GRADUATION PROJECT

Degree in Dentistry

REVIEW ON THE USE OF GUIDED SURGERY IN IMPLANTS VS. CONVENTIONAL SURGERY

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RESUMEN

Introducción: La implantología podría definirse como un soporte protésico hecho de titanio aloplástico que se coloca en el hueso alveolar para reemplazar un diente. La implantología se ve afectada por avances e investigaciones considerables, particularmente gracias a los biomateriales. Siguiendo estos avances, se ha implementado la colocación de implantes mediante una guía. Esto permite una mayor precisión, evita ciertos errores y ahorra un tiempo considerable al cirujano. Sin embargo, la cirugía convencional sigue siendo un método adecuado para cirujanos experimentados y también es más rentable. **Objetivos**: Los objetivos son analizar en pacientes que requieren implantes la precisión y los resultados clínicos de la cirugía guiada en comparación con la cirugía convencional. **Métodos**: La estrategia de búsqueda se basó en la siguiente pregunta**:** en pacientes que requieren implantes, ¿es más beneficioso utilizar cirugía guiada o cirugía convencional para obtener mejores resultados reportados por los pacientes? Para encontrar los artículos adecuados para este estudio, se establecieron criterios de inclusión y exclusión (estudios publicados en los últimos 10 años, en inglés o español). **Resultados**: A partir de estas preguntas, encontramos 458 artículos en PubMed, que analizados con RAYANN QCRI para crear PRISMA. Esto resultó en 19 artículos para comparar y estudiar en función de nuestros resultados. Comparamos los artículos que mejor se ajustaban a nuestros objetivos, por ejemplo, las desviaciones del implante (coronal, apical), las complicaciones, el sangrado y el coste. **Conclusiones**: La cirugía guiada de implantes demuestra una mayor precisión en la colocación del implante y puede mejorar la predictibilidad quirúrgica y la comodidad del paciente en comparación con la cirugía convencional a mano alzada. Sin embargo, ambas técnicas presentan altas tasas de supervivencia de los implantes y siguen siendo fiables cuando se realizan en condiciones clínicas adecuadas. Por lo tanto, la cirugía guiada representa una herramienta valiosa en la implantología moderna, especialmente en los casos que requieren una alta precisión y una planificación protésicamente guiada.

PALABRAS CLAVES

Cirugía guiada, cirugía convencional, , colocación de implantes, implante dental.

ABSTRACT

Introduction: Implantology could be defined as a prosthetic support made of alloplastic titanium that is positioned in the alveolar bone to replace a tooth. Implantology is affected by considerable advances and research, particularly thanks to biomaterials. Following these advancements, implant placement using a guide has been implemented. This allows for a greater precision, avoids certain errors and saves the surgeon considerable time. Conventional surgery, however, remains an adequate method for experienced surgeons and is also more cost-effective. **Objectives**: The objectives are to analyze in patient requiring implant the accuracy and clinical outcomes of guided surgery in comparison to conventional surgery. **Methods**: The search strategy was based on this question: In patients requiring implants it is beneficial to use guided surgery or conventional surgery for a better patient-reported outcomes? To find the corrects articles for this study we established inclusions and exclusions criteria (Studies from less than 10 years, English, Spanish studies). **Results**: Form these questions, we found 458 articles on PubMed which we sorted using RAYANN QCRI to create PRISMA, resulting in 19 articles to compare and study for our results. We compared the articles to best meet our objectives for example, the deviations of the implant (coronal, apical), the complications, the bleeding, the cost. **Conclusions**: Guided implant surgery demonstrates greater accuracy in implant positing and may improve surgical predictability and patient comfort compared with conventional freehand surgery. However, both techniques show high implant survival rates and remain reliable when performed under appropriate clinical conditions. Therefore, guided surgery represents a valuable tool in modern implantology, particularly in cases requiring high precision and prosthetically driven planning.

KEYWORDS

Conventional surgery, dental implant ,guided surgery , implant placement.

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1. INTRODUCTION

1.1. Background of implant

1.1.1. General principle of implant

Do to advances and research, the use of implant is still growing nowadays. It's true that implantology was able to emerge thanks to the innovation of replacing a missing tooth. When, we talk about an implant, we could describe a material that is made of alloplastic titanium in order to support a prosthetic structure and it is positioned in the alveolar bone with the aim of replacing teeth (1). An implant is mainly based on the principle of Per Ingvar Bränemark: the osseointegration. Which represents the direct, functional and structural contact between the bone and the implant (2). Since then, implants have become the treatment of choice for partially or fully edentulous patients, providing a durable and functional solution; indeed, the success rate of an implant is over 95% after 5 years. This success is due to advances in biomaterials as well as various techniques that we will describe in this study. In order to ensure the ideal restoration and respect the patient's aesthetic, optimal and precise placement, angulation of the implant become essential (3).

1.1.2. Limitation of two-dimensional imaging in implant surgery

Traditionally, implant placement was performed using the surgeon 's knowledge, tactile sense and 2D imaging using X-rays (panoramic and periapical radiographs) (4).
This surgery aims to place the implant manually without the use of a digital guide or computer-assisted navigation. However, it's important to notice that this technique lacks information on anatomical conditions and is affected by significant accuracy limitations such as distortion and magnification. To reduce complications during the placement of the implant, it is essential to know the exact position, thickness and angulation of the implant. But this information cannot be generated with periapical radiographs. With this lack of advantages, we see the introduction of the computer-assisted implant planning based on the three-dimensional (3D) computed tomography (CT) data. With this diagnostic method we can overcomes the limitations of two-dimensional radiographic methods, by reducing the errors and positioning artifacts, including expansion and distortion factors (4). The position of the implant becomes guided by measurable and valeted criteria.

1.1.3.3D imaging in conventional implant surgery: Accuracy without guidance.

