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Review Article

Computer-assisted navigation in oral and maxillofacial surgery: A systematic review

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ABSTRACT

Background: The term "navigation" describes a device that can pinpoint critical anatomical features, the most direct path to the target, and the optimal surgical orientation. This study aimed to conduct a comprehensive literature search on computer-assisted navigation for use in oral and maxillofacial surgery.
Methods: Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement, relevant studies were retrieved from five electronic databases: Medline, Web of Science, PubMed, Google Scholar, and Saudi Digital Library (SDL). The central question was, "Does the computer-assisted navigation system improve the outcome of surgical procedures in the oral and maxillofacial region?" The Cochrane Risk of Bias 2 was used to determine the various types of bias.
Results: Post-traumatic midfacial reconstruction is one of the many fields that have benefited from the use of computer-assisted navigation because of its reliability. It can also be used to extricate difficult foreign entities from the operative zone. Locating critical anatomical components, communicating the surgical plan to the patient, and verifying surgical success can improve the function and appearance of patients with dentofacial abnormalities. In addition, it decreases the surgical error margin and duration.
Conclusion: Computer-assisted navigation is promising in surgical practice. The accuracy of surgery can be significantly enhanced by first planning the process in a virtual environment and then performing it under close supervision in real time. In addition, the time required for preoperative planning and surgery can be reduced by creating and improving software programs.

1. Introduction

Throughout the years, technology has undergone continual advancements, particularly after the digitization of numerous disciplines in response to the COVID-19 pandemic. Modern imaging methods have increased surgical success rates and treatment results. Kumar et al. (2018) A three-dimensional (3D) plan can be completed to evaluate procedures and operations, making this technology useful in many situations. This method is difficult due to the lack of anatomical markers and limited surgical site access. Collyer (2010).

Real-time imaging surgery is sometimes called computer-assisted and surgical navigation. Kaduk et al. (2013) The navigation system helps see landmarks, structures, and surgical approaches. All information is available and displayed in pictures on a computer monitor during the procedure. The intraoperative transfer of patient data during registration links the patient. To collect data, 3D detectors are rigidly attached to patients, buildings, and surgical devices. (Millesi et al., 1997).

Displaying the patient's structures in 3D is essential for maxillofacial surgery. This method improves implant, bone transplant, and tumor

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excision accuracy (Kawachi, 2010) and reduces iatrogenic damage and surgical complications. (Landaeta-Quinones et al., 2018).

A navigation system precisely identifies, safely accesses, and guides essential anatomical structures for safe and reliable surgery. Sukegawa et al. (2018) Surgeons can reach inaccessible places with the technology. (Anand and Panwar, 2021).

Computer-assisted navigation systems use multiple imaging modalities to reveal structures seen only clinically during surgery and navigate in anatomically sensitive areas. (Azarmehr et al., 2017, Dong, 2020) Data can also be linked to diagnostic images (Bouchard et al., 2012)

Active and passive optical traceability systems dominate this method. Active systems track and capture light with infrared cameras. (Li et al., 2016) Passive devices track with the reflector rather than light and don't need batteries or power connections. Hassfeld and Mühling (1998), Samarakkody and Abdullah (2016) A camera-attached identification gadget changes a patient's morphological position into simulated software. Navigation is essential for merging CT scan coordinates with patient coordinates. Registration methods include point, surface, and hybrid. (Dai et al., 2016) Point registration's precision and low failure rate make it the standard. The program can prepare and register patients pre- and post-op. (Nottmeier and Crosby, 2007) Several investigations have shown that this technique is accurate, practical, and time-saving. (Dai et al., 2016).

Dental computer-assisted systems are most commonly used for face trauma, TMJ surgery, orthognathic surgery, implant implantation, and maxillofacial reconstruction (Heiland et al., 2008). Gellrich et al. (2002) This study evaluates oral and maxillofacial surgery computer-assisted navigation literature.

2. Materials and methods

The titles and abstracts of the selected articles were initially reviewed. The main research question was "Does the computer-assisted navigation system improve the outcome of surgical procedures in the oral and maxillofacial region?" (Table 1). The eligibility was determined by reading the entire manuscript.

