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Literature on the accuracy of guided surgery for dental implants: A scoping review

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ABSTRACT

Aim To summarise data available in the PubMed database regarding the accuracy of dental implants placed by means of static and navigated guided surgery.
Methods A search strategy was performed in order to find eligible articles in English reporting the accuracy of dental implants placed in humans with guided surgery techniques.
Results The search resulted in 387 articles for screening. After the selection, 44 articles were included for data extraction. 22 articles reported the accuracy of static guided surgery with mucosa-supported guides, 20 with tooth-supported, 3 with bone-supported and 7 with dynamic guided surgery.
Conclusions All studies with Static Guided Surgery and Dynamic Guided Surgery included in this review present deviations within the clinical accepted limits and represent excellent alternatives for guided implant placement.

INTRODUCTION

Tooth loss, functional and aesthetic aspects and patient perception

Tooth loss impairs masticatory function and prejudices patient's aesthetic perception specially if located in the anterior region. There is also a trend for patients to present a poor general health and less satisfaction with life when they have a bad oral condition (1-6). The rehabilitation of missing teeth with implant-supported prosthesis provides adequate restoration of function, with satisfactory aesthetic outcomes, when compared with removable dentures, as well as improved patient's satisfaction and their perception of quality of life related to oral health immediately after the finalisation of treatment. This perception could remain for a long time (7-10). Implant-supported rehabilitations present good outcomes in the short and in the long term, with success rates reported in the literature in a range between 87,8% and 100% (11-14). Nowadays, the aesthetic and functional perception of the patients and the impact of the rehabilitations on long-term quality of life are important factors to consider when treating the stomatognatic system (15-17). Therefore, the careful planning of an implant-supported rehabilitation with dental implants is extremely important to reach the desired functional and aesthetic goals and, for that to occur, the tridimensional positioning of implants has to be precise (18-20).

Malpositioning of dental implants

Malpositioning of dental implants can lead to countless problems such as the appearance of peri-implant diseases, the necessity of patient to undergo an explantation surgery with or without the replacement of a well-positioned implant, the loss of soft tissue or aesthetic impairment due to gingival recession of vestibularized implants, the difficulty to perform reconstructive procedures, the necessity to produce customized abutments in order to solve the cases or to bury the implant (21-27).

Guided surgery

Nowadays, it is possible to plan the insertion of dental implants with predictability on the imaging exam, in a digital setting, with the aid of CAD/CAM technology and planning softwares in which the professional designs a surgical guide (28-31). This technique allows the individual planning of each dental implant regarding their depth of insertion, mesio-distal, bucco-lingual

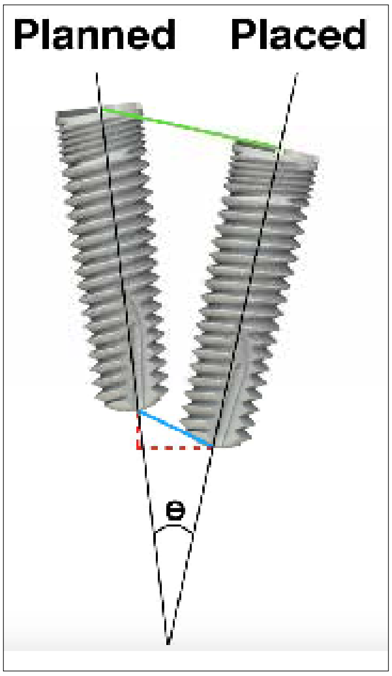

FIG. 1 Accuracy measures between planned and placed implant: Green line: Coronal deviation; Blue Line: Apical Deviation; Theta Letter:Angular Deviation; Striped Red Line: Depth Deviation.

and angular positioning (32-35). There are two types of guided surgery: the static and the dynamic. In the static guided surgery (SGS), the perforations and the implant installation are partially or completely done through holes in a restrictive appliance positioned over the oral structures. It is also possible to insert dental implants with dynamic or navigated guided surgery (DGS), in which the surgeon visualizes the direction of perforation drills and the implant itself, with the assistance of a navigation system that tracks the position of the drills and implant and shows the deviations, in real time, allowing the surgeon to correct the positioning during surgery (29).

Accuracy

The accurate positioning of dental implants can be affected by a number of factors throughout the workflow, from the virtual planning to the execution. One way to measure the accuracy is by superimposing the pre-operatory tomography images, in which the implant planning was done, and the post-operatory tomography images with the actual position of the implants installed. This way, one can digitally measure the linear deviations regarding (i) the entry point (in mm), (ii) the apical deviation, (iii) the vertical or depth deviation, and (iv) the angular deviation between the long axes of the planned and the inserted implant (Fig. 1) (34-36).

Objective

This article aims to describe the data available in the PubMed Database regarding the positioning accuracy of dental implants inserted with static-guided surgery and dynamic-guided surgery available until May 2020.

METHODS

A PubMed search was performed in May 2020 using the keywords "Surgery, Computer-assisted" or "guided surgery", and "dental implants" and "accuracy". The following inclusion criteria were applied.

a) Studies in English language.
b) Human studies (excluding cadaver).
c) Studies with fully guided surgeries.
d) Studies reporting linear and angular deviations.
e) Studies with at least 20 implants.

Reviews, systematic reviews and meta-analyses were excluded from this study. This report was structured following the PRISMA-ScR guideline.

RESULTS

The initial search yielded a total of 387 articles from PubMed. Two independent reviewers (MNG and KBK) screened through titles and abstracts and selected 86 articles for full-text review. Articles that were not chosen by both reviewers were added after agreement. After the full-text review, 44 articles were selected for data extraction. The workflow for articles selection and reasons for exclusions are presented in the flowchart (Fig. 2). Out of 44 articles, 22 reported accuracy with mucosa-supported guides, 20 reported with tooth-supported guides, 3 with bone-supported guides and 7 reported accuracy with dynamic surgery.
An overview of the 22 studies reporting on the accuracy of SGS with mucosa-supported guides shows that 7 were conducted in Italy, 5 in Belgium, 3 in Brazil and 3 in the Netherlands. The most frequent

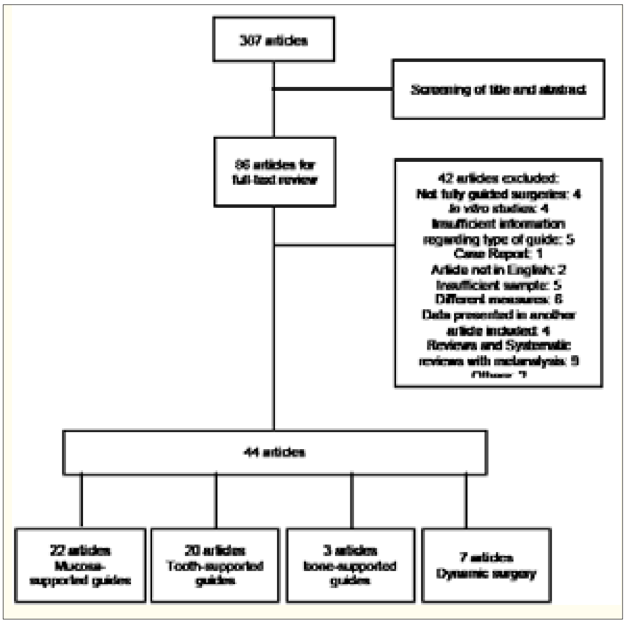

FIG. 2 Flowchart of the articles selection.

