

## Systematic Review

# Navigation in oral surgery: a systematic review

Alexis Oillic<sup>\*</sup>, Andrea Varazzani, Benjamin Fitouchi, Adelaide Carlier, Pierre Bouletreau

Department of Maxillofacial and Facial Plastic Surgery, Lyon Sud Hospital, Hospices Civils de Lyon, 165 Chemin du Grand Revoyet, 69495 Pierre-Bénite, Lyon, France

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/ oral surgery /  
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**Abstract – Introduction:** Dynamic navigation is a fast-growing technology in the field of head and neck surgery, which is now taking its place in oral surgery. The aim of this review was to present and describe all the uses of navigation in oral surgery. **Materials and methods:** A systematic review was conducted using all clinical trial/cases reports (Embase/PubMed) in which navigation is used during oral surgery, published over the last 5 yr. A total of 32 clinical trial/cases reports were analyzed. **Results:** Dynamic navigation was used in 7 different indications: implantology (55%), foreign body removal (15%), dental avulsion (12%), bone augmentation (9%), cellulitis (3%), benign tumour (3%), pre-prosthetic surgery (3%). A total of 335 patients were treated, 631 implants, 8 foreign bodies, 1 benign tumour, 24 dental avulsions, 3 bone augmentations, 1 cellulitis, and 1 pre-prosthetic surgery were found. In implantology, there were 500 standard implants, 75 zygomatic implants, 31 pterygoid implants, 1 short implant and 24 angulated implants. **Conclusion:** This review showed the recent development of dynamic navigation in oral surgery. The most common indication is dental implantology and few others indications seemed promising. This technique broadened its scope and might become an indispensable tool that can be used in many situations, increasing safety and predictability of a lot of procedure.

## Introduction

The advent of digital technology made virtual surgical planning (VSP) an everyday tool. Surgical planning software are a powerful diagnostic tool, they allow the anticipation of potential problems and facilitate communication with patients and colleagues. It is thus possible to perform the surgery almost completely in advance, without the patient, on planning software such as BlueSkyPlan<sup>®</sup>, CoDiagnostix<sup>®</sup>, DTX<sup>®</sup>, ProPlan<sup>®</sup> etc. Once the planning is validated by the operator and the patient, it remains a challenge to transfer the VSP to the operating room (OR). Several methods already exist, such as the design of computer-assisted static guides that can be 3D printed, through protocols commonly called CAD/CAM (computer assisted-design/computer assisted-manufactured). These techniques are widely documented in the literature and have multiple indications, well-described accuracy, known advantages and shortcomings [1]. This work will focus on surgical navigation, a dynamic guidance method that appeared in the field about 20 yr ago; and will try to understand its applications and its place in the field. In oral surgery, the accuracy of surgical navigation is most often assessed in implantology and it is compared with freehand implant surgery and statically guided implant surgery. The recently published

review by Parra-Tressera *et al.* 2021 [2] showed a better accuracy of navigation on implant placement compared to the freehand technique and a similar accuracy to static guides [3,4].

However, the literature is limited, most of the reviews focus on single implantology case, due a lack of scientific data [2,5]. A systematic review was conducted of the last 5 yr, with the aim of overlooking the different applications available in oral surgery. This review described all the indications, results and calibration techniques of oral surgery that used navigation. The hypothesis is that the recent development of dynamic navigation in oral surgery broadened its scope and is becoming an indispensable tool that can be used in different indications.

## Materials and methods

### Search strategy and eligibility criteria

Were searched, all studies, about patient who underwent an oral surgical procedure, using a dynamic navigation, published between April 2017 and May 2022.

The databases **MedLine by Pubmed** and **Embase** were investigated at two periods of time, with a 4 months interval (April and July 2022). The searched terms were: “navigation”, “jaw”, “mandibular”, and “maxilla”, “zygomatic implant”, “pterygoid implant”, “dental implant”, “tooth extraction”, “foreign body”, “orthodontics”. The PubMed equations were:

\* Correspondence: [alexis.oillic@gmail.com](mailto:alexis.oillic@gmail.com)

**Table I.** Inclusion/Exclusion criteria.

Inclusion criteria	Exclusion criteria
In vivo study Study less than 5 yr old Article on dynamic navigation in oral surgery English or French language	Animal study <i>In vitro</i> study Article that does not mention navigation Article about static guides Article not related to oral surgery Article about virtual planning only Otorhinolaryngology and maxillofacial surgery

**Table II.** Evaluation criteria.

Primary evaluation criteria	Secondary evaluation criteria
Indications Navigation system used Types of patient reflectors used Calibration method Results of the surgeries	Associated imaging type Type of anaesthesia Duration of the intervention Follow-up Complication Accuracy Complementary technique to navigation

(navigation AND zygomatic implant) OR (navigation AND pterygoid implant) OR (Navigation AND dental implant) OR (navigation AND tooth extraction) OR (navigation AND foreign body) OR (navigation AND jaw) OR (navigation AND mandibular) OR (navigation AND maxilla) OR (navigation AND orthodontics) AND ((y\_5 [Filter]) AND (casereports [Filter] OR clinicalstudy [Filter] OR clinicaltrial [Filter] OR comparativestudy [Filter] OR controlledclinicaltrial [Filter])).