2.1. Study inclusion and exclusion criteria

Inclusion criteria for this *meta*-analysis were studies with patients who required at least one maxillofacial surgical procedure and who underwent computer-aided navigation for surgical planning; for the interventional group, inclusion criteria additionally required transfer of the surgical plan to an actual operation. Additionally, at least one parameter (accuracy, efficiency, reconstructive outcomes, postoperative complications, and cost-effectiveness) had to be included in the results of the selected studies.

Some studies were excluded because they dealt with unrelated themes or used methodologies that were not applicable to ours. Studies that were not fully accessible and those only partially translated to English were excluded. This review did not include case reports, series, *meta*-analyses, or literature reviews.

Table 1
PICO table to determine eligibility of research question.

Criteria	Determinants
Population	Patients who require oral and maxillofacial invasive surgical procedures.
Intervention	Successful navigation to the surgical site with no collateral injury
Comparison	In comparison with comparable conventional surgical procedures
Outcome	Result of computer-assisted navigation obtained during surgical procedures.

2.2. Search strategies

We performed an extensive online search and literature review to determine whether a computer-assisted navigation system improves oral and maxillofacial surgical outcomes. The Saudi Digital Library, Google Scholar, PubMed, and Medline databases were searched for articles published up to July 2022. Specific search strategies is described in Table 2.

Oral and maxillofacial surgery, robotic surgery, image-guided surgery, computer-assisted surgery, preoperative planning, simulated surgical procedures, and surgical navigation systems were terms included in the search. There was no specific timeframe for included papers.. The selected articles were streamlined using the PRISMA 2020 statement and flow diagram. In total, 1087 unique records were identified after duplicates were eliminated. Electronic files were organized using EndNote version 20. Two reviewers manually evaluated each article's citations to ensure relevance.

2.3. Review process and data extraction

EndNote X7 (Clarivate Analytics; Philadelphia, USA) was used as the reference management system, in which all papers found in the literature search were collected. Two external observers qualitatively assessed the entire review process. Article titles were filtered for duplication, and only relevant studies were included. Next, we reviewed the abstracts to determine if the papers were suitable for inclusion. Abstracts were selected when at least one reviewer deemed the abstract appropriate for further examination. After exhausting the free and low-cost options to obtain the full texts of the abstracts of interest, we purchased access to the articles via their publishers or paid for access to the articles themselves. Full-text submissions were reviewed carefully by two reviewers, with special attention given to the research design and findings. To ensure that no pertinent papers were missed during the database search, cited studies were reviewed. Disputes were resolved by conversation, and articles were not included in the review until both reviewers agreed that the inclusion and exclusion criteria had been fulfilled. From the selected full text articles, data, including author names, publication years, research designs, aims, and results, were

Table 2
Electronic search strategies for Web of Science, PubMed, Medline, Google Scholar, and Saudi Digital Library databases.

Web of Science	1	("oral and maxillofacial surgery" OR "maxillofacial surgery")
	2	("computer-assisted" OR "image-guided")
	3	("operation planning" OR "operation simulation" OR "navigation system")
	4	#1 AND #2 AND #3
PubMed	1	((oral and maxillofacial surgery) OR (maxillofacial surgery))
	2	((computer-assisted) OR (image-guided))
	3	((operation planning) OR (operation simulation) OR (navigation system))
	4	#1 AND #2 AND #3
Medline	1	(oral and maxillofacial surgery or maxillofacial surgery).af.
	2	(computer-assisted or image-guided).af.
	3	(operation planning or operation simulation or navigation system).af.
	4	#1 AND #2 AND #3
Google Scholar	1	(oral and maxillofacial surgery OR maxillofacial surgery)
	2	(computer-assisted OR image guided)
	3	(operation planning OR operation simulation OR navigation system)
	4	#1 AND #2 AND #3
Saudi Digital Library	1	(oral and maxillofacial surgery) OR (maxillofacial surgery)
	2	(computer-assisted) OR (image-guided)
	3	(operation planning) OR (operation simulation) OR (navigation system)
	4	#1 AND #2 AND #3

collected and assembled into an Excel spreadsheet. (Table 3).

The desired outcome is the feasibility of using computer-assisted navigation in oral and maxillofacial surgery and the determination of its advantages and disadvantages.