Author and Year	Country	Implant Manufacturer and number of implants placed	Planning Software	Software for accuracy analysis	Deviations			
					Coronal (SD, min - max) in mm	Apical (SD, min - max) in mm	Angular (SD, min - max) in degrees	Depth (SD, min - max) in mm
Albiero et al., 2019[37]	Italy	Ankylos Plus (Dentsply) 114 implants	Simplant (Dentsply Sirona)	Mimics (Materialise)	1.20 (0.56, 0.25 - 2.88)	1.51 (0.71, 0.36 - 3.85)	3.30 (1.65, 0.16 - 11.53)	0.52 (0.85, -1.75 - 2.57
Arisan et al., 2010[38]	Turkey	N/D 104 implants	N/D	Analyse (Analyze Direct)	0.7 (0.13, 0.2 - 0.83)	0.76 (0.15, 0.4 - 0.99)	2.9 (0.39, 0.8 - 3.5)	N/D
Cassetta et al., 2012[39]	Italy	N/D 95 implants	Simplant (Dentsply)	Mimics (Materialise)	1.65 (SD 0.56)	2.15 (SD 0.81)	Desvio Angular: 4.64 (SD 2.74)	N/D
Cassetta et al., 2013[40]	Italy	Plan 1 Health N/D	Simplant (Dentsply)	Mimics (Materialise)	1.63 (N/D, 0.13 - 3.0)	2.10 (N/D, 0.34 - 4.23)	4.71 (N/D, 0.28 - 15.25)	0.82 (N/D, 0.03 - 2.29)
Cassetta et al., 2014a[41]	Italy	Prime (Impladent) 225 implants	Simplant (Dentsply)	Mimics (Materialise)	1.68 (0.6, N/D - N/D)	2.19 (0.83, N/D - N/D)	4.67 (2.68, N/D - N/D)	N/D
Cassetta et al., 2014b[42]	Italy	Prime (Impladent) 172 implants	Simplant (Dentsply)	Mimics (Materialise)	1.10 (0.39, N/D - N/D)	N/D	4.33 (1.42, N/D - N/D)	N/D
Cassetta & Bellardini, 2017[43]	Italy	Sharp Implant (ImplaDent) 70 implants	Diagnosys (3Diemme)	Geomagic Studio (Geomagic)	Experienced surgeons: 0.60 (0.25, 0.06 - 1.00) Inexperienced Surgeons: 0.75 (0.18, 0.51 - 1.01)	Experienced Surgeons: 0.67 (0.34, 0.24 - 1.67) Inexperienced Surgeons: 1.02 (0.44, 0.64 - 1.99)	Experienced Surgeons: 3.21 (1.57, 1.41 - 8.01) Inexperienced Surgeons: 3.07 (SD 2.70, 0.73 - 9.22)	N/D
Cassetta et al., 2020[44]	Italy	Sharp Implant (ImplaDent) 33 implants	3Diagnosys (3Diemme)	Geomagic Studio (Geomagic)	1.24 (0.79, 0.72 - 2.67)	1.52 (1.15, 0.88 - 3.84)	3.59 (1.65, 1.69 - 6.30)	N/D
D'haese et al., 2012[45]	Belgium	OsseoSpeed (Astra Tech) 78 implants	Facilitate (Astra Tech)	Mimics (Materialise)	0.91 (0.44, 0.29 - 2.45)	1.13 (0.52, 0.32 - 3.01)	2.60 (1.61, 0.16 - 8.86)	N/D
De Oliveira et al., 2019[46]	Brazil	Slice Guide (Conexão) 115 implants	Dental Slice (Bioparts)	Dental Slice (Bioparts)	Maxilla: 1.72 (0.22, N/D - N/D) Mandible: 1.83 (0.21, N/D - N/D)	Maxilla: 2.41 (0.74, N/D - N/D) Mandible: 2.18 (0.43, N/D - N/D)	Maxilla: 2.41 (0.15, N/D - N/D) Mandible: 2.50 (0.43, N/D - N/D)	N/D
Di Giacomo et al., 2012[47]	Brazil	E-fix (AS Technology) 62 implants	Implant Viewer (Anne Solutions)	N/D	1.35 (0.65, 0.09 - 2.69)	1.79 (1.01, 0.11 - 4.0)	6.53 (4.31, 0.04 - 18.64)	N/D
Ochi et al., 2013[48]	Japan	Speedy Grove (Nobel Biocare) 30 implants	Procera (Nobel Biocare)	Mimics (Materialise)	0.89 (0.44, 0.21 - 2.66)	1.08 (0.47, 0.20 - 2.21)	N/D	N/D
Ozan et al., 2009[49]	Turkey	Swiss Plus (Zimmer Dental) 30 implants	Stent Cad (Media Lab)	Rhinoceros (McNeel Ins)	1.06 (0.6, N/D - N/D)	1.6 (1.0, N/D - N/D)	4.51 (2.1, N/D - N/D)	N/D