### Study design and literature screening

The data were compared using the Population, Intervention, Comparison, Outcomes (PICO) criteria, were kept only articles about patients/population in need of an oral procedure, dynamic navigation was used each time, controlled or not and with results properly described.

The records and data were collected by a single reviewer. The selection criteria, the primary and secondary outcomes were described in [Tables I](#) and [II](#).

The surgical indications were categorized according to the initial diagnosis and the treatment received; their distribution were expressed as percentages. The navigation systems used were also expressed as percentages; when it was not specified in the study, it was expressed in the final calculation as not reported (NR) The results of the surgeries were reported according to the initial surgical indication. The reflector used were classified according to their support (bone, dental, skin...) and whether they were invasive or not. The calibration methods were classified according to the types of fiducial markers (invasive or not).

Only the imaging used for real time navigation were collected; the imaging related to the diagnosis were not. The accuracy was related to implantology, it was described by 4 parameters: the coronal deviation (millimeters, mm), the apical deviation (mm), the angular deviation (degrees °), and the depth deviation (mm), missing data were not reported. The duration of the surgeries were compared according to the surgical indication; missing data were reported as NR.

### Data extraction and method of analysis

The search was run in 4 phases and is documented in the flowchart presented in [Figure 1](#).

#### Identification phase

The total numbers of recorded extracted articles was 166. Sixteen duplicated articles were eliminated.

#### Screening phase

The abstracts of the remaining 150 articles were examined based on our review questions and 112 articles were excluded. Only 38 articles remained.

#### Eligibility phase

After full text reading, 6 articles were excluded due to the confusion of some authors between "computer navigation" and "computer-guided (static guidance)", or because they were comparative studies of dynamic navigation *versus* static guides.