2.4. Quality and risk of bias assessment of selected studies

The Cochrane risk-of-bias 2 test (ROB 2) was used to evaluate the potential for bias in the selected articles. Assessments were made in several areas such as randomization bias, intervention variations, data and measurement inaccuracies, and reporting of results. The quality of the research and, by extension, the potential for bias were rated out of nine for each study. Randomized controlled trials were classified as having a low risk of bias if they received 79 points, a moderate risk if they received 56 points, and a high risk if they received less than 5 points. Two of the 10 articles were very suspect, two raised some questions, and the remaining eight were safe. Non-randomized control studies (retrospective studies) were evaluated using the modified Newcastle-Ottawa scale, which focuses on three aspects of the research design: group comparability, patient selection, and outcome assessment.

2.5. Quality assessment

The methodological quality assessment using Cochrane ROB 2 is presented in Table 4. Among the selected articles, two had high-risk of bias and scored less than 5. (Mazzoni et al., 2010, Grobe et al.) Two articles had medium risk and scored 5–6. (Badiali et al., 2015, Abbate et al., 2017) All others had low risk of bias and scored 7–9, indicating good quality studies with results that are considered valid.

D1 - Bias resulting from the randomization process; D2 - Bias resulting from a departure from the intended interventions; D 3- Bias resulting from missing data outcomes; D4 - Bias resulting from faulty measurement of the outcome; and D 5- Bias resulting from the selective reporting of results. The risk of bias is indicated by red (high), yellow (some), and green (low).

3. Results

3.1. Flow diagram

The PRISMA flowchart is presented in Fig. 1. After a preliminary search, 42 publications were identified in the PubMed database, 700 in Medline, 128 in Web of Science, 254 in Google Scholar, and 132 in the SDL. Only 1256 articles were finalized, of which 169 were eliminated because they were duplicates. Another 725 were disqualified after abstract and title reviews, leaving 362.

A further 352 were rejected as they did not fulfil the inclusion criteria of being literature, systematic review, case report, or series, and were unrelated to our topic due to different treatment approaches or methods, were not in English, or full text was not available. Ten articles were selected for the final qualitative synthesis after the selection process.

3.2. Study characteristics

Most of the included retrospective studies had a sample size greater than 15, although they ranged from just four in the Abbate (2017) study (Abbate et al., 2017), to 50 in the Grobes (2014) study (Ayoub et al., 2014). However, most clinical trials included 1031 patients (Mazzoni et al., 2010, Ayoub et al., 2014, Wilkat et al., 2021), and one clinical trial included a sample size of five patients (Gui et al.) (Table 3). Of the ten included articles, only two studies had a control group, and the participants in the experimental (computer-assisted) and control (conventional) groups were comparable (Ayoub et al., 2014, Wilkat et al., 2021). In five studies, male and female participants were comparable (Mazzoni et al., 2010, Palla and Callahan, 2021, Badiali et al., 2015, Lin et al., 2015, Ayoub et al., 2014, Gui et al.). However, in three studies, there were significantly more men than women (Pierrefeu et al., Grobe et al., Wilkat et al., 2021), in one study, there were significantly more women than men (Badiali et al., 2015), and one study reported no information on males and females (Abbate et al., 2017). The participants' mean age was comparable in the included studies, ranging from 9 years (Palla and Callahan, 2021) to 81 years (Ayoub et al., 2014).

The computer-aided navigation system in patients undergoing various oral and maxillofacial surgeries was supported and compared with conventional surgical methods in available controls in the included studies. Computerized navigation systems are used for various purposes and outcomes. Pierrefeu et al. studied the use of navigation systems in midface fracture reconstruction. (Pierrefeu et al.) Second, Grobe et al. and Gui et al. studied computer navigation systems in removing foreign bodies from surgical sites. (Gui et al., Grobe et al.) Third, Mazzoni et al., Badiali et al., and Line et al. investigated simulation-guided navigation during orthognathic surgeries. (Mazzoni et al., 2010, Badiali et al., 2015, Lin et al., 2015) Finally, Abbate et al., Palla et al., Ayoub et al., and Wilkat et al. investigated its use in the resection and reconstruction of mandibular tumors. (Palla and Callahan, 2021, Ayoub et al., 2014, Wilkat et al., 2021, Abbate et al., 2017).

4. Discussion

This review describes the results and significance levels from studies using computer-assisted navigation systems in oral and maxillofacial surgery. These parameters include their use in fracture reconstruction, foreign body removal, orthognathic surgery, and the resection and reconstruction of mandibular tumors.