With the use of 3D imaging, the surgeon can carefully plan the surgical intervention and prosthetic rehabilitation. This is the conventional surgery with 3D planning. It is based on CBCT (cone-beam computed tomography) or also on CT scans (5). The CBCT allows major advances during the recent years which is based on a visualization of the patient's bone anatomy. This technique used a freehand operation. In order to ensure a correct placement of dental implant, we use plan based on 3D plans, diagnostic wax-up and gypsum cast (6). Initially, in this surgery we will realize the lifting of flap to expose the alveolar ridge. Then we realize the drilling manually. It is essential that the surgeon maintains the desired depth and angulation. The next step is the osteotomy that is prepared to insert the implant. Depending in each patient, the flap is then closed in two or single step (7). But carefully this technique based on free-hand depends mainly on the surgical skills and decision-making of the surgeon, which will act on the correct osseointegration of the dental implant (1). When we compare it with guided surgery, this technique is still chosen by some surgeons due to the complexity of guidance and cost (6). This method is facing some disadvantages such as a lack of precision in implant positioning and a significant risk of complications (such as nerve damage or cortical perforation). Facing this, conventional implant surgery is keeping excellent long-term results in experienced hands, it will have a real importance in the foundation of the modern computer-guided surgery.

1.2. Evolution of implant

1.2.1.Computer-assisted implant surgery: the basis of guided protocols

The evolution of implant is still growing nowadays; in this fact the new surgery techniques have lead to the emergence of guided surgery with the improvements of materials. By introducing more precision, smaller incisions and quicker recovery, the use of CAIS (computer assisted implant surgery) is gaining increasingly. Computer assisted surgery is a surgical process that uses computer technology to implement the guided surgical placement of a dental implant (5). This technique is based on the superimposed of the CBCT, the intraoral scanner and digital wax's-up

to generate the correct placement of the implant. To realize a correct drilling and correct placement prosthetically driven, the wanted implant position is transferred to the surgical site. Today, there are two types of computer-assisted surgery: dynamic guides and static guides. The first term refers to dynamic surgery, a real-time navigation system for implant modifications. Unlike static computer-assisted surgery, which does not provide real-time information on implant modifications, it simply allows for planning of the implant's future position. Static surgical guides are currently the one used to transfer as best at possible the surgical plan to the patient's mouth (8). Furthermore, this static surgery has enabled the development of “flapless surgery”, allowing for better and more adequate implant placement (9). According to the literature, this method is safe, short-term and causes no discomfort. Its approach is minimally invasive, and the procedure is very quick. In the static computer-assisted implant surgery we could find the CAD-CAM surgical guide and the guided implant surgery system.

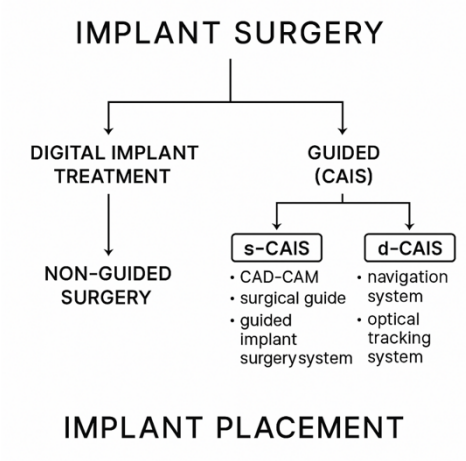


Figure 1: Overview of implant placement adjusted from the Glossary of Computer-assisted implant surgery (10).

1.2.2.From planning to placement: Advantages of guided surgery

When we talk about guided implant surgery, we are integrating an important evolution in modern implantology. All planning and execution steps are realized thanks to the intervention of digital technology. Following the superimposed of the CBCT and intraoral scan in standard triangular language (STL) format , the clinician can determine the ideal position, depth, and angulation of the implant (4). Guided surgery transfers the rehabilitation project directly to the surgical field (11). The guided surgery is able also to reduce the risk of alveolar nerve injury, sinus perforation, fenestration, and dehiscence (12).

The realization of this guided surgery still following very specific steps. First the surgeon will observe the patient’s health to check the density of the alveolar bone as well as the status of

the gums. As previously mentioned, the dentist then uses advanced 3D imaging to create a digital plan to ensure a precise and appropriate treatment plan for the patient. Second, a surgical guide must be created adapted to the patient's mouth. This guide provides an indication of the positioning, depth and expected angle to control the trajectory during the drilling. During the placement, the surgeon only has to perform the drilling without flap by simply following the pre-planned canals (13). But this surgery, being a subset of CAIS, could still in some cases performs flapless approaches with a shorter procedure and reduced patient morbidity. Some studies show the importance of keratinized tissue to increase the stability and duration of an implant. In this fact, this flapless or minimal flap surgery offers numerous advantages when compared to conventional surgery (13). It is important to notice that this surgery, at the time of drilling, can induce thermal damage following external irrigation. This causes an inability to handle soft tissues during the procedure (9). Indeed, the advancement of new technologies, guided surgery will become more present in the daily life of the dentist.

1.3. Justification: the need for comparative analysis in implantology

1.3.1. From manual to digital

Nowadays, the use of implant is becoming increasingly important both to replace one or more missing teeth and to improve the patient's aesthetic function (14). Implantology is still improving, thanks to the use of digital technology in both implant placement and treatment planning. These systems are based on scanners and 3D surgical guided, this is referred to the guided surgery (13). This surgery is often presented as a less invasive alternative which provides more on the surgeon's experience, anatomical knowledge and visual assessment during the procedure. Indeed, the main idea behind this surgery is to reduce operating time to minimize the risk of damage to anatomical structures (nerves or sinuses). It allows the surgeon to adapt to preoperative problems such as tissue pathologies, it allows for clear visualization of the amount of bone, it is less expensive and it is easier to implement (15).

According to the literature, these two surgeries have been compared but their results appear controversial. In fact, some studies show that guided surgery is facing the previous advantages, while others find no difference in terms of complications, satisfaction, or correct placement. It is important also to discuss the cost of these methods. However, guided surgery requires additional digital equipment and software, which is not always justified, especially for simple cases or single implants. Even, with different result, it is essential to compare these two surgeries through published clinical studies. This allows us to assess, which technique offers the best balance between precision, efficiency and accessibility, for both clinicians and patients.