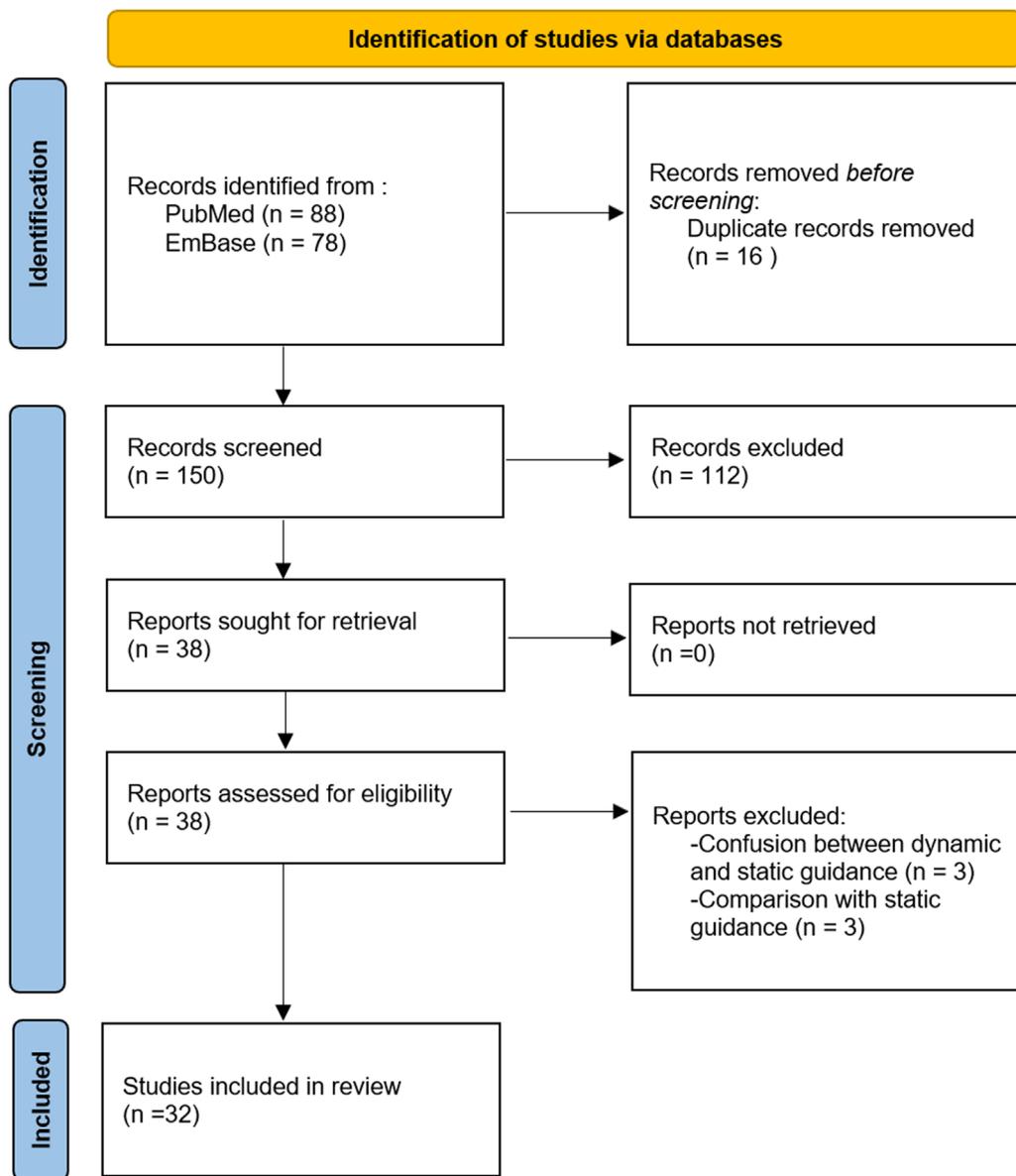


Fig. 1. Flowchart.

**Inclusion phase**

The remaining 32 articles were included, and analyzed by the reviewer. Those articles represent a total of 335 patients who had undergone oral surgery in the past 5 yr.

**Level of evidence and bias assessment**

The level of evidence for each article selected was determined based on the concept outlined by the Oxford Centre for Evidence-Based Medicine (CEBM).

Revised Cochrane risk-of-bias tool for randomized trials (RoB 2) [6] was used for the assessment of quality of randomized clinical trials (RCTs) and the Risk of Bias in Non-randomized Studies of Interventions (ROBINS-I) instrument [7] was used for non-randomized controlled trials (NRCTs).

**Results**

The type of the included studies, their characteristics and their level of evidence are presented in Table III.

Risk of bias ranged from low to high with a high risk for the vast majority of included studies, especially concerning bias due to confounding or deviations from intended interventions. Detailed results of risk of bias assessment are presented in Tables IV–VI. This high risk of bias illustrate the versatility of the studies and could be a limitation of this current review.

A total of 7 main surgery indications were find regarding the use of navigation in oral surgery (Fig. 2).

The characteristics of the surgeries performed on the 335 patients are presented in Table VII.

No meta-analysis was performed because most of the data came from cases reports.



**Table III.** (continued).

Authors (Years)	Study	Level of evidence	Diagnostics	Treatment (*under navigation)	System	Reflector	Calibration	Patient	Results
Jain, Zolanky et al. (2021) [30]	CC	4	Alveolar cleft	Iliac graft + gingivoperioplasty	Accu-Navi	Non-invasive	Non-invasive	3	75% of residual bone volume at 3 months
Zhang et al. (2021) [31]	RCS	2b	Mixed edentulism	Single or plural implants (SI)	Navident	Mixed	Mixed: Radiological	89	231 SI: Deviations 0.71/1.00/2.21°/NR
Stefanelli et al. (2019) [32]	CC	4	Single edentulism	Single implant (augmented-reality)	ImplanNav	Non-invasive	Non-invasive	2	2 SI : Deviations 0.52/0.47/2.62°/0.32
Pellegrino et al. (2019) [33]	RCS	2b	Terminal teeth	All on X	DHC-DI2	Non-invasive	Invasive: Radiological	12	24 SI + 24 AI
Meng, Zangh et al. (2021) [34]	CC	4	Supernumerary teeth	Avulsion of impacted teeth	NR (Brain Lab)	Non-invasive	Non-invasive	1	Successful avulsions, NC
Wang et al. (2017) [35]	CC	4	Mandibular KOC	Enucleation of the cyst	NR	NR	NR	1	Successful enucleation, NC, no recurrence
Hong et al. (2019) [36]	CC	4	Intraosseous FB	Ablation by intra-oral approach	StealthStation	Non-invasive	Non-invasive	1	Successful removal, NC
Sukegawa et al. (2019) [37]	RCT	1b	Partial edentulism	Placement of SI	Navident	Non-invasive	Non-invasive	30	43 SI, better accuracy than control
Aydemir et al. (2020) [38]	RCT	1b	NCT	Extraction-implantation	DCarer	Non-invasive	Non-invasive	20	20 SI, no difference between two type of implants
Wei et al. (2022) [39]	RCT	1b	NCT	Extraction-implantation	DCarer	Non-invasive	Non-invasive	20	20 SI, no difference between two type of implants