4.1. Fracture reconstruction

Pierrefeu et al. evaluated the accuracy of a particular navigation system in the rehabilitation of midface injuries in a study of 20 subjects (15 males and 5 females) by distinguishing between intended and post-intervention 3D images. The proportion of values across the two surfaces included within the accuracy interval was greater than 90 % in six patients, 80–90 % in six patients, 50–80 % in seven patients, and less than 50 % in one patient. Consequently, the authors stated that posttraumatic midface reconstruction can be accurately predicted for most patients using a specific navigation system that integrates computer-aided planning. (Pierrefeu et al., 2015).

4.2. Removal of foreign bodies

Grobe et al. studied 50 patients (39 men and 11 women), and reported that some experience with image-guided projectile removal and the associated intra- and postoperative consequences can be used. There was a clear association ($p = 0.0136$) between computer-navigated surgical procedures and postoperative complications ($p = 0.038$), and between surgery time and associated complications. The authors concluded that when the navigation system was used correctly, there was a significant correlation between overall postsurgical complications and duration. (Grobe et al.).

A clinical trial by Gui et al. included five individuals (three males and two females) and assessed the benefits of using image-guided technology to remove deep maxillofacial foreign bodies. All five procedures were minimally invasive without any disadvantages. In addition, the operation duration was approximately 40 % shorter than that of the non-computer-aided image-guided navigation technique. Therefore, the authors concluded that navigation-guided foreign body removal is an option to consider in the deep and complicated maxillofacial region, where proximity to vital structures is present. (Gui et al.).

4.3. Orthognathic surgery

Several studies have examined the use of computer navigation

Table 3
Summarized data of the 10 included studies.

