surgeons is twice the rate of deviation of implants implanted by experienced surgeons. In a randomized controlled trial, implants were compared between two groups. The first group of experienced surgeons who performed Computer-assisted surgery, and the second group of newly trained surgeons. The results showed that the total error of the exact position of the implant was higher in the group of inexperienced surgeons (higher apical and coronal deviations). As previously explained, the result of this randomized controlled trial emphasizes the need for experience and skill of the surgeon when using the guided implant surgery approach (Sicilia & Botticelli, 2012). The notion that guided implant surgery requires less training and experience is incorrect. Many authors have referred to the relationship between the success rate of guided implant surgery and surgeon learning (Moraschini *et al*., 2015). In addition, a dentist who uses guided implant surgery must have the necessary and sufficient training, surgical skills, and equipment to convert the case to conventional implant surgery in cases where an implant or guided surgery is not safe enough.

To reduce the position error of the surgical guide template on both jaws, the surgical guide can be attached to the bone with at least three mini-screws under the guidance of a bite index (Cassetta & Bellardini, 2017). However, these mini-screws may also loosen during the surgical procedure and sometimes need to be tightened (Vercruyssen *et al*., 2008). Some authors consider the use of tightening screws as a barrier to the fact that the surgeon cannot constantly monitor the location of the osteotomy (Verhamme *et al*., 2015a). Tahmaseb *et al*. (2009) in a clinical study suggested that the surgical pattern on toothless jaws could be more accurately supported by mini-implants. However, the use of mini-implants increases the cost and creates possible complications for the patient.

2-2 surgical instruments and components

Another possible source of error during guided implant surgery can be the technique of drilling and components of implant placement and including the tolerance to the rotation of drills in tubes, straight or tapered drills, availability of drill stops, the height of tube and drill, And installation of guided or freehand implants. The sequence of use of drills and osteotomy protocol has been used consistently over the years. Different osteotomy methods have been used using several consecutive guides that increase the diameter of the tube to accommodate the drill sequence during the surgical procedure or use one guide to reduce the diameter of the tube using different categories for the drill handles. Today, all implant systems use a guide to enable proper guidance and minimize problems that have arisen in the past. Drill tolerances inside tubes or keys can be a source of significant error due to the cylinder gap required to rotate the drills in the tube. The effect of accuracy on the fit between the diameter of the drill and the diameter of the tube should be an important factor. Therefore, the surgeon must constantly follow the correct path of the tube throughout the osteotomy process. Also, the lateral movement of the drill can be reduced by using a shorter drill length and increasing the height of the drill key or the height of the guide tube. (Schneider *et al*., 2015) Compared to using bone support guides or posterior position therapy, the height of the tube usually increases when using the tooth and mucosal support guides or treating the anterior points. This significantly reduces deviations and leads to better accuracy (Vasak *et al*., 2011). Erosion of keys and drills, after prolonged use, can also be a contributing factor by increasing the tolerance between components (Horwitz *et al*., 2009). Parallel (cylindrical) or tapered wall drills can also be confusing, as freedom of movement and the possibility of deflection, especially at the point of bone entry, are greater in tapered design (Tatakis *et al*., 2019). Some guided implants Surgical implant systems have physical drill stops to control the depth of the osteotomy (bone preparation). When guided implant surgery does not stop the drill, the depth of the drill should be checked visually at all times. although, clinical evidence shows that the addition of a physical stop in the system does not necessarily lead to increased accuracy (Vercruyssen *et al*., 2014). Implant-guided surgery usually requires the use of longer drills than conventional implant surgery due to the use of guide tubes and the distance between the guide and the bone. Increasing the drill length, possible friction between the drill and the guide tube, and the physical barriers indicated by the guide and guide tube can significantly help reduce irrigation efficiency, thus preventing adequate cooling of the drill. This causes the bone to overheat, which can lead to thermal osteonecrosis (dos Santos *et al*., 2013). Disruption of the irrigation process, which is the site of ossification, is one of the most common problems reported for using the surgical guide. Due to the small space between the surgical guide and the sleeve, the irrigation process does not work well and the temperature at the ossification site increases. Separate irrigation after each stage of drilling in the osteotomy process is one of the solutions to this problem. Either using drills with internal holes to irrigate the osteotomy site can be a solution or the drilling process can be done in several stages (Liu *et al*., 2018). Cooling recovery techniques, such as repeated harvesting and repositioning of the drill during osteotomy preparation, use of internal cooling drills, and frequent and continuous irrigation with cold saline solution, should be used during guided implant surgery.

Guided osteotomy can be advocated in clinical practice with stops (fully guided protocol) or with a freehand implant installation. Recent studies have shown that the fully guided protocols which include guided implant placement, had better accuracy compared to the partially guided systems.