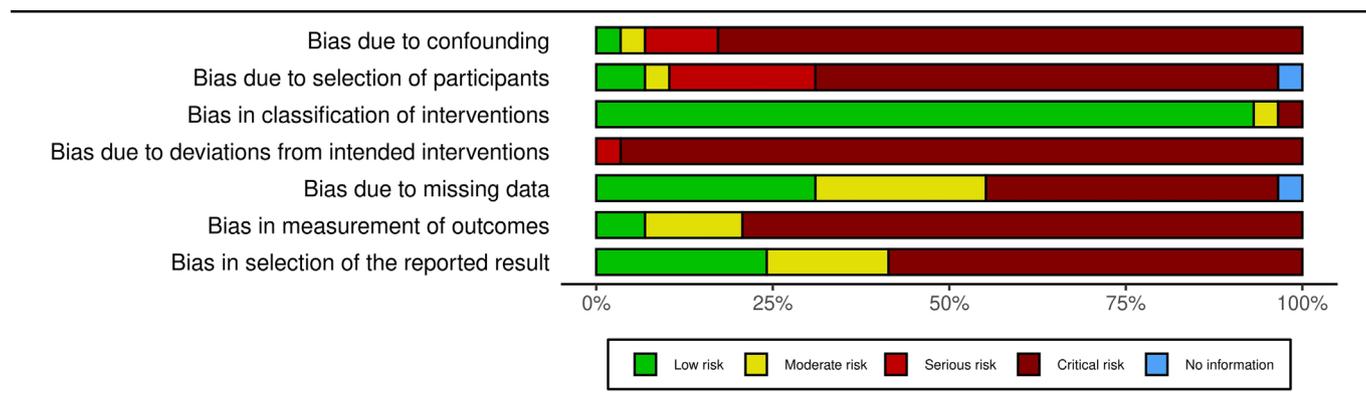
**Table IV.** Quality assessment of each included study using the Cochrane ROBINS-I (Non randomised studies).

Study	Risk of bias domains						
	D1	D2	D3	D4	D5	D6	D7
Pellegrino <i>et al</i> (2021) [8]	!	X	+	!	+	!	-
Lopes <i>et al</i> (2020) [10]	!	X	+	!	-	!	!
Pellegrino <i>et al</i> (2018) [11]	!	X	+	!	!	!	!
Tso <i>et al</i> (2018) [12]	!	!	+	!	-	!	!
Wang <i>et al</i> (2017) [13]	!	X	+	!	?	!	!
Zhou <i>et al</i> (2020) [14]	!	!	+	!	+	-	+
Stefanelli <i>et al</i> (2020) [15]	X	-	+	!	+	+	+
Wang <i>et al</i> (2021) [16]	!	!	+	!	+	-	+
Magic <i>et al</i> (2021) [17]	!	!	+	!	!	-	-
Pozzi <i>et al</i> (2021) [18]	-	+	+	X	+	+	+
Pellegrino <i>et al</i> (2018) [19]	!	?	+	!	+	!	!
Pellegrino <i>et al</i> (2017) [20]	!	!	+	!	!	!	!
Wang <i>et al</i> (2018) [21]	!	!	+	!	!	!	!
Sato <i>et al</i> (2018) [22]	!	!	+	!	-	!	!
Zhang <i>et al</i> (2020) [23]	!	!	-	!	-	!	!
Chen <i>et al</i> (2020) [24]	!	!	+	!	+	!	!
Bensing <i>et al</i> (2020) [25]	!	!	+	!	!	!	!
Han <i>et al</i> (2019) [26]	!	!	+	!	+	!	!
Wang <i>et al</i> (2021) [27]	+	+	+	!	+	!	+
Pellegrino <i>et al</i> (2021) [28]	!	!	+	!	-	!	-
Felice <i>et al</i> (2021) [29]	!	!	+	!	!	!	!
Jain, Zolanky <i>et al</i> (2021) [30]	!	!	+	!	-	!	!
Zhang <i>et al</i> (2021) [31]	!	!	+	!	-	!	-
Stefanelli <i>et al</i> (2019) [32]	X	X	+	!	!	!	+
Pellegrino <i>et al</i> (2019) [33]	!	!	+	!	!	!	+
Meng, Zangh <i>et al</i> (2021) [34]	X	X	+	!	!	-	-
Wang <i>et al</i> (2017) [35]	!	!	+	!	!	!	!
Hong <i>et al</i> (2019) [36]	!	!	!	!	!	!	!
Sukegawa <i>et al</i> (2019) [37]	!	!	+	!	!	!	!

Domains:  
D1: Bias due to confounding.  
D2: Bias due to selection of participants.  
D3: Bias in classification of interventions.  
D4: Bias due to deviations from intended interventions.  
D5: Bias due to missing data.  
D6: Bias in measurement of outcomes.  
D7: Bias in selection of the reported result.

Judgement  
! Critical  
X Serious  
- Moderate  
+ Low  
? No information

**Table V.** Risk of bias summary for the included studies using the Cochrane ROBINS-I.



**Table VI.** Risk of bias assessment for the included studies using the Cochrane Risk of Bias Tool 2 (Randomized studies).

Study	Risk of bias domains				
	D1	D2	D3	D4	D5
Stefanelli <i>et al</i> (2019) [9]	+	+	-	+	+
Aydemir <i>et al</i> (2020) [38]	-	-	+	?	+
Wei <i>et al</i> (2022) [39]	+	+	+	+	+

Domains:  
 D1: Bias arising from the randomization process.  
 D2: Bias due to deviations from intended intervention.  
 D3: Bias due to missing outcome data.  
 D4: Bias in measurement of the outcome.  
 D5: Bias in selection of the reported result.