Continued

Author and Year	Country	Implant Manufacturer and number of implants placed	Planning Software	Software for accuracy analysis	Deviations			
Petterson et al., 2012[50]	Sweden	Branemark System MkIII TiUnite (Nobel Biocare) 139 implants	Procera (Nobel Biocare)	Nobel Guide Validation	0.80 (N/D, 0.10 - 2.68)	1.09 (N/D, 0.24 - 3.62)	2.26 (N/D, 0.24 - 11.74)	-0.15 (N/D, -2.33 - 2.05)
Sun Y et al., 2015[51]	Belgium	Branemark System MkIII TiUnite (Nobel Biocare) Speed Groovy (Nobel Biocare 80 implants	Procera (Nobel Biocare)	Procera (Nobel Biocare)	1.15 (0.78, 0.2 - 3.5)	N/D	3.33 (2.32, 0.1 - 11.6	0.83 (0.71, 0.2 - 4.7)
Van de Wiele et al., 2015[52]	Belgium	OsseoSpeed (Astra Tech) 75 implants	Simplant (Dentsply Sirona)	Mimics (Materialise)	0.87 (0.49, 0.15 - 2.75	1.10 (0.53, 0.33 - 2.68)	2.78 (1.47, 0.23 - 7.03)	0.48 (0.45, 0.01 - 2.38)
Vercruyssen et al., 2014[53]	Belgium	Astra Tech 52 implants	Simplant (Dentsply)	Mimics (Materialise)	1.38 (0.64, 0.39 - 2.68)	1.60 (0.70, 0.23 - 3.27)	2.71 (1.36, 0.20 - 6.36)	N/D
Vercruyssen et al., 2015[54]	Belgium	Ankylos (Dentsply) 90 implants	Simplant (Dentsply)	Mimics (Materialise)	0.9 (N/D, 0.1 - 4.5)	1.2 (N/D, 0.2 - 4.9)	2.7 (N/D, 0.0 - 6.6)	0.5 (N/D, 0.0 - 3.2)
Verhamme et al., 2013[55]	Netherlands	Branemark System MkIII Groovy (Nobel Biocare) 20 implants	Procera (Nobel Biocare)	Procera (Nobel Biocare)	1.39 (0.49, N/D - 2.59)	1.57 (0.51, N/D - 2.97	2.43 (1.19, N/D - 4.32)	0.91 (0.44, N/D - 1.69)
Verhamme et al., 2015a[56]	Netherlands	Branemark System MkIII Groovy (Nobel Biocare) 150 implants	Procera (Nobel Biocare)	Nobel Guide Validation	1.96 (0.23, N/D - 7.81)	2.28 (0.26, N/D - 8.72)	3.92 (0.41, N/D - 19.78)	-0.58 (0.15, N/D - -4.10)
Verhamme et al., 2015b[57]	Netherlands	Branemark System MkIII Groovy (Nobel Biocare) 104 implants	Procera (Nobel Biocare)	Nobel Guide Validation	1.36 (N/D, N/D - 4.20)	1.58 (N/D, N/D - 4.33)	2.81 (N/D, N/D - 13.47)	-0.84 (N/D, N/D - -1.5)
Vieira et al., 2013[58]	Brazil	N/D 62 implants	Dental Slice (Bioparts)	N/D	Maxilla: 2.17 (0.87, N/D - N/D) Mandible: 1.42 (0.76, N/D - N/D)	Maxilla: 2.86 (2.17, N/D - N/D) Mandible: 1.57 (0.84, N/D - N/D)	Maxilla: 1.93 (0.17, N/D - N/D) Mandible: (1.85 (0.75, N/D - N/D)	N/D

TABLE 1 Data regarding the deviations in SGS with mucosa-supported guides.

implant manufacturers were Impladent (500 implants) and Nobel Biocare (423 implants). The most frequent softwares for planning were the Simplant (Dentsply), used in 8 studies and the Procera (Nobel Biocare), used in 6 studies. The most used software for analysis (10 studies) was the Mimics (Materialise). Data regarding the accuracy of dental implants installed in SGS with mucosa-supported guide is summarized in table 1.

Of the 20 studies reporting on the accuracy of SGS with tooth-supported guides, 3 were conducted in

Author and Year	Country	Implant Manufacturer and number of implants placed	Planning Software	Software for accuracy analysis	Deviations			
					Coronal (SD, min - max) in mm	Apical (SD, min - max) in mm	Angular (SD, min - max) in degrees	Depth (SD, min - max) in mm
Alzoubi et al., 2016[59]	Kuwait	Immediate: Nobel Biocare 25 implants	Anatomage Invivo 5 (Anatomage)	N/D	0.85 (0.65, 0.21 - 2.80)	1.10 (0.65, 0.33 - 2.99)	3.49 (2.46, 0.57 - 9.82).	N/D
Arisan et al., 2010[38]	Turkey	N/D 104 implants	N/D	Analyse (Analyze Direct)	0.81 (0.33, 0.33 - 1.6)	1.01 (0.40, 0.29 - 1.72)	3.39 (0.84, 1.4 - 4.6)	N/D
Behneke et al., 2012[60]	Germany	Straumman 83 implants Nobel Biocare 43 implants	Med3D (GmbH)	med3D (GmbH)	0.32 (0.23, 0.01 - 0.97)	0.49 (0.29, 0.03 - 1.38)	2.1 (1.31, 0.07 - 6.26)	-0 (0.41, -1.2 - 1.47)
Cassetta et al., 2020[44]	Italy	Sharp Implant (ImplaDent) 23 implants	3Diagnosys (3Diemme)	Geomagic Studio (Geomagic)	0.87 (0.35, 0.34 - 1.27)	1.13 (0.39, 0.48 - 1.63)	2.63 (0.98, 1.89 - 4.50)	N/D
Chang et al., 2018[61]	China	E system and C system (Royal Dent) 20 implants	ImplantMax (Saturn Imaging)	ImplantMax (Saturn Imaging)	0.86 (N/D, 0.30 - 1.30)	1.38 (N/D, 0.10 - 3.60)	4.62 (N/D, 0.44 - 11.66)	N/D
Derksen et al., 2019[62]	Netherlands	Straumman Tissue Level 145 implants	coDiagnostiX (Dental Wings)	coDiagnostiX (Dental Wings)	0.75 (0.34, 0.69 - 0.80)	1.06 (0.44, 0.99 - 1.13)	2.72 (1.42, 2.48 - 2.95)	N/D
Fang et al., 2019[63]	South korea	UFII (DIO Inc) 40 implants	Implant Studio (3Shape)	Mimics (Materialise)	0.46 (N/D, 0 - 1.15)	0.67 (N/D, 0.14 - 1.19)	1.40 (N/D, 0.30 - 2.57)	0.15 (N/D, 0.10 - 0.82)
Fürhauser et al., 2015[64]	Austria	Replace TiU (Nobel Biocare) 27 implants	Nobel Clinician (Nobel Biocare)	N/D	0.84 (0.44, 0 - 1.6)	1.16 (0.69, 0 - 2.6)	2.7 (2.6, 0 - 12.7)	N/D
Kaewsiri et al., 2019[65]	Thailand	Straumann 60 implants	coDiagnostiX (Dental Wings)	coDiagnostiX (Dental Wings)	0.97 (0.44, 0.18 - 1.83)	1.28 (0.46, 0.49 - 2.13)	2.84 (1.71, 0.20 - 6.60)	N/D
Kiatkroekkrai et al., 2020[66]	Thailand	Straumman Bone Level 60 implants	coDiagnostiX (Dental Wings)	coDiagnostiX (Dental Wings)	Intraoral Scan: 0.87 (0.49, N/D - N/D) Extraoral Scan: 1.01 (0.56, N/D - N/D)	Intraoral Scan: 1.10 (0.53, N/D - N/D) Extraoral Scan: 1.38 (0.68, N/D - N/D)	Intraoral Scan: 2.41 (1.47, N/D - N/D) Extraoral Scan: 3.23 (2.09, N/D - N/D)	N/D
Lin et al., 2020[67]	Taiwan	I5 Conical Implant (AB Dental) 43 implants	BenQ AB Guided Service	Geomagic Control X (3D Systems Inc)	0.78 (0.39, N/D - N/D)	1.28 (0.72, N/D - N/D)	4.30 (2.87, N/D - N/D)	N/D