2-3 location and position of the surgical guide

The proper positioning and stabilization of the surgical guide is a crucial factor for the safety and predictability of guided implant surgery (Hämmerle *et al*., 2009). The routine method of choice is the static guided system when guided implant surgery is needed (D' Haese et al., 2017; Garcia-Hammaker & George, 2019). This consists of a stereolithographic surgical template with guide sleeves for implant placement and the stabilization of the template. A systematic review of a static guided system illustrated that the tooth and mucosa-supported templates are more accurate than the bone-supported systems (Tahmaseb *et al*., 2009). Another meta-analysis reported that the bone-supported guides provided lesser accuracy when compared with mucosa/tooth-supported templates; although, the differences for angle, entry point and apex deviation between the groups were not significant (Ruppin *et al*., 2008; Arisan *et al*., 2013). Bone guides have been reported to move frequently and spontaneously during drilling, and drill depth adjustment requires repeated checks when using a bone support guide. The less accurate bone support guides may also be explained by the fact that the intraoral fit of the surgical cast is more difficult due to the possible interference of the reflected tissue (Lal *et al*., 2006). It has been reported that the position and stabilization of the surgical template have a major effect on the surgical accuracy of guided implants. D' Haese *et al*. (2012; 2017) illustrated that the overall inaccuracy of the pattern supported by the mucosa on the maxilla depends largely on the positional error of the mold. Mucus thickness is one of the factors influencing the accuracy of implant placement with a mucosal-supported surgical template, with greater mucosal thickness increasing the likelihood of deviation (Ochi *et al*., 2013; Schneider *et al*., 2015). Swollen mucus from local anesthetic injections can also affect the position of the surgical template (Verhamme *et al*., 2015b). Significantly lower accuracy than guided implant surgery has been reported in completely edentulous patients, possibly due to difficulty in fitting the surgical template.

3-Post surgical complications

3-1 Prosthesis components

The misfit between the superstructure and the abutment is the most common complication related to the Prosthetic components.

At present, the expansion of dental activities has led to new, fast and simple methods which lead to successful treatments in the long term. According to the literature, guided surgery should still be considered an evolving method. It can be said that the use of dynamic surgical guidance is an extended part that can reduce complications. Other studies have checked the assessment of pain, operating room time, and marginal bone remodeling (Happea *et al*., 2018; Park *et al*., 2020; Wang *et al*., 2020). Due to the short follow-ups, we were not able to assess the long-term success rate of computer-assisted implant surgeries with the conventional free-hand technique.

However, the number of case studies that have examined the cases in this field is small and this causes the samples to be reduced in size and there is an error in this study.

Due to the limited quality and the number of clinical papers, further randomized controlled trials with large sample sizes and long-term follow-ups are warranted.

CONCLUSION

Accuracy and precision in computer-based implantation require the accurate transfer of the patient's oral anatomy, which is possible only if the hardware and software used are accurate. The surgical guides are not fully accurate and flawless in routine practice. Note that dentists should receive comprehensive training before using the surgical guide to prevent serious complications. Sufficient mastery to create a correct and accurate position for the implant and observing the important points of anatomical structures such as the alveolar nerve is one of the important points of this technique.

AEINEHVNAD M, RAMEZANZADE S, MIRZAHOSEINI S, MEHRYAR P, YOUSEFI P, OMID KS, REZA FH. Existe alguna complicacion en implantes dentales guiados: Una revisión sistemática. *Craniofac Res.* 2022; 1(1):48-61.

RESUMEN: El objetivo fue revisar estudios clínicos en términos de reporte de complicaciones en la instalación de implantes realizados con cirugía guiada por computadora en pacientes desdentados totales o parciales. Se realizaron búsquedas en las bases de datos de PubMed y Google Scholar desde 2000 hasta 2020 en busca de estudios clínicos pertinentes escritos en inglés. Se siguieron los lineamientos PRISMA 2020. Dos examinadores condujeron el análisis de calidad de acuerdo a la metodología de calidad y síntesis de series de caso y reportes de caso. En un primer momento, se cribaron un total de 1057 artículos y finalmente se incluyeron 17 artículos, de los cuales uno era la cohorte, tres eran series de casos y 13 eran informes de casos. Complicaciones y errores de la cirugía guiada se observaron en tres etapas: 6 de los 17 artículos reportaron complicaciones preoperatorias, 9 artículos reportaron complicaciones durante la cirugía asociadas al paciente o al cirujano y 11 artículos reportaron complicaciones postoperatorias. La implantología guiada por computadora no es perfecta, por lo que los odontólogos deben recibir una formación integral para prevenir complicaciones graves. El dominio suficiente para crear una posición correcta y precisa para el implante y observar los puntos importantes de estructuras anatómicas, como el nervio alveolar, es uno de los aspectos importantes de esta técnica.

PALABRAS CLAVE: Implante dental, cirugía computacionalmente asistida, precisión, complicaciones en cirugía guiada.

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