1.3.2. The role of new technologies in the future of dentistry

This topic is also relevant to the future of dentistry, as a profession that moves toward digital workflow. It will be necessary to understand the benefits and limitations of the new technologies.

2. OBJETIVE

2.1. Main objective

Analyze in patient requiring implant the accuracy and clinical outcomes of guided surgery in comparison to conventional surgery in a systemic review.

2.2. Specific objectives

- Evaluate the accuracy and deviation in implant positioning using guided surgery and conventional surgery.

- Determine the differences in the bone resorption between guided surgery and conventional surgery.

- Assess the aesthetic results and patient comforts obtained with guided surgery and freehand surgery.

- Analyze the differences in postoperative bleeding, inflammation and pain between guided and conventional surgical technique.

- Study the survival rates and long-term results of implants placed with guided technique and with freehand technique.

3. MATERIAL AND METHODS

This systemic review was realized in accordance to the guidelines of Preferred Reporting items of systematic reviews and Meta-analyses (PRISMA).

3.1. PICO question

The PICO framework for this study was as follows:

In patients requiring implants (P) it is beneficial to use guided surgery (I) or conventional surgery (O) for a better patient-reported outcomes (C)?

Population	**Patient older than 18 years old requiring dental implant**. **#1-** ((dental implant) OR (end osseous patient)) OR (dental implants))
Intervention	**Implant planning using guided applications for surgical placement**. **#2**((guided surgery) OR (guided placement in implantology)) OR (computer guided) **#3**(computer aided surgery) OR (computer assisted surgery)
Comparison	**Conventional (non-guided) treatment for implant planning.** **#4** ((dental placement) OR (conventional surgery)) OR (implant surgery)
Outcomes	**Patient-reported outcomes : accuracy of implant positioning, patient satisfaction, implant survival and complications** #5 ((patient outcome assessment) OR (patient centered outcomes)OR (satisfaction)) #6 ((Implant survival) OR (complications)) #7 ((implant positioning) OR (implant angulation)) #8 ((economics) OR (costs, cost analyze))
Search combination	**(#1 or #4) AND (#2 or #3) AND (#5 or #6 or #7 or #8)**

Table 1. Search according to the PICO question.

3.2. Search Strategy

A search strategy was developed based on the PICO question and applied on the electronic search: Medline, PubMed (table 1). This search strategy was elaborated using free-text words and medical subject heading. The following research is on PubMed: ((dental implant) OR (end osseous patient)) OR (dental implants)) OR ((guided surgery) OR (guided placement in implantology)) OR (computer guided) OR ((dental placement) OR (conventional surgery)) OR (implant surgery) OR ((patient outcome assessment) OR (patient centered outcomes) OR (satisfaction)).

3.3. Eligibility criteria

3.3.1.Inclusion criteria

The inclusion criteria consist of:

- **Study design:**
    - Comparative studies
    - Case reports, case series
    - Clinical trials and
    - Randomized controlled trials
    - Publications in English, Spanish or French published between 2015 and 2025
- **Patients:** Adult receiving dental implant (more than 18 years old, healthy or with specials needs).
- **Intervention:** Studies containing information about guided surgery, free-hand surgery, conventional surgery, CAIS surgery in implantology.
- **Outcomes variables:** Studies that present at least one outcome (patient satisfaction, angulation of the implant, deviation of the implant, position of the implant, position of the implant, cost, complications, bleeding, pain).

3.3.2.Exclusion criteria

Exclusion criteria consist of:

- **Study design:**
    - In vitro studies
    - Systemic studies

- Cross-sectional retrospective studies
- Retrospective or prospective cohort studies
- Publications in other languages published before 2010

- **Patients:** less than 18 years
- **Outcomes variables:** studies without outcomes measurables.

4. RESULTS

4.1. Study selection

A total of 458 articles were obtained from the primary search on PubMed guided (n=458). Before screening, 4 duplicate records were removed, resulting in 454 that became available to screening. During the screening phase, 422 records were excluded for the following reasons: In vitro study (n =68), systematic review (n=42), case report (n= 41), meta-analysis (n= 27), cohort study (n=19), review analysis (n=50), trials (n= 44), retrospective study (n=12), observational study (n=19),animals studies (n=44), others (n=56). After the screening process, 32 reports were obtained and carefully assessed. Among them 14 where not retrieved due to: Not full text available (n = 6), different languages (n=8). As a result, 19 studies were finally included in this review.