Judgement  
 - Some concerns  
 + Low  
 ? No information

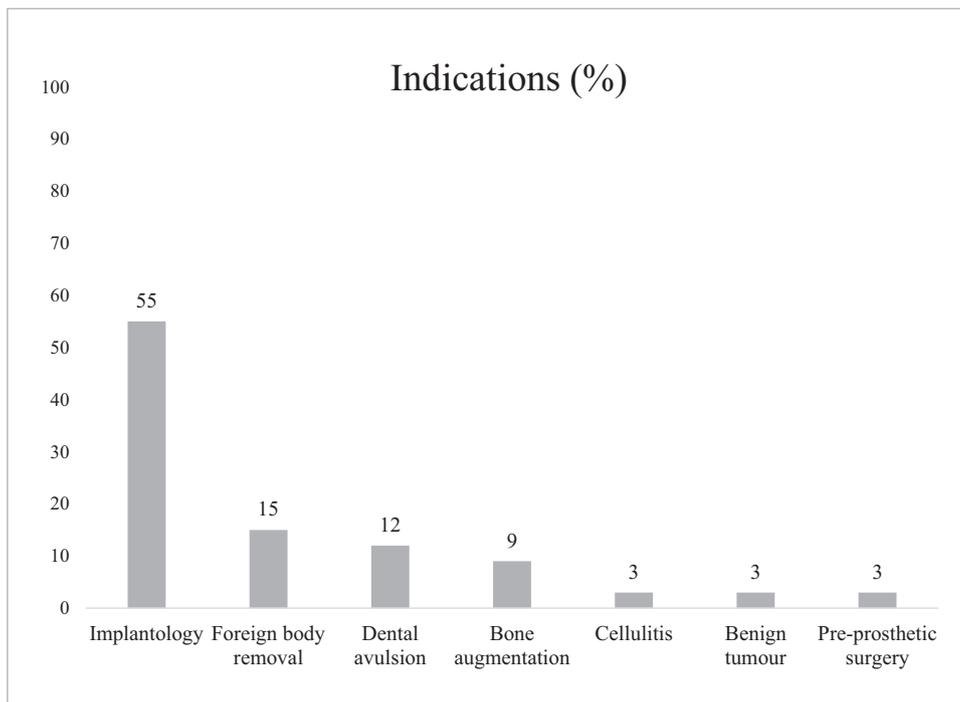
**Primary evaluation criteria**

**Indications, outcomes**

**Implantology**

This review showed that the use of navigation in implantology is prominent, representing 19 articles (55%). A total of 631 implants were placed; short implant [8], pterygoid implant [9] and zygomatic implants [10–14]. The indications were varied; rehabilitation of the edentulous jaw using immediate implant loading with fixed prosthesis, extraction-implantation, single implant in aesthetic zone [10,11,15–17], single implant with immediate loading in aesthetic zone [18] or the placement of standard minimally invasive implants (flapless) [19]. This review also found that navigation was used in the rehabilitation of carcinological sequelae by zygomatic implants (epithesis or maxillofacial prosthesis) [12,14]. The authors displayed a wide variety of techniques, which allowed for less invasive approaches in

potentially irradiated patients, at risk of osteoradionecrosis [12,14]. Pellegrino *et al.* [11] described a technique comparable to a first drill guide for zygomatic implants, where a piezotome was used with a diamond insert that allowed a pre-drilling on the alveolar ridge and the zygomatic bone, without sliding on the bone surfaces. This technique allowed the passage of the drill and the implant in a non-guided way, avoiding a potential significant angular deviation on a 30 to 50 mm long implant. Pellegrino *et al.* [20] also described a technique where navigation permitted to prepare the site of implantation using a piezotome to perform a selective osteotomy, allowing the preparation of the different bone zones (cortical and trabecular bone). A benefit of navigation described by Stefanelli *et al.* [9] on pterygoid implant placement was that no loss of tactile sensation occurred during the drilling (in comparison with static guide). This is very valuable on implants of this type due to the low bone marrow density of the tuberosity.