Author and Year	Country	Implant Manufacturer and number of implants placed	Planning Software	Software for accuracy analysis	Deviations			
Nickenig et al., 2010[68]	Germany	Replace Select (Nobel Biocare) 23 implants	coDiagnostiX (Dental Wings)	coDiagnostiX (Dental Wings)	0.9 (0.94, 0.0 - 3.4)	0.9 (1.22, 0.0 - 4.5)	4.2 (3.04, 0.0 - 10)	N/D
Ozan et al., 2009[49]	Turkey	Swiss Plus (Zimmer Dental) 30 implants	Stent Cad (Media Lab)	Rhinoceros (McNeel Ins)	0.87 (0.4, N/D - N/D)	0.95 (0.6, N/D - N/D)	2.91 (1.3, N/D - N/D)	N/D
Schnutenhaus et al., 2018[69]	Germany	N/D 122 implants	SMOP (Swissmeda)	Geomagic Studio (Geomagic)	1.2 (0.7, 0.0 - 3.4)	1.8 (0.9, 0.3 - 5.1)	4.8 (3.1, 0.2 - 14.6)	0.8 (0.7, 0.0 - 3.4)
Skjevern et al., 2019a[70]	Norway	Straumman Bone Level 28 implants	coDiagnostiX (Dental Wings)	coDiagnostiX (Dental Wings)	0.9 (0.44, 0.03 - 1.91)	1.11 (0.44, 0.44 - 2.1)	2.58 (2.07, 0.7 - 10.6)	0.49 (0.38, 0.1 - 1.78)
Skjevern et al., 2019b[71]	Norway	N/D 27 implants	3Shape Implant Studio	3Shape Convince	1.05 (0.59, 0.36 - 2.74)	1.63 (1.05, 0.56 - 5.16)	3.85 (1.83, 1.25 - 8.6	0.48 (0.50, -0.52 - 1.34
Smitkarn et al., 2019[72]	Thailand	Straumman Bone Level 30 implants	coDiagnostiX (Dental Wings)	coDiagnostiX (Dental Wings)	1.0 (0.6, 0.20 - 2.67)	1.3 (0.6, 0.24 - 2.57)	3.1 (2.3, 0.00 - 8.60)	0.7 (0.6, 0.05 - 2.14)
Sun et al., 2020[73]	Taiwan	MaxFit (TITC Ltd) 32 implants	SmilePlan (TITC Ltd)	Solidworks (Dassault Systems)	N/D	1.49 (0.08, N/D - N/D)	4.54 (0.29, N/D - N/D)	1.00 (0.15, N/D - N/D)
Varga Jr et al., 2020[74]	Hungary	MultiNeO (Alpha-Bio Tec) 52 implants	SMART Guide	Amira (Thermo Fisher Scientific)	1.40 (0.54, 0.49 - 2.94)	1.59 (0.59, 0.31 - 2.99)	3.04 (1.51, 0.42 - 6.30)	N/D
Younes et al., 2018[75]	Belgium	OsseoSpeed EV (Astra Tech) 21 implants	Simplant (Dentsply Sirona)	Mimics (Materialise)	0.73 (0.10, N/D - N/D)	0.97 (0.19, N/D - N/D)	2.30 (0.92, N/D - N/D)	0.43 (0.09, N/D - N/D)

N/D - Not Detailed

TABLE 2 **Data regarding the deviations in SGS with tooth-supported guides.**

Germany and 3 in Thailand. The most frequent implant manufacturer was Straumman (406 implants) followed by Nobel Biocare (118 implants). The most frequent software was the coDiagnostiX (Dental Wings) which was used in 6 studies for both planning and analysis.
Data regarding the accuracy of dental implants installed in SGS with tooth-supported guide is summarized in Table 2.
Three studies reported on the accuracy of SGS with bone-supported guides, 1 was conducted in Turkey, 1 in Switzerland and 1 in Belgium. The most frequent implant manufacturer was Astra Tech (93 implants in 2 studies). The software Mimics (Materialise) was also used in 2 studies for analysis. Data regarding the accuracy of dental implants installed in SGS with bone-supported guide is summarized in Table 3.
Seven studies reported on the accuracy of DGS. Three studies were conducted in Italy. The most frequent implant installed in this modality was the Osseotite (Zimmer Biomet - 136 implants). Both softwares from ClaroNav were the most frequently used: Navident for planning and EvaluNav for analysis. Data regarding the accuracy of dental implants installed in DGS is summarized in Table 4.

Author and Year	Country	Implant Manufacturer and number of implants placed	Planning Software	Software for accuracy analysis	Deviations			
					Coronal (SD, min - max) in mm	Apical (SD, min - max) in mm	Angular (SD, min - max) in degrees	Depth (SD, min - max) in mm
Ozan et al., 2009[49]	Turkey	Swiss Plus (Zimmer Dental) 50 implants	Stent Cad (Media Lab)	Rhinoceros (McNeel Ins)	1.28 (0.9, N/D - N/D)	1.57 (0.9, N/D - N/D)	4.63 (2.6, N/D - N/D)	N/D
Stübinger et al., 2014[76]	Switzerland	OsseoSpeed (Astra Tech) 44 implants	Facilitate (Astra Tech)	Mimics (Materialise)	0.71 (0.39, 0.20 - 1.77)	0.77 (0.38, 0.23 - 1.78)	2.39 (0.97, 0.53 - 4.52)	0.47 (0.42, 0.0 - 1.70)
Vercruyssen et al., 2014[53]	Belgium	Astra Tech 49 implants	Simplant (Dentsply)	Mimics (Materialise)	1.33 (0.82, 0.30 - 3.58)	1.50 (0.72, 0.33 - 3.56)	3.20 (2.70, 0.19 - 16.03)	N/D

N/D - Not detailed

TABLE 3 **Data regarding the deviations in SGS with bone-supported guides.**

DISCUSSION

The highest mean values presented in this review were found in static mucosa-supported guides (highest means in all deviations analysed, as well as highest maximum values) when compared with the other modalities of guided implant surgery. Some reasons highlighted by the authors that may explain the worse values obtained with this type of guide are the soft tissue resilience, the thickness of gingiva and the swollen tissue after anaesthesia (45,48,55). The use of fixation pins in mucosa-supported guides remains controversial. Some authors state that the use of fixation pins reduces the final deviation of the implants (38,45,47), while Verhamme et al. (2015) (56) argue that the use of these screws prevent the surgeon to check constantly the implant site preparation. More recently, the systematic review by Seo and Juodzbalys (2018) (82) pointed that the use of fixation pins is beneficial for attaining more accuracy with mucosa-supported guides. However, only two non-randomized studies presented data regarding the use of guides with and without retaining screws.

Another important point raised by Verhamme et al. (55) in relation to mucosa-supported guides is the optimal value for reconstructing the reference denture, with the fiducial markers used for planning, into an identical surgical template. If the 3D reconstruction done in order to design the template is generated with a too low gray value threshold, the surgical guide will be thicker than the radiographic reference and may not fit on the alveolar process properly. On the contrary, if the 3D reconstruction is done with a too high gray value threshold, the surgical guide will be too thin and may translate in the bucco-lingual direction.