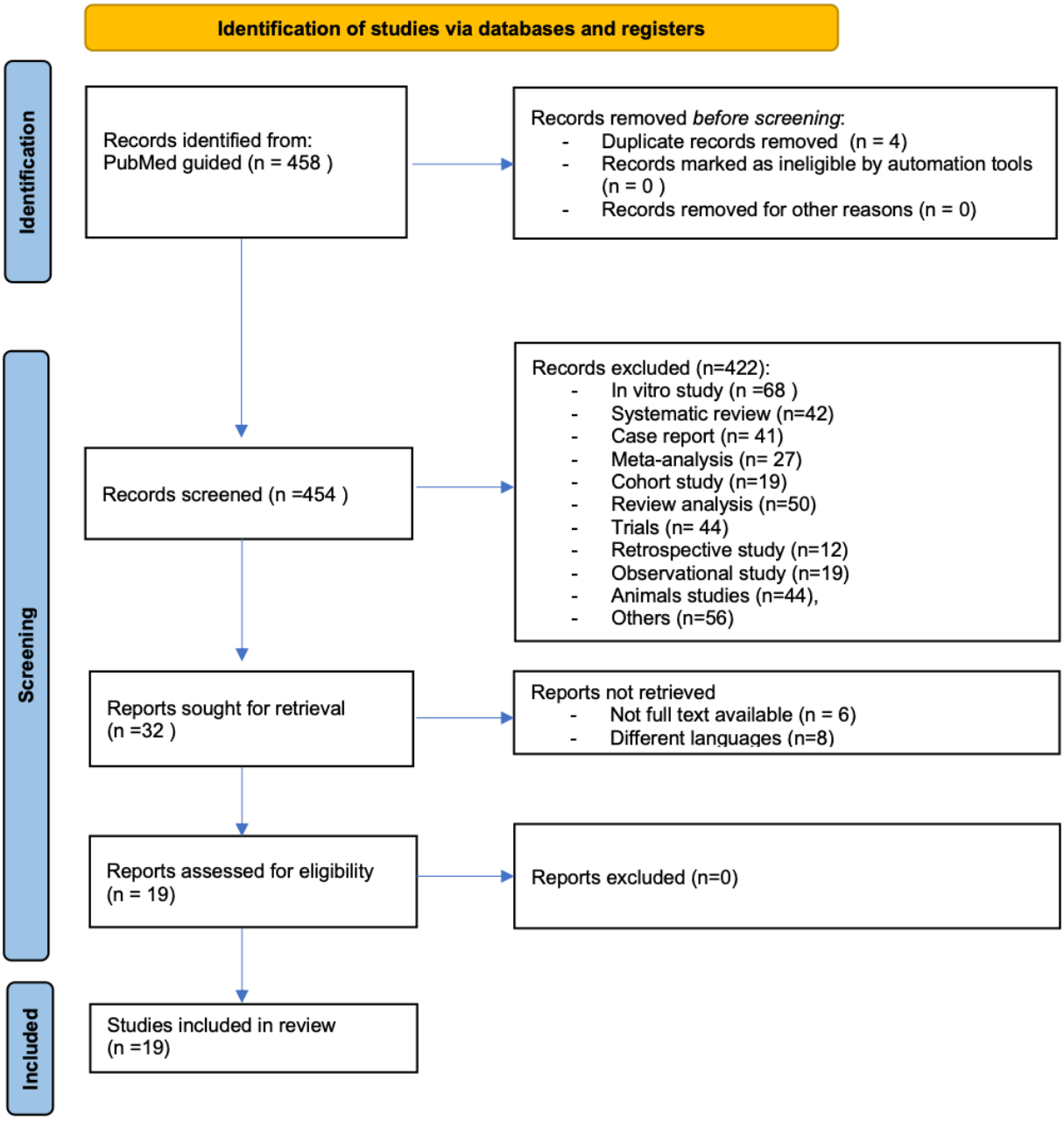


Figure 2: PRISMA flow diagram of the search flow and title selection process during the systematized review.

Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372: n71.doi:10.1136/bmj.n71

4.2. Summary of results

	Author, years, title	Study design	Follow-up time	Number of patients	Age range (years old)	Type of patients	Conventional surgery	Guided surgery	Implant survival in GS	Implant survival in CS
1.	**Lixuan Huang**, Evaluation of the accuracy of implant placement by using implant positional guide versus freehand: a prospective clinical study (2023) (16)	Prospective clinical study	Not applicable (Only immediate CBCT post-Surgery)	48	18–65 years old	Single-tooth cases	24	24	Not reported	Not reported
2.	**Lucas Massaru Nomiyama,** Comparison between flapless-guided and conventional surgery for implant placement: a 12-month randomized clinical trial (2023) (7)	Randomized, controlled, double-blind, split-mouth clinical trial	12 months	29 (1 out of follow-up)	18-76	6 implants in each patient (3 in each side of maxillary bone)	Installed implant: 87 Analyzed implants: 86	Installed implant 87 Analyzed implants: 86	1 implants loss (survival 98,8%)	2 implants loss (survival rates 97,6%)
3.	**Gabriel L. Magrin,** Clinical and tomographic comparison of dental implants placed by guided virtual surgery versus conventional technique. (2019)(15)	Split-mouth randomized clinical trial	1 week (immediate)	12	mean 42	Bilateral single-tooth posterior mandible	12	12	100%	100%

4.	**Chatchai Kunavisarut,** Patient-- reported outcome measures comparing static computer-- aided implant surgery and conventional implant surgery for single-- tooth replacement: A randomized controlled trial. (2021) (14)	Randomized Controlled Trial	Post-op immediate 1week	40	51.71 years	Single posterior tooth (premolars/ molars)	20	20	Not reported	Not reported
5.	**Nitin Verma:** Cone Beam Computed Tomography-Based Evaluation of the Accuracy of Implant Surgery with Conventional (Free Hand) Implant Placement vs Computer Fabricated 3D Guide Implant Placement. (2023) (17)	Comparative split-mouth study	6 months	20	more than 18 years	Bilateral partial edentulism	20	20	100%	100%
6.	**Andrea Ravidà,** Clinical outcomes and cost effectiveness of computer-guided versus conventional implant-retained hybrid prostheses: A long-term retrospective analysis of treatment protocols. (jan 2018) (18)	Retrospective comparative study	Minimum: 5 years, Mean: 9.6 years	45	58.9 ± 13.1	Fully edentulous patients with 4–8 implants per arch	19	26	96.7%	80.2%

7.	**Yingkai Wang, DDS, PhD,** Accuracy of Intraoperative Measuring Guide and Conventional Surgical Guide in Anterior Implant Surgery: A Retrospective Case-Control Study. (2023) (19)	Retrospective Case-Control Study	September 2020 – August 2021	47	more than 18 years	Single anterior implant	23	24	100%	100%
8.	**Fausto Frizzera, DDS, MSc, PhD,** Flapless Guided Implant Surgeries Compared with Conventional Surgeries Performed by Non experienced Individuals: Randomized and Controlled Split-Mouth Clinical Trial. (May 2021) (20)	Randomized and Controlled Split-Mouth Clinical Trial	1week of follow-up	10	more than 18 years	Split - mouth: 2implants CS+ 2 implants GS = 4 implants per patient	10	10	100%	100%
9.	**Alessandro Pozzi,** Computer-guided versus free-hand placement of immediately loaded dental implants: 1-year post-loading results of a multicenter randomized controlled trial. (2014) (21)	Randomized controlled trial	1-year post-loading	51	63.06 years mean	22 single implants 29 edentulous patients	103	99	100%	99% 1 implant loss