**Fig. 2.** Distribution of indications found in oral surgery.

**Table VII.** Outcomes of the interventions.

<b>Implantology</b>	Standard implant	Zygomatic implant	Pterygoid implant	Short implant	Angled implnat	<b>Total</b>
Number	500	75	31	1	24	631
<b>Foreign bodies(location)</b>	Intra simus	Lingual floor	Pterygoid fossa			<b>Total</b>
Number	3	2	3			8
<b>Bengin tumours</b>	Odontogenic keratocyst					<b>Total</b>
Number	1					1
<b>Dental avulsion</b>	Mandibular wisdom teeth	Mesiodens				<b>Total</b>
Nubmer	6	18				24
<b>Reconstructions</b>	liac graft	Segmental rotation ostation osteotomy	Sinus lift (summers technique)			<b>Total</b>
Number	1	1	1			3
<b>Cellulitis</b>	Pterygomandibular cellulitis					<b>Total</b>
Number	1					1
<b>Pre-prosthetic surgery</b>	Bone resection					<b>Total</b>
Nubmer	1					1

**Foreign body removal**

This review found 5 studies (15%) using navigation in foreign body removal [13,22–24,37]. Two studies [23,25] described a technique that used resin mouthpieces, incorporated with radiological fiducial markers (for calibration), to

allow mandibular blocking with the aim to limit anatomical differences related to mandibular dynamics, during surgery and imaging (muscular or cellulosic tissues causing migrations). On anatomical areas that are complex to access, some authors recommended to use endoscopes associated with navigation, to perform minimally invasive approaches.

**Table VIII.** Systems of navigation.

Different systems	Distributions
Vector vision 2(Brain Lab)	5
Kick (Brain Lab)	1
Curve (Brain Lab)	1
NR (Brain Lab)	2
ImplaNav (Bresmedical)	6
Navident (ClaroNav)	5
Dcarer (Medical Technology Co)	1
AccuNavi (UEG medical)	3
StealthStation S7(Medtronic)	2
DHC-DI2(Suzhou Digital-health care Co)	1
Scopis Hybrid Navigation system (Mega medical corporation)	1
X-guide (X-Nav)	2
NR	2
Total	32

### Dental avulsion

A total of 4 articles (12%) of the reviewed studies were about navigation in the dental avulsion indication. When using navigation, Wang *et al.* [27] found no difference in their controlled preclinical study regarding avulsion of supernumerary teeth on operative time, unnecessary bone trauma, and position of supernumerary teeth. Pellegrino *et al.* [28] described a technique for the avulsion of impacted mandibular wisdom teeth without a flap (flapless); no postoperative painkiller was required.

### Bone augmentation

The literature on bone augmentation associated with navigation is very limited. No clinical trial was found, only 3 case reports (9%). In one case, navigation was used for segmental rotation osteotomies [29]; the aim was to limit the damage of the inferior alveolar nerve. For that indication, the use of a system that integrates the piezotome was mandatory. Another case was a sinus augmentation with crestal approach (Summers technique) using Densah® drills that was performed using navigation [30]. The third case was the use of navigation to delineate graft areas and facilitate anatomical recognition to manage an alveolar cleft [31].

### Cellulitis

The navigation was used by Han *et al.* [26] in abscess drainage (after 2 failures of conventional abscess drainage) on patient with deep abscess in the pterygomandibular space.

### Benign tumours

Hong YP *et al.* [36] justified the use of navigation in surgical enucleation to get a safer surgery and to have a more complete curettage, especially with keratinized odontogenic

cyst (KOC), which has a high recurrence rate. They described no recurrence within 2 yr follow-up.

### Pre-prosthetic surgery

Magic *et al.* [17] used navigation to perform a bone reduction; the location of the reduction was decided according to a virtual wax-up and the smile line position.

### Navigation systems

All the surgeries were performed using 12 systems, listed in Table VIII. The BrainLab© brand is the most used (30%).

### Calibration technique and nature of reflector

The patient reflector was non-invasive in 20 articles (62.5%), invasive in 7 articles (21.9%), both (mixed) in 3 articles (9.4%) and not indicated in 2 articles (6.2%). In the non-invasive reflectors and mixed (23 articles), the brackets were dental supported in 11 articles (47.8%), 9 were skin supported (39.1%) and 3 were implant anchored (13.1%). The implant supports were categorized as non-invasive because they were freehand implants that were an integral part of the treatment plan. All invasive reflectors are bone anchored (100%). Calibration was performed using fiducial markers that were non-invasive in 21 articles (65.6%), invasive in 6 articles (18.8%), mixed in 2 articles (6.2%), and NR in 3 articles (9.4%). Fiducial markers were radiological in 22 articles (68.7%) and anatomical in 7 articles (21.9%).

Some authors used extra oral bone anchorage (parietal bone, mastoid, zygomatic arch, supraorbital) to fix the fiducial markers in the edentulous and did not describe any complication [12,15].

### Secondary primary evaluation

#### Duration of surgery

In implantology, only 3 articles mentioned the duration of surgery. Meng *et al.* [34] described an average time of 81.9 min for placement of 4–6 maxillary implants with a relatively long calibration of 10–15 min. Stefanelli *et al.* [9] found a significant difference in surgical time for pterygoid implant placement compared to the control group, with an average of 9.3 min with the navigated technique *versus* 22.1 min freehand. Pellegrino *et al.* [35] reported an average surgical time of 33 min for standard implant placement with augmented reality headset. For foreign body removal, abscess drainage, 5 articles mentioned [21,22,24,–26] the duration of surgery, ranging from 33 min to 1 h and 55 min. Zhang *et al.* [23] reported that the duration of surgery was non-extended when navigation was used. For avulsions of impacted teeth, 2 articles [27,35] reported the duration of surgery, ranging from 10.7 min to 30 min. Pellegrino *et al.* [27] described surgical times of less than 20 min for the avulsion of 2 third mandibular lower molars.