Studies on static guided surgery modalities supported by hard structures, teeth and bone, showed maximum mean values of 1.40 mm and 1.33 mm for coronal deviation, 1.8 mm and 1.57 mm for apical deviation, 4.8° and 4.63° for angular deviation and 0.8 mm and 0.47 mm for depth deviation respectively. Even though, when extracting from the articles only the highest mean values, bone-supported guides display better values, the systematic review done by Raico-Gallardo et al. in 2016 (34) reported that tooth-supported guides are more accurate than bone-supported guides regarding the entry point, apical deviation and angular deviation. In this systematic review, only one randomized clinical trial (RCT) was included for qualitative analysis and, to minimize the risk of bias, the study was excluded from the metanalysis. Only 5 studies were included in the metanalysis (3 prospective and 2 retrospective studies), evidencing the lack of well designed RCT's that could provide reliable data to assess the accuracy of different types of surgical guides.

The studies by Cassetta and Bellardini (2017) (43) and Cassetta et al. (2020) (44) evaluated if the surgeon experience has an influence on the accuracy of the implant or if there is a learning curve with SGS. Both studies showed that there was no influence of experience on the accuracy and also there is no learning curve in this modality. Thus, this type of surgery is an excellent and resolutive alternative for inexperienced surgeons in challenging cases that require optimal tridimensional positioning of dental implants.

On the other hand, the study conducted by Stefanelli et al. (2019) (79) showed that the acquisition of experience with DGS influenced the positioning accuracy of the implants.

Author and Year	Country	Implant Manufacturer and number of implants placed	Planning Software	Software for accuracy analysis	Deviations			
					Coronal (SD, min - max) in mm	Apical (SD, min - max) in mm	Angular (SD, min - max) in degrees	Depth (SD, min - max) in mm
Aydemir et al., 2020[77]	Turkey	Southern Implants 43 implants	Navident (ClaroNav)	EvaluNav (ClaroNav)	1.01 (0.07, 0.41 - 2.00)	1.83 (0.12, 0.11 - 4.55)	5.59 (0.39, 2.06 - 10.18)	N/D
Block et al., 2017[78]	USA	N/D 219 implants	N/D	N/D	1.16 (0.59, N/D - N/D)	1.29 (0.65, N/D - N/D)	2.97 (2.09, N/D - N/D)	0.78 (0.60, N/D - N/D)
Kaewsiri et al., 2019[65]	Thailand	Straumann 30 implants	Iris-100 (EPED Inc)	Iris-100 (EPED Inc)	1.05 (0.44, 0.37 - 2.04)	1.29 (0.50, 0.61 - 2.31)	3.06 (1.37, 0.43 - 6.54)	N/D
Stefanelli et al., 2019[79]	Italy	N/D 231 implants	CAI Navident (ClaroNav)	EvaluNav (ClaroNav)	0.71 (0.40, N/D - N/D)	1.00 (0.49, N/D - N/D)	2.26 (1.62, N/D - N/D)	N/D
Stefanelli et al., 2020[80]	Italy	Osseotite (Zimmer Biomet) 136 implants	Navident (ClaroNav)	EvaluNav (ClaroNav)	0.67 (0.29, 0.11 - 1.45)	0.99 (0.33, 0.12 - 2.01)	2.50 (1.04, 0.35 - 5.81)	0.55 (0.25, 0.01 - 1.5)
Sun et al., 2020[73]	Taiwan	MaxFit (TITC Ltd) 32 implants	AQNavi (TITC Ltd)	Solidworks (Dassault Systems)	N/D	1.25 (0.09, N/D - N/D)	3.24 (0.36, N/D - N/D)	0.73 (0.13, N/D - N/D)
Testori et al., 2014[81]	Italy	N/D 117 implants	Simplant (Dentsply Sirona)	Geomagic Studio (Geomagic)	Tooth-mucosa-supported: 1.63 (0.98, N/D - N/D) Mucosa-supported: 1.12 (0.65, N/D - N/D) Bone-supported: 1.33 (0.47, N/D - N/D)	Tooth-mucosa-supported: 1.84 (1.00, N/D - N/D) Mucosa-supported: 1.36 (0.64, N/D - N/D) Bone-supported: 1.40 (0.43, N/D - N/D)	Tooth-mucosa-supported: 2.94 (1.84, N/D - N/D) Mucosa-supported: 4.06 (2.82, N/D - N/D) Bone-supported: 3.19 (1.95, N/D - N/D)	N/D

N/D - Not detailed

TABLE 4 Data regarding the deviations in DGS.

In this study, the first 50 implants installed by the surgeon had statistically significant higher mean deviations than the last 50 implants for all measures (entry point, apex and angular deviations).

Stefanelli et al. (2019) (79) highlighted that the up-front investment in equipment, training and the time needed to acquire experience in dynamic surgery are factors that may slow down the adoption of this technology. Kaewsiri et al. (2019) (65) compared the average surgical time between SGS and DGS and, although all the procedures were well tolerated by the patients, for all cases evaluated, the DGS took longer, besides needing an additional mean time of 3 min (2-5 min) for the registration procedure so that the device tracks the position of the drills in the CBCT. In cases involving guided bone regeneration, the mean time with SGS was 40 min (max 45 min). However, the same cases done with DGS took an average time of 48 min, reaching a maximum duration of 90 min. These factors may justify the small number of studies with this technology. Three out of the 7 studies with DGS included in this review had data extracted from private practices. The two studies with more implants installed were completely done in private offices (78,79). The lack of this type of equipment in academic settings may hampers the randomisation of patients and consequently the conduction of well designed studies.

In relation to the linear deviations, Behneke et al. (2012) (60) stated that the standard deviation (SD) and maximum values are important to determine a safety limit. A control margin is set at one to three times the SD. Based on their results, when taking into account the SD, the authors argued that a safety margin of 0,9 mm must be respected. When taking into account the maximum deviations found in their results, they suggested a margin of 1.4 mm. Tahmaseb et al. (2018) (36), based on the mean values of the results retrieved in their systematic review, suggested a safety margin of 2 mm to avoid damages to important anatomical structures. From all studies included in this review, only the mean apical deviation reported by De Oliveira et al. (2019) (46) presented values higher than 2 mm in the maxilla and in the mandible. The authors believe that the results on the contrary trend found in the literature were affected by the sample size. This study was conducted with mucosa-supported guides and presented a higher apical deviation in the maxilla, as well as the study by Vieira et al. (2013) (58) that showed higher mean deviation at the cervical and apical level of the implants in the upper arch. The authors argument that the less dense bone of the maxilla offers less resistance, making it easier to deviate while preparing the sites for implantation. However, the most recent systematic review published by Marlière et al. (2018) (83) evaluated the accuracy of dental implants inserted in SGS in fully edentulous patients and concluded that the highest angular deviations are obtained in the maxilla, but regarding the linear deviations (cervical and apical), the accuracy was higher in the mandible.

Although there are some deviations from the planned to the actual implant position, the magnitude of the divergences does not affect the rehabilitation of the patients if the prosthetic workflow is realized after implant installation. Nevertheless, in cases where the framework of the prosthesis is fabricated before implant placement, the deviations can make the rehabilitation impossible (58).