10.	**Anik Sarkar,** Surgical Stent Guided Versus Conventional Method of Implant Placement. (2022) (22)	Case–control comparative clinical study	Control of bone loss at 6 months	20	15 to 60 years old	Single implant per patient (one per group: guided or conventional)	10	10	100%	100%
11.	**Manuel Sancho-Puchades,** A Randomized Controlled Clinical Trial Comparing Conventional And Computer-Assisted Implant Planning and Placement in Partially Edentulous Patients. Part 2: Patient Related Outcome Measures. (2019) (23)	Randomized Controlled Clinical Trial	7 days after operation	73	more than 18 years	Partially edentulous patients	26	47	100%	100%
12.	**Diego Lops,** Guided versus freehand single implant placement: A 3-year parallel randomized clinical trial. (2024) (24)	Parallel randomized clinical trial	3 years	18	22–84 years	Partially edentulous, single implants only	30 implants	30 implants	100%	100%
13.	**David Schneider,** A Randomized Controlled Clinical Trial Comparing Conventional and Computer-Assisted Implant Planning and Placement in Partially Edentulous Patients. Part 3: Time and Cost Analyses. (2019) (25)	Randomized Controlled Clinical Trial	No follow-up -time analysis -economic analysis	73	more than 18 years	Partially edentulous patients	26	47	100%	100%

14.	**David Schneider,** A Randomized Controlled Clinical Trial Comparing Conventional and Computer-Assisted Implant Planning and Placement in Partially Edentulous Patients. Part 4: Accuracy of Implant Placement. (2019) (26)	Randomized Controlled Clinical Trial	No follow - up -Only accuracy	73	More than 18 years	Partially edentulous patients	26	47	100%	100%
15.	**Leonardo Amorfini DDS,** Implant rehabilitation of the esthetic area: Five-year retrospective study comparing conventional and fully guided surgery. (2023) (13)	Retrospective clinical study	5 years	44	38-74 years old	Maxillary esthetic zone, single-tooth implants	20	24	100%	100%
16.	**Thanida Yotpibulwong,** Accuracy of implant placement with a combined use of static and dynamic computer-- assisted implant surgery in single tooth space: A randomized controlled trial. (2023) (27)	Randomized controlled trial	No follow-up (only accuracy)	120	More than 20 years	Partially edentulous	30	90	Not reported	Not reported
17.	**Priya Nagar,** Comparative Study of Implant Placement Techniques and Their Effect on Long-Term Success of Implant-Supported Restorations. (2024) (28)	Randomized Controlled Trial	3 years	120	25-75 years old	1 implant for each patient	40	40	Not reported (but lowest bone loss + highest stability + lower complications suggest near 100%)	Not reported

18.	**Marco Tallarico,** Computer-guided vs freehand placement of immediately loaded dental implants: 5-year post- loading results of a randomised controlled trial. (2018) (29)	Randomized controlled trial	5 years	20	28-84 years old	Partially or fully edentulous patients needing more than 2 implants under the same prothesis.	30	32	100%	94,4% (2 failed implants)
19.	**Endre Varga Jr,** Guidance means accuracy: A randomized clinical trial on freehand versus guided dental implantation. (2020) (30)	Randomized Clinical Trial (RCT)	No follow-up (only accuracy)	101	24-82 years old	Partially edentulous patients only	18	15	Not reported	Not reported

Table 2: Overview of study characteristic for trials evaluating guided versus conventional implant surgery.

We were able to compare 19 studies, that appears in this first table of the results. Each article compares guided (GS) and conventional (CS) implant surgery. We can notice that they conducted randomized controlled trials, case controls clinical study and comparative study. The duration of patient follow-up varied from 7 days to 5 years post-placement. Patient were over 18 years old, but often over 50 years on average. Some patients were followed for a single implant placement, while others were followed for multiple implants. Finally, regarding the results in this table, most studies compare implant survival for both types of implant placement.

Studies	Types of surgery (GS or CS)	Coronal linear deviation (mm)	Apical linear deviation (mm)	Correct angular deviation (mm)	Implant complications	Prothesis complications	Conclusions
1.	GS	0.48 ± 0.26	0.97 ± 0.39	2.36 ± 1.70	Not reported	Not reported	→ GS better accuracy with huge difference in angular deviation
	CS	1.07 ± 0.44	1.44 ± 0.63	4.31 ± 3.37	Not reported	Not reported	
2.	GS	2.01 ± 0.77	2.41 ± 1.45	2.39 ± 0.79	Not reported	Not reported	→ GS better accuracy with huge difference in angular deviation
	CS	2.27 ± 1.05	2.87 ± 1.36	6.6 ± 3.15	Not reported	Not reported	
3.	GS	2.34 ± 1.01	2.53 ± 1.11	2.2 ± 1.1	0	2 technical (1 bone wall fracture, 1 driver fracture)	→ GS better accuracy → CS no prosthesis complications
	CS	1.93 ± 0.95	2.19 ± 1.00	3.5 ± 1.6	0	Not reported	
5.	GS	2.164 ± 0.92	4.084 ± 1.88	14.632 ± 8.69	0	none	→ GS better accuracy
	CS	1.996 ± 1.13	3.522 ± 1.66	11.891 ± 7.53	0	0	
7.	GS	0.67 ± 0.44	0.93 ± 0.40	2.27 ± 0.96	No failures, no peri-implant issues	None	→ GS shows better coronal and apical accuracy
	CS	1.10 ± 0.66	1.34 ± 0.66	2.51 ± 1.19	No failures, no peri-implant issues	None	
10.	GS	0.08 ± 0.05	Not reported	2.05° ± 1.32°	None	None	→ GS provide better position
	CS	0.50 ± 0.37	Not reported	6.10° ± 3.08°	None	None	
14.	GS	0.72 ± 0.31	1.08 ± 0.57	3.13° ± 2.12°	Not reported	Not reported	→ GS provide better accuracy (lower coronal, apical and angular deviation)
	CS	1.25 ± 0.62	2.32 ± 1.24	7.36° ± 3.36°	Not reported	Not reported	
16.	GS	0.62 ± 0.50	0.75 ± 0.57	1.24 ± 1.41	Not reported	Not reported	→ GS provide better accuracy (lower coronal, apical and angular deviation)
	CS	1.48 ± 0.68	2.18 ± 0.95	7.50 ± 4.06	Not reported	Not reported	
19.	GS	Much lower errors	Much lower errors	3.04° ± 1.51	Not reported	Not reported	→ GS shows lower errors in all accuracy
	CS	highest errors	highest errors	7.03° ± 3.44	Not reported	Not reported	

Table 3: Comparison of implant positioning errors and complications in Guided Surgery. (16), (7), (15), (17), (19), (22), (26), (27), (30).