Literature	Research Design	Research Purpose	Subjects	Results	Conclusions
Pierrefeu et al. (2015)	Retrospective cohort study	Analyze design and postsurgical images to determine the accuracy of specific navigation in the treatment of facial fractures.	20 patients, ranging in age from 17 to 62 (15 male and 5 female). Comminuted midface fractures were found in all patients (19 orbital zygomatic fractures, 1 isolated zygomatic fracture)	There were six cases where value overlap was greater than 90 % between the two surfaces and the accuracy interval, six cases where the value overlap was between 80 % and 90 %, seven cases where it was between 50 % and 80 %, and one case where it was less than 50 %.	A particular navigation system that incorporates computer planning can correctly determine post-traumatic midface reconstruction for most patients.
Grobe et al. (2009)	Retrospective study	Reports on intra- and postoperative complications associated with image-guided projectile abolishment.	50 patients (39 male, 11 female) Between the ages of 17 and 77 32 had image-guided surgical removal of facial projectiles, while the 18 were conventionally treated.	There was a significantly ($p = 0.0136$) strong association among both navigated/non-navigated surgery and complication rate, and also between surgical intervention time and postoperative complications.	When a navigation system is used correctly, there is a clear association with both reduced complications and surgery time.
Mazzoni et al. (2010)	Comparative Study	A novel approach to improving simulation accuracy and precision through the transmission of a patient's 3D virtual planning to the operating room via a navigation system.	10 patients (5 men and 5 women) between the ages of 18 and 45 with mandibular abnormalities were cared for between November 2008 and May 2009.	The mean reproducibility of the presurgical plan using simulation-guided navigation was 86.5 %, relative to 80 % in previous group, which did not use intraoperative navigation.	To help enhance the reproducibility of preoperative simulated surgery planning, simulation-guided navigation would be a useful method in orthognathic surgery.
Palla et al. (2021)	Retrospective cohort study	Recognize how computer-assisted surgery (CAS) affects marginal status in ameloblastoma surgical removal.	31 people, ranging in age from 9 to 77 (19 males and 12 females). The research examined 2 different surgical margin sizes (5 mm and > 5 mm) and 2 different surgical techniques (CAS and non-CAS).	There was no significant difference between the CAS and non-CAS groups when the surgical margins were categorized as less than or equal to 5 mm and larger than 5 mm ($P = 0.5368$).	Using CAS and guides at predetermined margins did not affect marginal status in surgical ameloblastoma resections.
Abbate et al. (2017)	Comparative Study	By positioning the DRF directly on the mandibular ramus and allowing for mandibular movement during surgery, we can evaluate the feasibility of mandibular surgical navigation.	4 patients who underwent mandibular excision and repair using a free fibula flap between 2011 and 2015 were included. The majority of the patients needed some form of reconstructive surgery.	Intersegmental and mandibular articular congruence, as well as congruence at the bone interfaces between the two. From 0.33 to 8.9, the SD of the fit can be found (mean SD 4.67)	In the disclosed approach, intermaxillary fixation was not required to facilitate precise surgical navigation of the jaw. This method has the potential to greatly streamline jaw excision and reconstruction surgery and increase the likelihood of success.
Badiali et al. (2015)	Retrospective study	Maxillary reduction accuracy in orthognathic surgery can be evaluated by simulation-guided navigation, which integrates navigation with 3D simulated surgery.	The study included 15 patients who were treated between January 2010 and January 2012 for class II or III maxillofacial malformations with severe variation.	All clinical results were favorable. Between 180 and 240 min of actual use was recorded. It took about 10–20 min to set up the navigation system and patient records, then another 5–10 min to adjust the maxilla using navigation.	SGN allows accurate postoperative results compared to surgical computer projects realized with dedicated software
Lin et al. (2015)	Prospective observational study	To improve planning and outcomes, 3D computer-assisted orthognathic surgery was used. This study presents findings using this modality for simulating navigating surgery.	The study included 37 adult patients with an average age of 18.8, from September 2012 to August 2013.	All patients underwent successful computer-assisted orthognathic surgery. The simulation and postoperative images were superimposed to produce a satisfactory result with minimum errors. In patients using positioning aids, the difference ranged from 0.05 to 1.46 mm. In patients using the navigation system, the difference ranged from 0.07 to 2.30 mm.	This computer-assisted orthognathic surgery system improves surgical outcomes by assisting with preoperative planning, reducing surgical complexity, and facilitating maxillomandibular complex positioning, fixation, and outcomes.
Ayoub, et al. (2014)	Randomized Prospective Clinical Trial	The benefits of computer-assisted mandibular repair using bone grafts from the iliac crest were compared to those of traditional surgery.	20 patients underwent mandibular restoration utilizing a vascularized iliac crest bone transplant, with half receiving computer-assisted care and the other half receiving traditional care.	There was no difference in overall surgical time, the amount of bone harvested was proportional to the size of the defect, and the intercondylar space was less damaged before and after surgery when comparing computer-assisted surgery to traditional surgery.	Computer-assisted surgery can help to reduce the time required for mandibular defect reconstruction.
Wilkat et al. (2021)	Randomized Prospective Clinical Trial	To understand how far CAS can go beyond conventional therapy in midface oncological surgery.	31 patients with upper jaw malignancies were treated between 2011 and 2019 with computer-assisted tumor removal, which entailed tumor	The CAS group scored higher overall and in the areas of mood and physical appearance when the two groups were compared.	Maintaining the goal of increasing treatment success, optimizing interdisciplinary teamwork, and bettering patient quality of life is

(continued on next page)

Table 3 (*continued*)

Literature	Research Design	Research Purpose	Subjects	Results	Conclusions
			mapping and primary reconstruction. Sex distribution (male/female): CAS group (22/9), no CAS group (15/14). Both groups were compared on several characteristics, including quality of life and response to resection.		possible with thorough tumor excision and appropriate rebuilding.
Gui, et al. (2013)	Clinical Trial	Explored advantages of image-guided technology for deep maxillofacial foreign body removal.	5 patients had image-guided removal of foreign objects left in their jaws and faces as a result of accidents. 3 men and 2 women Trauma etiology: 3 accidental and 2 expulsive injuries.	Foreign bodies were removed with minimal invasiveness and without complications in all five cases. The operating time was approximately 40 % less than that of the conventional technique, which did not use image-guided navigation.	For these potentially complicated procedures, navigation-guided foreign object withdrawal in the complex, deep maxillofacial area near vital areas is a suitable option.

Table 4
Risk of bias assessment with the recommended approach of Cochrane ROB 2.