**Table IX.** Accuracy of navigation in implantology [coronal deviation (mm), apical deviation (mm), angular deviation (°) and depth deviation (mm)].

	Dynamic navigation	Free-hand
Stefanelli <i>et al.</i>	0.66 mm/1.13 mm/2.64°/0.64 mm	1.54 mm/2.73 mm/12,49°/1.17 mm
Aydemir <i>et al.</i>	1.01 mm/1.83 mm/5.59°/NR	1, 70 mm/2, 51 mm/10, 01°/NR

On a serie of cases, Pellegrino *et al.* [33] described a potential time saving when using augmented reality headset associated with navigation, but further studies would be warranted to confirm this hypothesis.

### Imaging

The imaging systems used in the studies for dynamic navigation are Cone Beam Computed-Tomography (CBCT), 87.5%, and Computer tomography (CT) scan, 12.5%.

### Complementary means

Some authors used the complementary tools; endoscopes in 3 cases [23,26,36], used for foreign body removal, benign tumour lesions or deep abscess drainage. In one case an augmented reality headset was used in [33], associated with standard implantology.

### Types of anesthesia

Local anesthesia was the most common technique, used in 56.3% of cases. General anesthesia was used in 37.5% of the cases and the remaining 6.2% were the so-called “mixed” cases; a local anesthesia was performed for the placement of radiological markers and reflectors (the day before), followed by a general anesthesia for the placement of implants.

### Accuracy

Navigation accuracy was only assessed in implantology. Only 2 articles were randomized controlled studies with the conventional technique (freehand) and navigation. Stefanelli *et al.* and Aydemir *et al.* found a significant difference between the navigated and freehand technique, with a better accuracy for navigation (Tab. IX).

### Follow-up and complications

Follow-up times ranged from no follow-up to 3 yr. Only 5 articles reported complications [12,15,18,25,27]. A total of 6/631 implants (0.05%) were lost due to failure of osseointegration. Wang *et al.* [27] described 2 complications for the navigated group, one early (1 hematoma), and one late (1 root hypoplasia). Bensing *et al.* [25] described a resolving lingual hypoesthesia following the removal of a foreign body located in the lingual floor.

## Discussion

This review showed that the use of navigation in oral surgery had 7 different indications: implantology, foreign body removal, dental avulsion, benign tumour, bone augmentation, cellulitis and pre-prosthetic surgery. A total of 55% of the articles described a use related to implantology. There were an increasing number of articles about navigation as 43% of the articles were published in 2021–2022, compared to 15% in 2017–2018, which might show the growth of the use of this technology.

Few limits were discussed by the authors, even though all the foreign bodies were removed successfully, some authors described a difference between endoscopic vision and imaging [26]. They explained the potential inaccuracies by the difference in patient position during the acquisition of the imaging (standing) and during the surgery (lying down); it should be discussed to perform a CT scan or CBCT, lying down, like during the future procedure. They also explained the potential inaccuracies by the potential migration of the foreign body in soft tissues. To limit the movement of the foreign body during the removal surgery, the authors recommended to wait for fibrous encapsulation (3 to 6 weeks). It might decrease the discrepancies between imaging and per-op situation due to the gravity-related localization (soft tissues, sinus). Another limitation of the technology is that the guidance is based on a static and old image (its quality and the type of acquisition). All space modifications of our tissues shape will not be visible in preoperative or perioperative, as well as the migration of a foreign body. The use of imaging techniques only allows the visualization of radiopaque foreign bodies. These limitations are frequently discussed [21–24].

The calibration, as well as the fixation of the reflector are problematic for the edentulous jaw (absence of dental anatomical markers, or adjustable thermoformed bracket). Calibration is frequently performed using bone-anchored radiological markers. This implies the placement of bone anchored screws using local anesthesia (an additional procedure) with a postoperative CBCT or integrated into the final procedure (but requiring the realization of a per-operative CBCT), lengthening the procedure and complicating the management when a general anesthesia is performed. Fixing the reflector (bone anchor) on site can limit the implant positions and be cumbersome [10]. The nature of reflectors and fiducial markers can be different, which implies advantages and disadvantages. The skin as a reflector support or fiducial marker

(surface calibration) was reported as a source of inaccuracy [22] compared to point calibration; as the skin is a depressible and mobile surface. Moreover, although it was not observed, the risk of skin-supported reflector eschar on long procedures (>2h), is mentioned by Sato *et al.* [22]. However, this protocol is still widely used in dynamic navigation for implantology, for the removal of foreign bodies or dental avulsions as it is very simple to use, with a rapid, non-invasive and less radiating calibration. The initial diagnostic imaging is sufficient, it seems interesting to recall that surface calibration (skin) is still used in neurosurgery, in systems such as BrainLab© or Medtronic [40].