This table examines 9 of the 19 studies comparing criteria for guided and conventional surgery. These criteria are angular, apical and coronal deviations. We can highlight also the complications related to prosthetic devices and implants. Based on this studies, guided surgery demonstrates lower linear coronal and apical deviations, as well as a lower angular deviation. In fact, conventional surgery is subject to more angular errors, sometimes double or triple those of guided surgery.

Focusing on complications, we observe that implant related complications are not often studies, but when they are reported, we don't observe peri-implant issues or implants failures in either group. Furthermore, prosthetic complications are minimal, but one of them show a complication due to a bone fracture and another due to driver fracture. To summarize, we can state that across the 9 studies, guided surgery has a lower coronal and apical deviations, better overall implant positioning, reduced angular deviation and lower overall placement errors.

Studies	Types of surgery (GS or CS)	Pain after surgery (type of measurements)	Pain Results	Bleeding after surgery (type of measurements)	Bleeding results	Cost status (type of measurements)	Costs Results	Conclusions
2.	GS	Not reported	-	Not reported	-	Qualitative	Higher	→ GS more expensive.
	CS	Not reported	-	Not reported	-	Qualitative	Lower	
3.	GS	Categorical (none/few/ moderate/intense)	22.2 % none / 55.6 % few / 22.2 % moderate	Qualitative	Slightly less in GS	Qualitative	Higher (complex system & software)	→ GS shows less bleeding and milder pain distribution. → CS less expensive
	CS		11.1 % none / 55.6 % few / 22.2 % intense		more than with GS		lower	
8.	GS	VAS 0-10 (mean ± SD)	1.17 ± 0.72	Not reported	-	Not reported	-	→ GS shows milder pain distribution
	CS		4.62 ± 2.17		-		-	
9.	GS	VAS 0-10 (mean ± SD)	0.32 ± 0.56	Not reported	-	Numerical	+ €646	→ GS shows less postoperative pain → CS les expensive
	CS		0.92 ± 0.74			Not reported	-	
11.	GS	No reported	No difference GS vs CS	VAS 0-100 mm	100mm	Not reported	-	No significant differences
	CS				100mm		-	
13.	GS	Not reported	-	Not reported	-	Numerical	CHF 1,946 (+20%)	→ GS considerably more expensive
	CS		-		-		CHF 1,567	
15.	GS	VAS 0-10 (comparative)	GS better at 1W and 6W ($p < 0.001$)	Not reported	-	Not reported	-	→ GS provides better postoperative pain outcomes vs CS.
	CS				-		-	

Table 4: Clinical and economic outcomes of guided surgery: pain, bleeding and cost analysis in GS vs CS.

This table allows us to compare 7 studies based on different criteria (bleeding, pain, cost...). When examining postoperative pain, most studies describe a low level of pain for guided surgery. Some compare pain using Visual Analogue Scale (VAS), and the result is similar, with a lower level for guided surgery compared to conventional surgery. Focusing on the study *Leonardo Amorfini DDS*, we can state that the difference is significant also indicating a reduction in early postoperative discomfort. The study of *Gabriel L. Magrin***,** describe the categorical pain, reports a moderate pain distribution for guided surgery and few refers severe pain. Pain measurements are quite heterogenous, and some studies report no data. The study of *Manuel Sancho-Puchades,* reports no difference in pain between the two surgical procedures.

When we compare the bleeding criterion, studies place less emphasis on this criterion. One study describes low bleeding for the guided surgery, which id likely due to the flapless or minimally invasive approaches used in guided surgery. However, we must not that these studies do not describe quantitative bleeding data, in fact the measurements are qualitative. Therefore, it is quite limited to establish a true comparison.

Cost analysis describes guided surgery as more expensive than conventional surgy. This is due to the materials needed for guided surgery such as digital planning software, surgical guide fabrication and additional technological requirements. However, its important to notice that these studies do not focus on the long-term economic implications.

12.	**Marginal Bone Level T3**	**Probing Depth (PPD) mm**	**Plaque Index (PI) mm**	**Bleeding on Probing (BOP)**	**STH (Supra-crestal Tissue Height) <3 mm**	**Conclusions**
GS	0.35 ± 0.47 mm	4.34	53.7%	47.5%	No difference	Very similar peri-implant outcomes; no clinically relevant differences between GS and CS.
CS	0.23 ± 0.75 mm	4.32	47.5%	40.7%	No difference	

Table 5: Peri-implant clinical parameters at T3: Comparison between Guided Surgery and Conventional Surgery. (24)

This study compares peri-implant clinical parameters by including marginal bone level at 3 months, probing depth, plaque index, bleeding on probing and supra-crestal tissues height in

guided surgery and in conventional surgery. This study suggests that both techniques show comparable surgical stability at the peri-implant level.

15.	Marginal Bone Level (MBL) 3Y	Marginal Bone Level (MBL) 4Y	Marginal Bone Level (MBL) 5Y	Aesthetic outcomes PES/WES	Conclusions
GS	0.52	0.53	0.59	Higher PES/WES at 3Y (p=0,023), stable esthetic improvement 4-5Y.	GS → Superior esthetics with similar long-term bone stability vs CS
CS	0.43	0.49	0.56	Lower PES/WES, less esthetic evolution.	