The number of studies retrieved for each modality of surgery might reflect the clinical daily necessity: after all, tooth-supported guides are used for simpler cases of small edentulous spaces, and most of these cases are solved with the traditional mental navigation (26,6).

CONCLUSIONS

As observed in this scoping review, the deviations between planned and actual implant positions showed in studies with SGS and DGS are within the clinical accepted limits and both modalities represent excellent alternatives for guided implant placement. Once deviations are expected and many factors play a role in the process from the planning to the surgery, a safety margin of 2 mm should be respected in relation to important anatomical structures. Better designed studies are necessary to investigate the weight of each factor leading to inaccuracies.

REFERENCES

1. Brennan DS, Spencer AJ, Roberts-Thomson KF. Tooth loss, chewing ability and quality of life. Qual Life Res 2008;17:227-235.
2. Hugo FN, Hilgert JB, da Luz Rosário de Sousa M, Cury JA. Oral status and its association with general quality of life in older independent-living south- Brazilians. Community Dent Oral Epidemiol 2009;37: 231–240.
3. Dannemand K, Øzhayat EB. Recognition of patient-reported impairment in oral aesthetics. J Oral Rehabil 2014;41:692-699.
4. Sukumar S, John MT, Schierz O, Aarabi G. Reissmann DR. Location of prosthodontic treatment and oral health-related quality of life - an exploratory study. J Prosthodont Res 2015;59:34-41.
5. Jamieson L, Brennan D, Peres M, Luzzi L, Miller C, Bowden J, McCaffery N. Having fewer than 21 teeth associated with poorer general health among South Australians. J Public Health Dent 2017;77:216-224.
6. Rosing K, Christensen LB, Øzhayat EB. Associations between tooth loss, prostheses and self-reported oral health, general health, socioeconomic position and satisfaction with life. J Oral Rehabil 2019;00:1-8.
7. Sanchez-Siles M, Ballester-Ferrandis JF, Salazar-Sanchez N, Gomez-Garcia FJ, Morajela-Ruiz R, Camacho-Alonso F. Long-term evaluation of quality of life and satisfaction between implant bar over dentures and conventional complete dentures: a 23 years retrospective study. Clin Implant Dent Relat Res 2017;00:1-7.
8. Coltro MPL, Ozkomur A, Villarinho EA, Teixeira ER, Vigo A, Shinkai RSA. Risk factor model of mechanical complications in implant-supported fixed complete dentures: A prospective cohort study. Clin Oral Impl Res 2018;00:1-7.
9. Ali Z, Baker SR, Shahrbaf S, Martin N, Vettore MV. Oral health-related quality of life after prosthodontic treatment for patients with partial edentulism: A systemic review and meta-analysis. J Prost Dent 2019;121:59-68.
10. ELsyad MA, Elgamal M, Mohammed Askar O, Youssef Al-Tonbary G. Patient satisfaction and oral health-related quality of life (OHRQoL) of conventional denture, fixed prosthesis and milled bar over denture for All-on-4 implant rehabilitation. A crossover study. Clin Oral Implants Res 2019;30(11):1107-1117.
11. Moraschini V, Velloso G, Luz D, Cavalcante DM, Barbosa E. Fixed rehabilitation of edentulous mandibles using 2 to 4 implants: A Systematic Review. Imp Dent 2016:25(3);435-444.
12. Testori T, Galli F, Fumagalli L, Capello M, Zuffetti F, Deflorian M, Parenti A, Del Fabbro M. Assessment of long-term survival of immediately loaded tilted implants supporting a maxillary full-arch fixed prosthesis. Int J Oral Maxillofac Implants 2017:32(4);904-911.
13. Ayub KV, Ayub EA, Lins do Valle A, Bonfante G, Pegoraro T, Fernando L. Seven-year follow-up of full arch prostheses supported by four implants: A prospective study. Int J Oral Maxillofac Implants 2017:32(6);1351.
14. Chrcanovic BR, Kisch J, Albrektsson T, Wennerberg A. A retrospective study on clinical and radiological outcomes of oral implants in patients followed up for a minimum of 20 years. Clin Implant Dent Relat Res 2018:20(2);199-207.
15. Feine J, Abou-Ayash S, Mardini MA, et al. Group 3 ITI Consensus Report: Patient- reported outcome measures associated with implant dentistry. Clin Oral Implant Res 2018;29(Suppl. 16):270-275.
16. Wittneben JG, Wismeijer D, Bragger U, Joda T, Abou-Ayash S. Patient-reported outcome measures focusing on aesthetics of implant- and