Authors	D1	D2	D3	D4	D5	Overall
Pierrefeu et al. (2015)	+	+	+	+	?	+
Grobe et al. (2009)	−	+	−	+	?	−
Mazzoni et al. (2010)	−	+	−	+	−	−
Palla et al. (2021)	+	+	+	+	?	+
Abbate et al. (2017)	?	−	?	+	?	?
Badiali et al. (2015)	+	?	?	+	?	?
Lin et al. (2015)	−	+	+	+	−	+
Ayoub, et al. (2014)	+	+	+	+	?	+
Wilkat et al. (2021)	−	+	+	+	+	+
Gui, et al. (2013)	+	+	+	+	?	+

D1 - Bias resulting from the randomization process; D2 - Bias resulting from a departure from the intended interventions; D 3- Bias resulting from missing data outcomes; D4 - Bias resulting from faulty measurement of the outcome; and D 5- Bias resulting from the selective reporting of results. The risk of bias is indicated by red (high), yellow (some), and green (low).

systems in orthognathic surgery. A clinical study by Mazzoni et al. included 10 individuals (5 males and 5 females). They presented a new method for moving a patient's individualized virtual 3D plan into the operating room using a navigation system, thus improving the reproducibility of the simulation. The reproducibility of the preoperative plan was found to have an average of 86.5 % using simulation-guided navigation, compared with an average reproducibility of 80 % when no navigation was used. The authors concluded that navigation