Table 6: Assessment of Marginal bone loss and aesthetic outcomes at 3, 4 and 5 years old follow up in Guided and Conventional Surgery. (13)

This study of *Leonardo Amorfini DDS,* show that guided surgery offers aesthetic advantages in the first few years (3years). The maintenance of bone stability is comparable to conventional surgery. The marginal bone level is quite similar in both surgeries.

17.	Bone loss 3 yrs (mm)	Satisfaction 3 yrs	Complications (%)	Implant Stability (ISQ values) 6 months	ISQ 1 yr	ISQ 3 yrs	Conclusions
GS	0.6	9.3	5%	76.5	78.0	79.3	GS>CS: less bone loss, higher satisfaction, fewer complications, higher ISQ
CS	1.2	8.3	15%	71.8	73.5	74.1	

Table 7: Comparison of bone loss, patient satisfaction, complications and implant stability in Guided Surgery and Conventional Surgery. (28)

This study suggests that GS could lead to fewer complications, greater patient satisfaction, improved implant stability and reduced bone loss.

18.	Marginal bone loss 1 yr	Marginal bone loss 5 yrs	Post-op pain (Ordinal Scale 0–3)	Post-op swelling (Ordinal Scale 0–3)	Patients satisfied (aesthetics)	Complication time	Conclusions
GS	0.63 mm	0.87 mm	0	0	100%	18.5 min	GS>CS: Less bone loss, less pain, swelling, faster, same esthetic
CS	0.85 mm	1.29mm	1	1	100%	26.5 min	

Table 8: Comparison of early and long-term outcomes between Guided Surgery and Conventional Surgery. (29)

This study shows that Guided surgery provides less bone loss, less pain and same esthetic.

5. DISCUSION

This study allows us to compare guided surgery and conventional surgery in a systemic review, focusing on implant placement, complications, patient outcomes and economic considerations. The major clinical concerns in implantology are based on the previously mentioned criteria. This study was conducted by collecting data using the PRISMA protocol. Following the 19 studies selected with a single reviewer, we were able to develop comparisons to follow our objectives.

5.1. Implant positioning accuracy

Across the articles, nine of the study allowed us to compare apical, coronal and angular deviations. Indeed, the results show that guided surgery demonstrated superior positional accuracy. In the study of *Gabriel L. Magrin,* for example, the coronal linear deviation (mm) is 2.34 ± 1.01 in GS and 1.93 ± 0.95 in CS, the apical linear deviation (mm) is 2.53 ± 1.11 in GS and 2.19 ± 1.00 in CS, the angular deviation (mm) is 2.2 ± 1.1 in GS and 3.5 ± 1.6 in CS (15). This study shows us that guided surgery offers the advantage of more precise control over the implant angulation. This represents a relevant factor for achieving better prosthetic results. It is important also to emphasize that the difference between the two studies is still small, therefore we need to evaluate each criterion independently to obtain more concrete results. The observations are the same in the study of *Park*, in which very little significant difference was observed between the two methods. This study also shows us that no significant difference was found between the groups regarding implantation sites, regardless of the parameter (31). The study of *Varga* demonstrates that the greater the level of guidance, the closer the actual position is to the planned position. Indeed, this similarity suggests that guided surgery (fully or partially guided) is more precise than freehand surgery (30). The previous systematic study of *Joscha G.Wermy*, however reveals significant differences in angular deviation between the two surgical methods. Indeed, the guided method (s-Cais) method demonstrated greater precision compared to the freehand technique (3).

Furthermore, implant positioning errors represent a large proportion of errors that could be observed in implantology (17). It is essential to verify the correct implant positioning to maintain the prosthetic phase to avoid aesthetic complications of the restoration, maintain a correct vascularization and reduce bone resorption in order to assess long-term stability of peri-implant hard and soft tissues (30).

Even if the guided surgery is observed with smaller data sets, we must still interpret these findings with caution because we can observe that in some studies conventional surgery also falls within accepted margin of deviation to have a correct implant placement. In fact, experienced surgeons can maintain correct positioning without guided surgery. Implant survival and biological outcomes

When comparing both techniques, we observed a success rate of almost 100% during medium and short-term follow-up. While some differences were present, they were minor (29), (21). As well, long-term data proved similar between the two groups. The study of *Marco Colombo*, also concludes that survival rate and effectiveness of implants are almost identical between the two surgeries (11). Some articles, such as *A Pozzi*, also discuss survival rate and marginal bone remodeling after 5 years and they seem to suggest that survival rate in edentulous patients is close to 100% with guided surgery (32).

Similarities between the two groups (GS and CS) were also observed regarding peri-implant parameters, such as bleeding on probing, and marginal bone loss. Furthermore, at 3 to 5 years follow-ups, the differences in marginal bone stability were quite small but higher in the implant placed with guided surgery (29), (30).

Guided surgery allows for a clear improvement in implant placement accuracy, but these 19 studies do not show significant long-term biological results.

5.2. Patient-reported outcomes

Some studies describe improved clinical outcomes with guided surgery. Indeed, postoperative pain is reduced (VAS, categorical), as bleeding also and discomfort during the healing process is improved (21), (20), (13), (15). Guided surgery reduces surgical trauma, which significantly decreases inflammation and promotes better recovery. It is also important to note that some studies have not demonstrated these improvements and do not reveal significant differences between the two surgical procedures. Since the results are not heterogenous, it becomes difficult, but some studies suggest that guided surgery offers a significant advantage in terms of postoperative pain. Somes articles such as the one from *Pozzi*, have found in their conclusions that intense pain was found after 3 days for implants places with conventional surgery with open flap even though in the other guided group without flap the cases were more complex and more edentulous (32).