tooth-supported fixed dental prostheses: A systematic review and meta-analysis. Clin Oral Implant Res 262018;29(Suppl 16):224-240.
17. Yao CJ, Cao C, Bornstein MM, Mattheos N. Patient-reported outcome measures of edentulous patients restored with implant-supported removable and fixed prostheses: A systematic review. Clin Oral Implant Res 2018;29(Suppl 16): 241-254.
18. Tahmaseb A, Wismeijer D, Coucke W, Derksen W. Computer technology applications in surgical implant dentistry: A systematic review. Int J Oral Maxillofac Implants 2014:29;25-42.
19. Yafi AF, Camenish B, Al-Sabbagh M. Is digital guided implant surgery accurate and reliable? Dent Clin North Am 2019:63;381-397.
20. Chackartchi T, Romanos GE, Sculean A. Soft tissue-related complications and management around dental implants. Periodontol 2000 2019;81:124-138.
21. Chen ST, Darby IB, Reynolds EC. A prospective clinical study of non-submerged immediate implants: clinical outcomes and esthetic results. Clin Oral Implants Res 2007;18:552-562.
22. Evans CD, Chen ST. Esthetic outcomes of immediate implant placements. Clin Oral Implants Res 2008;19:73-80.
23. Chen ST, Darby IB, Reynolds EC, Clement JG. Immediate implant placement postextraction without flap elevation. J Periodontol 2009;80:163-172.
24. Tomasi C, Sanz M, Cecchinato D, Pjetursson B, Ferrus J, Lang NP, Lindhe J. Bone dimensional variations at implants placed in fresh extraction sockets: a multilevel multivariate analysis. Clin Oral Implants Res 2010;21(1):30-36.
25. Canullo L, Tallarico M, Radovanovic S, Delibasic B, Covani U, Rakic M. Distinguishing predictive profiles for patient-based risk assessment and diagnostics of plaque induced, surgicallyandprostheticallytriggeredperi-implantitis. Clin Oral Implants Res 2016;27:1243-1250.
26. Anitua E, Murias-Freijo A, Alkhraisat MH. Conservative implant removal for the analysis of the cause, removal torque, and surface treatment of failed nonmotile dental implants. J Oral Implants 2016;42:69-77.
27. Hammerle CHF, Tarnow D. The etiology of hard- and soft-tissue deficiencies at dental implants: a narrative review. J Clin Periodontol 2018;45(20):S267 - S277.
28. Rosenfeld AL, Mandelaris GA, Tradier PB. Prosthetically directed implant placement using computer software to ensure precise placement and predictable prosthetic outcomes. Part 2: rapid-prototype medical modelling and stereolithographic drilling guides requiring bone exposure. Int J Perio Rest Dent 2006:26;347-353.
29. Jung RE, Schneider D, Ganeles J, Wismeijer D, Zahlen M, Hammerle C, Tahmaseb A. Computer technology applications in surgical implant dentistry: a systematic review. Int J Oral Maxillofac Implants 2009:24;92-109.
30. Ganz SD. Three-dimensional imaging and guided surgery for dental implants. Dent Clin North Am 2015:59;265-290.
31. Tapie L, Lebon N, Mawussi B, Fron Chabouis H, Duret F, Attal JP. Understanding dental CAD/CAM for restorations - the digital workflow from a mechanical engineering view- point. Int J Comput Dent 2015:18;21-44.
32. Komiyama A, Klinge B, Hultin M. Treatment outcome of immediately loaded implants installed in edentulous jaws following computer-assisted virtual treatment planning and flawless surgery. Clin Oral Implants Res 2008:19;677-685.
33. Horwitz J, Zuabi O, Machtei EE. Accuracy of a computerized tomography-guided template-assisted placement system: An in vitro study. Clin Oral Implants Res 2009:20;1156-1162.
34. Raico-Gallardo YN, Silva-Olivio IRT, Mukai E, Morimoto S, Sesma N, Cordaro L. Accuracy comparison of guided surgery for dental implants according to the tissue of support: a systematic review and meta-analysis. Clin Oral Implants Res 2016;00:1-11.
35. Bover-Ramos F, Almunia JV, Ballester JC, Diago MP, Mira BG. Accuracy of implant placement with computer-guided surgery: A systematic review and meta-analysis comparing cadaver, clinical, and in vitro studies. Int J Oral Maxillofac Implants 2018:33;101-115.
36. Tahmaseb A, Wu V, Wismeijer D, Coucke W, Evans C. The accuracy of static computer- aided implant surgery: a systematic review and meta-analysis. Clin Oral Implants Res 2018:29(S16);416-435.
37. Albiero AM, Quartuccio L, Benato A, Benato R. Accuracy of computer-guided flapless implant surgery in fully edentulous arches and in edentulous arches with fresh extraction sockets. Implant Dent 2019;28(3):256-64.
38. Arisan V, Karabuda ZC, Ozdemir T. Accuracy of two stereolithographic guide systems forcomputer-aidedimplantplacement:acomputedtomography-basedclinical comparative study. J Periodontol 2010;81(1):43-51.
39. Cassetta M, Pompa G, Di Carlo S, Piccoli L, Pacifici A, Pacifici L. The influence of smoking and surgical technique on the accuracy of mucosa-supported stereolithographic surgical guide in complete edentulous upper jaws. Eur Rev Med Pharmacol Sci 2012;16(11):1546-53.
40. Cassetta M, Stefanelli LV, Giansanti M, Di Mambro A, Calasso S. Accuracy of a computer-aided implant surgical technique. Int J Periodontics Restorative Dent 2013;33(3):317-25.
41. Cassetta M, Giansanti M, Di Mambro A, Stefanelli LV. Accuracy of positioning of implants inserted using a mucosa-supported stereolithographic surgical guide in the edentulous maxilla and mandible. Int J Oral Maxillofac Implants 2014;29(5):1071-8.
42. Cassetta M, Di Mambro A, Giansanti M, Stefanelli LV, Barbato E. How does an error in positioning the template affect the accuracy of implants inserted using a single fixed mucosa-supported stereolithographic surgical guide? Int J Oral Maxillofac Surg 2014;43(1):85-92.
43. Cassetta M, Bellardini M. How much does experience in guided implant surgery play a role in accuracy? A randomized controlled pilot study. Int J Oral Maxillofac Surg 2017;46(7):922-30.
44. Cassetta M, Altieri F, Giansanti M, Bellardini M, Brandetti G, Piccoli L. Is there a learning curve in static computer-assisted implant surgery? A prospective clinical study. Int J Oral Maxillofac Surg 2020.
45. D'Haese J, Van De Velde T, Elaut L, De Bruyn H. A prospective study on the accuracy of mucosally supported stereolithographic surgical guides in fully edentulous maxillae. Clin Implant Dent Relat Res 2012;14(2):293-303.
46. de Oliveira G, de Souza Mattos W, Albaricci M, Marcantonio É, Queiroz TP, Margonar R. Analysis of linear and angular deviations of implants installed with a tomographic-guided surgery technique: A prospective cohort study. J Oral Implantol 2019;45(4):281-7.
47. Di Giacomo GA, da Silva JV, da Silva AM, Paschoal GH, Cury PR, Szarf G. Accuracy and complications of computer-designed selective laser sintering surgical guides for flapless dental implant placement and immediate definitive prosthesis installation. J Periodontol 2012;83(4):410-9.
48. Ochi M, Kanazawa M, Sato D, Kasugai S, Hirano S, Minakuchi S. Factors affecting accuracy of implant placement with mucosa-supported stereolithographic surgical guides in edentulous mandibles. Comput Biol Med 2013;43(11):1653-60.
49. Ozan O, Turkyilmaz I, Ersoy AE, McGlumphy EA, Rosenstiel SF. Clinical accuracy of 3 different types of computed tomography-derived stereolithographic surgical guides in implant placement. J Oral Maxillofac Surg 2009;67(2):394-401.
50. Pettersson A, Komiyama A, Hultin M, Näsström K, Klinge B. Accuracy of virtually planned and template guided implant surgery on edentate patients. Clin Implant Dent Relat Res 2012;14(4):527-37.
51. Sun Y, Luebbers HT, Agbaje JO, Schepers S, Politis C, Van Slycke S, et al. Accuracy of dental implant placement using cbct-derived mucosa-supported stereolithographic template. Clin Implant Dent Relat Res 2015;17(5):862-70.
52. Van de Wiele G, Teughels W, Vercruyssen M, Coucke W, Temmerman A, Quirynen M. The accuracy of guided surgery via mucosa-supported stereolithographic surgical templates in the hands of surgeons with little experience. Clin Oral Implants Res 2015;26(12):1489-94.
53. Vercruyssen M, Cox C, Coucke W, Naert I, Jacobs R, Quirynen M. A