The reflector support most used herein is dental tissue, it seems to be the preferred support, when it is possible (dentate patient) and proposed by the system. It can also be used as a support for radiological fiducial markers (calibration by points). However, the choice of teeth, without temporary prosthetic care (for the thermoformed bracket) or without periodontal damage leading to mobility, remains essential [15]. Dental elements are more and more used as anatomical fiducial markers, called dental surface calibration. Surface calibration (dental and bone), also called "trace registration" [32] are technologies about to save operative time, by avoiding to use thermoplastic brackets and to perform a 2<sup>nd</sup> imaging for a point calibration using radiological markers [8].

Bone tissue for reflector support and invasive X-ray fiducial marker support remains the most reliable solution [15]. Nevertheless, the placement of these markers sometimes requires complex planning [17] in order to optimize their distribution and to avoid collision; the collision may occur with planned implants, noble anatomical areas or areas where the anchorage could be potentially weak and therefore mobile (anterior wall of the sinus). These markers are similar to the planning of bone anchorage screw in static guidance.

The presence of a learning curve is described almost systematically; due to navigation the surgeon has an indirect vision, which may seem counter-intuitive. The authors described learning threshold, but the results were very different even for the experienced operator. Meng *et al.* reported that 5 cases were enough to reach the threshold [34], whereas, Stefanelli *et al.* [32] observed a better precision of the last 50 implants placed compared to the first 50. This result may suggest that the threshold of progression is not necessarily reached as quickly.

As already said, general anesthesia was performed in 37.5% of the cases, which could be problematic as CBCT could not be performed intraoperatively when placement of radiological fiducial markers is necessary, thus, it must be done beforehand.

Hong YP *et al.* [36] in addition to the use of navigation during the surgery to perform enucleation of a KOC, performed a chemical enucleation using 80% ethanol (for the first time as well), therefore, a strong confusion bias exists.

Pellegrino *et al.* [28] study about minimal invasive wisdom teeth removal remains uncontrolled, a split-mouth design should be considered on a larger number of patients.

In all articles reviewed the duration of surgery using navigation was described in only 32%. It appeared that the data are slightly contradictory, the differences being explained by the variety of the surgeries in this review and of the systems used.

A majority of articles were case reports (71%), whose scientific value is questionable, more clinical trial are needed in these specific indications. Many surgeries were founding to be successful with aid of dynamic navigation but according to the low level of evidence and high level of bias of many articles, the results should be interpreted with caution.

#### Perspective

In addition to the versatility found of this technology, Wang *et al.* described the navigation as a potential educational tool to address the lack of experience of young surgeons [27,35] in complex dental avulsions; the parallel in oral implantology could easily be made. The navigation could be interesting for autogenous bone block harvesting (ramus, chin, and parietal) in order to limit the damages to nearby anatomical elements; no article in this review described this use. Stefanelli *et al.* [10] mentioned the possibility to use anatomical bone fiducial markers with surface calibration, which could be of great use for the edentulous in implantology, because the current protocol is often complex and time-consuming.

There is different systems of navigation and many systems are dedicated to implantology (ImplaNav/X-Guide/NaviDent), which testifies the orientation of navigation in oral surgery. Meng *et al.* [34] described the importance of having a system dedicated to an indication, to save time during the different steps (specific planning integrated in the software, calibrations). The absence of a navigation system integrating endoscopy was highlighted by Zhang *et al.* [23].

Moreover, it seemed it might be a successful surgical tool to help in the surgery of patients with deep abscess; when it is difficult to accurately target the abscess due to inflammation or trismus [26].

#### Conclusion

The indications of navigation in oral surgery are already multiple and surgical navigation systems are dedicated to some of these indications, such as implantology, the most common. As navigation co-exists with other technologies, its evolution will depend on their improvement, such as artificial intelligence. It is an essential basis for augmented surgery, or even passive and active robotic surgery. In the view of this work, further studies should focus on one of those specific indications with controlled clinical trial to measure the clinical relevance of this technology.

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## Authors contributions

A.Oillic: Investigation, Methodology, Writing original draft;  
A. Varazzani, A. Carlier: Supervision, Reviewing.

## Abbreviations

AI	Angled implant
All on X	Implant-supported prosthetic rehabilitation with immediate loading on X implant
CBCT	Cone Beam Computed-Tomography
CC	Clinical case
FB	Foreign body
IMR	Intermaxillary Ratio
KOC	Keratinized odontogenic cyst
NR	Not reported
NC	No complications
NCT	Non-conservable tooth
PI	Pterygoid implant
PES	Pink Esthetical score
PCS	Prospective clinical study
RCS	Retrospective clinical study
RCT	randomized clinical trial
SI	Standard implant
ShI	Short implant
SIOI	Surface in mm <sup>2</sup> of the implant-bone interface
ZI	Zygomatic implant

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