5.3. Aesthetic and prosthetic outcomes

In the study of *Leonardo Amorfini DDS,* which evaluates aesthetic outcomes (PES/WES score), guided surgery shows superior results particularly at 3 years. Marginal bone stability is similar between the two groups (GS and CS) (13). In the study of *Sidhartha Tomar* the results demonstrates that guided surgery is suggested in certain complex situations or that aesthetics is one of the major points of surgery, however this study also suggests that conventional surgery is recommended in simpler situations (33). Guided surgery offers excellent 3D positioning, which could improve soft tissue management and ensure good prosthetic emergence in the maxillary aesthetic zone.

Current literature shows that when we considered the esthetic criterion, the expected results are less pronounced. Some studies, such as those by *Ahmed Kotb* and by *Joscha G.Werny*, found no statistically significant difference between guided and conventional implant placement. This indicates that, despite significant precision, guided surgery does not necessarily translate into superior aesthetic results (34), (3). Furthermore, the systematic studies confirm that, while guided surgery improves the accuracy of implant positioning, the aesthetic parameters appear to remain comparable to freehand techniques. This can be explained by the rather broad nature of aesthetic in implantology, which depends not only on implant position but also on soft tissue management, bone quality, prosthetic design, and the experience of the surgeon. Indeed, even if guided surgery promises a more predictable outcome, its impact on aesthetic is rather variable and without significant difference compared to freehand surgery.

5.4. Economic considerations

Following various comparisons of studies, guided surgery involves higher costs than conventional surgery, up to 20% higher according to some studies (25), (21). Indeed, the guided surgery system with CAIS systems provides much greater precision but *Emery R.W*, looks further into subject and concludes that the complexity of the work and the significant cost have hindered wider adoption (35). However, *Tim Joda* concludes in his article that economic effects as well as the time saved on treatments remain quite uncertain (5).

Indeed, the fabrication of surgical guides and digital planning represent higher initial costs. However, it should be considered that guided surgery can reduce the cost of potentially complex

procedures resulting from incorrect implant placement when considering the overall economic impact. Therefore, we can conclude that guided surgery may be expensive initially but can be justified in certain complex cases with high aesthetic expectations. Its economic value appears to be context-dependent, potentially offering greater benefits in complex cases requiring high precision, while in straightforward cases, conventional surgery may remain a more cost-effective option.

5.5. Interpretations

The variability observed between different studies comparing guided and conventional surgery can be explained by several methodological and clinical factors. The choice of surgical protocols, such as the use of fully or partially guided systems or static or dynamic navigation, can significantly influence the accuracy of the results. Furthermore, in the study of *Abdelhay N* the type of guided support (dental, mucosal or osseous) impacts stability and accuracy during implant placement (36). The experience of the surgeon is another factor. Conventional surgery is perfectly suited to experienced surgeons and offers the same advantages when performed correctly over the long term. Moreover, the complexity of the cases varies, particularly in patients who are completely or partially edentulous (37). It is important to highlight that guided surgery allows for greater precision in implant placement and improves the patient's perception of pain and comfort. Measurement methods also differ; it is true that some studies use CBCT analysis while other use digital surface scans (38). Furthermore, guided surgery involves multiples technical steps, each introducing potential sources of cumulative error, from image acquisition to guide fabrication and positioning. It is essential also to consider certain criteria before choosing between the two surgical approaches such as: anatomical complexity, aesthetic, patient expectations, cots and surgeon experience.

5.6. Limitations

Following this study, we can consider certain limitations we encountered, including variability in follow-up duration, heterogeneous study (randomized controlled trials, split-mouth studies) that also limits the ability to draw conclusions regarding implant survival and long-term esthetic outcomes. Furthermore, some of the included studies presented relatively small sample size, potentially reducing the statistical power of the finding. And many studies primarily evaluated accuracy rather than long-term biological outcomes, which limits definitive conclusions regarding the clinical superiority of guided surgery.

Therefore, the discrepancies that may have been observed in this study can be explained by methodological differences, some variability in surgical protocols or limitations in guidance systems, which reinforces the idea that guided surgery should not be considered universally superior but rather context dependent.

Therefore, the results of this study should be interpreted with caution and further high-quality, long-term randomized controlled trials are needed to confirm these finding.

6. CONCLUSIONS

1. Guided surgery is relatively more precise than conventional surgery. Overall, guided surgery represents a valuable advancement in implantology, especially in certain cases requiring higher precision. However, conventional surgery remains a reliable and widely used technique.
2. Indeed, the results demonstrate higher accuracy in implant positioning (coronal, apical and angular deviation), allowing guided surgery to achieve more promising long-term prosthetic results.
3. Also, the differences in marginal bone stability were quite small but higher in the implant placed with guided surgery.
4. Guided surgery improves the patient's perception of pain, comfort and aesthetic. It is important to emphasize that guided surgery has an additional cost that must be justified by the complexity of the patient's case.
5. Guided surgery reduces certain surgeon errors and minimizes some pain and inflammation, but it does not eliminate all surgical variability.
6. We can also conclude that both techniques have a very high implant survival rate and good long-term results when conventional surgery is performed by an experiences surgeon. Guided surgery can be considered in some complex cases.

7. SUSTAINABILITY

In the healthcare sector, implant sustainability depends on several factors, including the environment, economic efficiency and clinical effectiveness.

From an environmental perspective, guided surgery contributes to sustainable development by offering greater precision in implant placement and significantly reducing long-term errors. This surgery therefore reduces material consumption and produces time thanks to its precision, as well as the need for further surgical interventions or implant modifications.

From an economic perspective, guided surgery requires higher initial costs (digital planning, surgical guided), but it leads to significant long-term efficiency. This can optimize resource utilization in dental clinics and reduce overall healthcare costs associated with implant failures or prosthetic corrections.

From a social and patient-centered perspective, guided surgery improves patient comfort, reduce postoperative pain and shorten recovery time. This contributes to better patient experience and facilitate access to safer and more predictable treatments.

Therefore, this research can support the development of more sustainable decision-making in implantology by providing evidence on situations where guided surgery offers real clinical advantages over conventional techniques. Promoting evidence-based treatment planning can help clinicians balance technological innovation, clinical effectiveness and responsible use of healthcare resources.

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9. ANNEXES