randomized clinical trial comparing guided implant surgery (bone- or mucosa-supported) with mental navigation or the use of a pilot-drill template. J Clin Periodontol 2014;41(7):717-23.
54. Vercruyssen M, Coucke W, Naert I, Jacobs R, Teughels W, Quirynen M. Depth and lateral deviations in guided implant surgery: an RCT comparing guided surgery with mental navigation or the use of a pilot-drill template. Clin Oral Implants Res 2015;26(11):1315-20.
55. Verhamme LM, Meijer GJ, Boumans T, Schutyser F, Bergé SJ, Maal TJ. A clinically relevant validation method for implant placement after virtual planning. Clin Oral Implants Res 2013;24(11):1265-72.
56. Verhamme LM, Meijer GJ, Bergé SJ, Soehardi RA, Xi T, de Haan AF, et al. An accuracy study of computer-planned implant placement in the augmented maxilla using mucosa-supported surgical templates. Clin Implant Dent Relat Res 2015;17(6):1154- 63.
57. Verhamme LM, Meijer GJ, Boumans T, de Haan AF, Bergé SJ, Maal TJ. A clinically relevant accuracy study of computer-planned implant placement in the edentulous maxilla using mucosa-supported surgical templates. Clin Implant Dent Relat Res 2015;17(2):343-52.
58. Vieira DM, Sotto-Maior BS, Barros CA, Reis ES, Francischone CE. Clinical accuracy of flapless computer-guided surgery for implant placement in edentulous arches. Int J Oral Maxillofac Implants 2013;28(5):1347-51.
59. Alzoubi F, Massoomi N, Nattestad A. Accuracy assessment of immediate and delayed implant placements using CAD/CAM surgical guides. J Oral Implantol 2016;42(5):391- 8.
60. Behneke A, Burwinkel M, Knierim K, Behneke N. Accuracy assessment of cone beam computedtomography-derivedlaboratory-basedsurgicaltemplatesonpartially edentulous patients. Clin Oral Implants Res 2012;23(2):137-43.
61. Chang RJ, Chen HL, Huang LG, Wong YK. Accuracy of implant placement with a computer-aided fabricated surgical template with guided parallel pins: A pilot study. J Chin Med Assoc 2018;81(11):970-6.
62. Derksen W, Wismeijer D, Flügge T, Hassan B, Tahmaseb A. The accuracy of computer-guided implant surgery with tooth-supported, digitally designed drill guides based on CBCT and intraoral scanning. A prospective cohort study. Clin Oral Implants Res 2019;30(10):1005-15.
63. Fang Y, An X, Jeong SM, Choi BH. Accuracy of computer-guided implant placement in anterior regions. J Prosthet Dent 2019;121(5):836-42.
64. Fürhauser R, Mailath-Pokorny G, Haas R, Busenlechner D, Watzek G, Pommer B. Esthetics of flapless single-tooth implants in the anterior maxilla using guided surgery: association of three-dimensional accuracy and pink esthetic score. Clin Implant Dent Relat Res 2015;17 Suppl 2:e427-33.
65. Kaewsiri D, Panmekiate S, Subbalekha K, Mattheos N, Pimkhaokham A. The accuracy of static vs. dynamic computer-assisted implant surgery in single tooth space: A randomized controlled trial. Clin Oral Implants Res 2019;30(6):505-14.
66. Kiatkroekkrai P, Takolpuckdee C, Subbalekha K, Mattheos N, Pimkhaokham A. Accuracy of implant position when placed using static computer-assisted implant surgical guides manufactured with two different optical scanning techniques: a randomized clinical trial. Int J Oral Maxillofac Surg 2020;49(3):377-83.
67. Lin CC, Wu CZ, Huang MS, Huang CF, Cheng HC, Wang DP. Fully digital workflow for planning static guided implant surgery: A prospective accuracy study. J Clin Med 2020;9(4).
68. Nickenig HJ, Wichmann M, Hamel J, Schlegel KA, Eitner S. Evaluation of the difference in accuracy between implant placement by virtual planning data and surgical guide templates versus the conventional free-hand method - a combined in vivo - in vitro technique using cone-beam CT (Part II). J Craniomaxillofac Surg 2010;38(7):488-93.
69. Schnutenhaus S, Edelmann C, Rudolph H, Dreyhaupt J, Luthardt RG. 3D accuracy of implant positions in template-guided implant placement as a function of the remaining teeth and the surgical procedure: a retrospective study. Clin Oral Investig 2018;22(6):2363-72.
70. Skjerven H, Olsen-Bergem H, Rønold HJ, Riis UH, Ellingsen JE. Comparison of postoperative intraoral scan versus cone beam computerised tomography to measure accuracy of guided implant placement-A prospective clinical study. Clin Oral Implants Res 2019;30(6):531-41.
71. Skjerven H, Riis UH, Herlofsson BB, Ellingsen JE. In Vivo accuracy of implant placement using a full digital planning modality and stereolithographic guides. Int J Oral Maxillofac Implants 2019;34(1):124-32.
72. Smitkarn P, Subbalekha K, Mattheos N, Pimkhaokham A. The accuracy of single-tooth implants placed using fully digital-guided surgery and freehand implant surgery. J Clin Periodontol 2019;46(9):949-57.
73. Sun TM, Lee HE, Lan TH. Comparing Accuracy of implant installation with a navigation system (NS), a laboratory guide (LG), NS with LG, and freehand drilling. Int J Environ Res Public Health 2020;17(6).
74. Varga E, Jr., Antal M, Major L, Kiscsatári R, Braunitzer G, Piffkó J. Guidance means accuracy: A randomized clinical trial on freehand versus guided dental implantation. Clin Oral Implants Res 2020;31(5):417-30.
75. Younes F, Cosyn J, De Bruyckere T, Cleymaet R, Bouckaert E, Eghbali A. A randomized controlled study on the accuracy of free-handed, pilot-drill guided and fully guided implant surgery in partially edentulous patients. J Clin Periodontol 2018;45(6):721-32.
76. Stübinger S, Buitrago-Tellez C, Cantelmi G. Deviations between placed and planned implant positions: an accuracy pilot study of skeletally supported stereolithographic surgical templates. Clin Implant Dent Relat Res 2014;16(4):540-51.
77. Aydemir CA, Arısan V. Accuracy of dental implant placement via dynamic navigation or the freehand method: A split-mouth randomized controlled clinical trial. Clin Oral Implants Res 2020;31(3):255-63.
78. Block MS, Emery RW, Cullum DR, Sheikh A. Implant placement is more accurate using dynamic navigation. J Oral Maxillofac Surg 2017;75(7):1377-86.
79. Stefanelli LV, DeGroot BS, Lipton DI, Mandelaris GA. Accuracy of a dynamic dental implant navigation system in a private practice. Int J Oral Maxillofac Implants 2019;34(1):205–13.
80. Stefanelli LV, Mandelaris GA, DeGroot BS, Gambarini G, De Angelis F, Di Carlo S. Accuracy of a novel trace-registration method for dynamic navigation surgery. Int J Periodontics Restorative Dent 2020;40(3):427-35.
81. Testori T, Robiony M, Parenti A, Luongo G, Rosenfeld AL, Ganz SD, et al. Evaluation of accuracy and precision of a new guided surgery system: a multicenter clinical study. Int J Periodontics Restorative Dent 2014;34 Suppl 3:s59-69.
82. Seo C, Juodzbalys G. Accuracy of guided surgery via stereolithographic mucosa- supported surgical guide in implant surgery for edentulous patient: a systematic review. J Oral Maxillofac Res 2018;9(1):e1.
83. Marlière DAA, Demètrio MS, Picinini LS, Oliveira RG, Netto H. Accuracy of computer-guided surgery for dental implant placement in fully edentulous patients: A systematic review. Eur J Dent 2018;12(1):153-60.