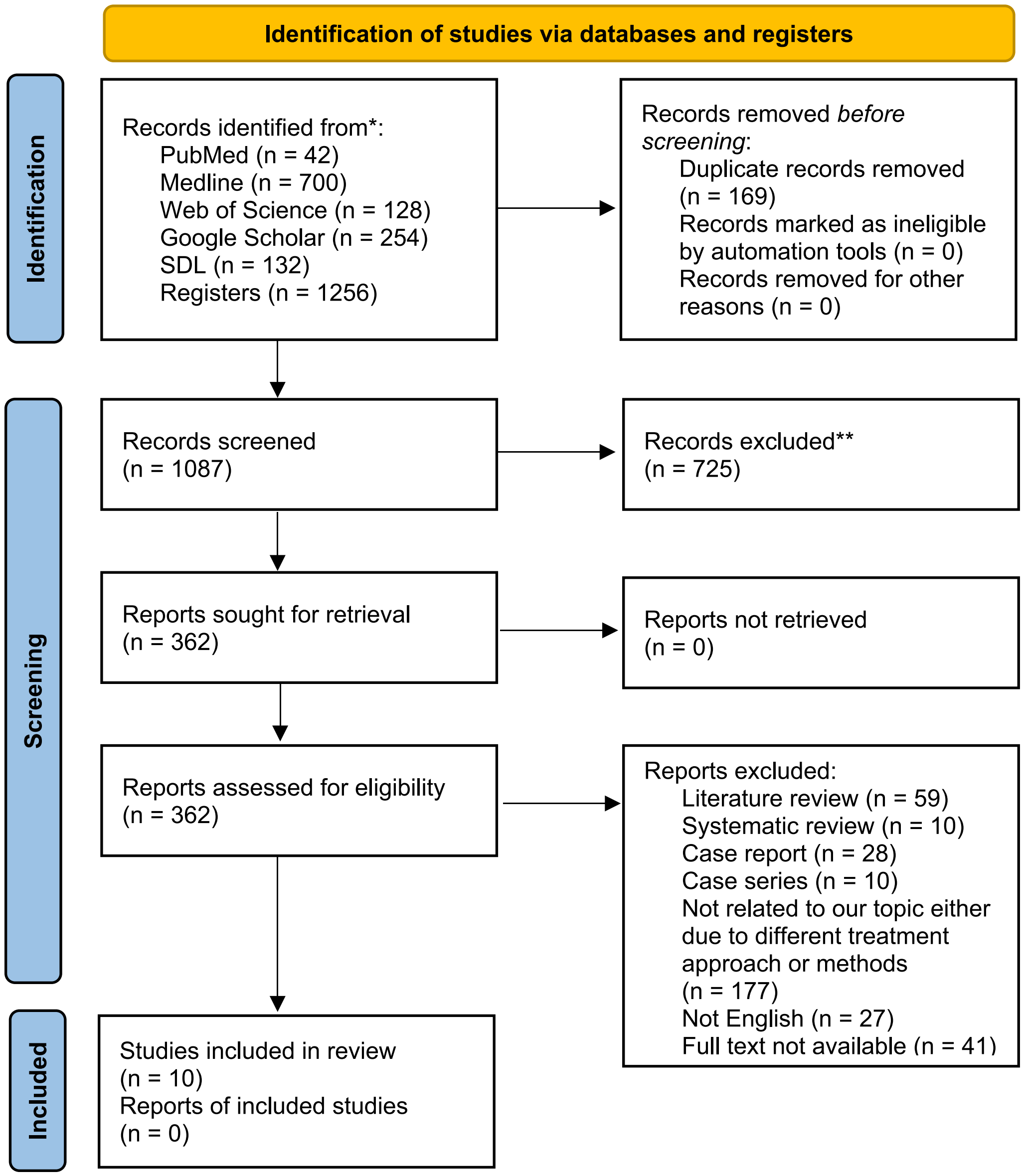

Fig. 1. PRISMA flow diagram.

has a significant effect during orthognathic surgery, thereby improving the reproducibility of preoperative simulated surgical procedure planning. (Mazzoni et al., 2010).

Another study by Badiali et al. included 15 subjects (3 males and 12 females) treated for class II or III maxillofacial malformations with severe complex and asymmetrical vertical dimensions. The clinical results were satisfactory with no significant complications. The operative time was 180–240 min. The computerized navigation system and patient registration took between 10 and 20 min to set up. The study concluded that navigation systems provide accurate postoperative results when used in conjunction with a computer-designed surgical project and dedicated software. (Badiali et al., 2015).

Lin et al. included 37 participants who had previously undergone orthodontic treatment. They presented their experiences with navigation systems for simulating operations, prefabricating positioning aids, and navigating in practice. To improve planning and outcomes, 3D computer-assisted orthognathic surgery was used. According to the authors, the system for computer-assisted orthognathic surgery may aid in better surgical planning, reduce surgical complexity, increase ease to position and fixate on the maxillomandibular complex, and enhance outcomes. (Lin et al., 2015).

By first analyzing various anatomical landmarks, transmitting the surgical scheme to the patient, and assessing the surgical outcome, navigation can significantly improve function and esthetics in patients with dentofacial malformations. (Bobek, 2014).

4.4. *Mandibular tumor resection and reconstruction*

One of the major areas to consider in oral and maxillofacial surgery is the appropriate way to manage pathology. Many studies have investigated this area to find better and more up-to-date ways to treat patients and preserve the remaining structures.

A study by Palla et al. included 31 people (19 males and 12 females) and investigated the impact of computer-assisted surgery (CAS) on the marginal status of ameloblastoma resection in 31 patients (19 men and 12 women). The researchers compared surgical approach (CAS and non-CAS) to surgical margin (5 mm and greater than 5 mm). When surgical margins were defined as less than or equal to 5 mm and greater than 5 mm, there was no significant difference between such surgical techniques ($p = 0.5368$). Therefore, we concluded that CAS and navigational guidance at predetermined margins did not affect the marginal status of surgical ameloblastoma resections. (Palla and Callahan, 2021).

Another study conducted by Abbate et al. included four subjects who underwent mandibular resection and had reconstruction proposed. This study investigated the feasibility of mandibular surgical navigation by placing a dynamic reference frame directly on the mandibular nerve branch, which permitted complete mandibular movement during surgery. This method can greatly simplify and ensure the precision and accuracy of resection and reconstruction procedures. (Abbate et al., 2017).

A study by Ayoub et al. included 20 patients (10 males and 10 females) and compared the benefits of computer-assisted mandibular reconstruction using iliac crest bone grafts to conventional surgery in terms of the duration of surgery, ischemia, amount of bone removed, and postoperative shift in condylar position. Results demonstrated that computer-assisted surgery could greatly decrease the mandibular reconstruction and transplant ischemic times. The defect size at the donor site was reduced in the computer-guided group and the postoperative position of the condyle was significantly affected, lowering the risk of postoperative complications at the site. (Ayoub et al., 2014).

Wilkat et al. conducted a clinical study in which 31 patients with maxillary tumors underwent computer-assisted surgical excision. The second group consisted of a retrospectively observed sample of 29 patients who were conventionally treated. Descriptive data, resection outcomes, and life expectancies of the two groups were compared. The results revealed that computer-aided surgical intervention has significant advantages over existing therapeutic approaches for tumor resection, such as precision, safety, and treatment success. (Wilkat et al., 2021) discusses her practice and findings regarding the efficacy of computer-assisted navigation in mandibular reconstruction. Eight patients who underwent fibula free flap mandibular repair under navigation guidance were analyzed. During the intraoperative navigation, the probe verified that the mandibular angles and condyles were at their optimal locations. Panoramic radiographs, coronal computed tomography scans, and image fusion were used to assess patient recovery after surgery. Preoperative planning and simulation informed navigation-guided mandibular reconstruction. Mandibular angle preoperative designs were 1.92 0.97 mm off from the final surgery results. All condyles were properly seated in their sockets, as seen on both panoramic radiography and coronal computed tomography images. All patients felt that the treatment outcomes met their expectations in terms of both function and appearance. The authors concluded that CAN is a promising tool for enhancing the surgical outcomes of mandibular reconstruction surgeries.(Wu et al., 2016).

According to these studies, the real-time guide offered by the navigation system reduced the margin of error and length of surgery compared to freehand techniques and allowed the surgeon to change the dimensions during resection and reconstruction. (Sozzi et al., 2022).

The areas of assessment included bias due to the randomization process, deviations from the intended interventions, missing outcomes in the data or measured outcomes, or in the selection of reported outcomes. Each study was assigned a maximum of nine stars, indicating research quality and, as a result, the risk of bias. Studies with 79 points were randomized as low risk of bias studies, 56 points indicated a moderate risk of bias, and fewer than 5 points indicated a high risk of bias. Of the ten articles selected, two were at high risk, two had moderate concerns, and all others were at a low risk of bias. The modified Newcastle-Ottawa scale was used to assess the methodological quality of non-randomized control studies (retrospective studies) with three factors: comparability of study groups, patient selection, and evaluation of results.

4.5. Limitations

The studies included in this review had some limitations, including (i) the intended use of the computer navigation system differed, which hampered the comparison, and (ii) some studies had small sample sizes or inadequate age/sex distributions. Due to these limitations, it is recommended that further high-quality studies with larger populations and required randomization be conducted. In addition, all other variables (including sex, age, and surgery type) must be controlled for to verify the findings of this review.

As only a few articles have discussed computer-aided navigation systems in oral and maxillofacial surgery, this represents a new subject of interest in dental research. Most of the included studies were uncontrolled or unrandomized, which could have led to potential bias in the results and conclusions. In addition, none of the included studies were publicly registered before study commencement, and we were unable to find additional studies on clinical trials, suggesting a current lack of ability to objectively assess publication bias.

4.6. Future perspectives

The ideal oral and maxillofacial navigation systems should be simple to use, allow for efficient configuration and registration, and allow visualization of anatomical structures without obstructing the surgeon or obscuring the field. (Yamamoto et al., 2012).

Furthermore, the platform should be accurate and allow the validation of the findings. Computer-assisted navigation enables unobtrusive visual analysis of morphology while increasing functionality. (Sukegawa et al., 2017).

The technical accuracy of navigation systems is relatively high. Achieving the maximum accuracy in complex cases is challenging. Augmented reality tracking of surgical instruments can provide a more direct input. (Vávra et al., 2017) Furthermore, replacing the human hand with a robotic arm could significantly improve surgical accuracy. Robotic and navigation technologies work together to provide significantly higher precision and stability than augmented reality and navigation systems alone. (Liu et al., 2017) Based on this review, computer-assisted navigation systems are most effective for the treatment of facial fractures, removal of foreign bodies, and mandibular tumor resection and reconstruction. The limitations of computer-assisted robotics and augmented reality in oral and maxillofacial surgery are primarily determined by medicolegal rather than technological concerns. (Burström et al., 2021).

5. Conclusion

Computer-assisted navigation is a promising addition to the surgical toolkit. The planning of surgical procedure details in a 3D virtual space and executing them with real-time guidance can significantly enhance accuracy. This technological advancement can increase accuracy and security, especially in complex advanced cases, and enhance time efficiency, thus benefiting the patient with better surgical outcomes. Additional development and improvement of software programs may reduce preoperative planning and operation times.

6. Ethical approval

This study was approved by the ethics committee of Riyadh Elm University (IRB approval number: SRP/2022/111/750/727).

7. Guarantor

NA.

8. Contributorship

All authors researched literature and conceived the study.

SA was involved in protocol development, gaining ethical approval and data analysis.

NA and HA wrote the first draft of the manuscript.

All authors reviewed and edited the manuscript and approved the final version.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sdentj.2023.12.002.

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