Int. J. Odontostomat.,
19(4):437-446, 2025.

Surgical Guidancea and other Prognostic Factors in the Long-Term Success of Dental Implants

Guía Quirúrgica y otros Factores Pronósticos en el Éxito a Largo Plazo de Implantes Dentales

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VALENCIA-METAUTE, A. M.; SALAZAR-PUERTA, M. J.; ZAPATA-RESTREPO, M.; MURILLO-MALDONADO. L. D.; BETANCUR-TOBON, S.; SOSA-LOPEZ, S.; TOVIO-MARTINEZ, E. & BENITEZ-MORENO, L. F. Surgical guidance and other prognostic factors in the long-term success of dental implants. *Int. J. Odontostomat., 19(4)*:437-446, 2025.

ABSTRACT: Dental implants are a widely used method for oral rehabilitation, consisting of prosthetic elements surgically placed into the alveolar bone to replace missing teeth. The biological process critical for implant success is osseointegration, which establishes a strong and stable bond between titanium and the surrounding bone. The objective of this study was to evaluate the long-term success rates of dental implants placed with surgical guidance compared to those placed without guidance, using three different commercial implant systems, in a dental clinic in Medellín during the period 2011-2021. A retrospective observational study was conducted involving 234 patients, in which sociodemographic characteristics, radiographic parameters, and established criteria for implant success were analyzed. Data were collected using Microsoft Excel, and statistical analysis was performed with the chi-square test in Jamovi. A total of 499 implants were evaluated in these 234 patients. The most common systemic conditions were cardiovascular disease and diabetes. Fifty-six percent of the implants were placed in the maxilla, with implant site 36 exhibiting the highest success rate. Surgical guides were employed in 89.8 % of cases, resulting in success rates of 93.3 % for guided implants and 98 % for unguided implants, with no statistically significant differences between the groups. Overall, 64.9 % of implants were successfully rehabilitated. Radiolucency was observed in 87.1% of failed implants, whereas only 3.2 % of failures occurred in smokers, suggesting that additional factors may influence implant outcomes. No significant differences were observed in the success rates between implants placed with and without surgical guides, although there was a trend favoring guided placement. The high rate of guide utilization indicates their potential positive impact on implant rehabilitation. These findings highlight the importance of comprehensive clinical and radiographic assessment in treatment planning to optimize implant outcomes and long-term success.

KEYWORDS: Computer assisted surgery, dental implants, maxillary, oral surgery, osseointegration.

INTRODUCTION

Dental implants represent a cornerstone in oral rehabilitation, serving as prosthetic elements surgically placed within the alveolar bone to replace missing teeth. This process, known as osseointegration, establishes a stable and durable bond between the implant and the surrounding bone (Pandey *et al*., 2022). Implant therapy has become the preferred restorative option, offering predictable functional and esthetic outcomes, and its use has increased steadily in contemporary dental practice (Alzahrani, 2020). In recent years, implant dentistry has experienced significant advancements, providing innovative solutions for the restoration of both smile esthetics and oral function. Tooth loss not only compromises facial appearance but also impairs essential functions such as mastication and speech, negatively impacting daily activities and exerting a psychological burden on patients (Nabbiya *et al*., 2023).

There are two primary techniques for dental implant placement, one of which is guided surgery. This method employs digital planning to ensure precise positioning of implants. Guided surgery is minimally invasive and utilizes a surgical guide, a prosthetic template that provides detailed visualization of the

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Received: 2025-05-02 Accepted: 2025-09-20

operative site based on preoperative imaging and planning (Afshari *et al*., 2022). This approach facilitates controlled and accurate implant insertion, reducing surgical time and minimizing postoperative discomfort and inflammation (Fávero Alves *et al*., 2023).

On the other hand, the conventional technique, also known as freehand surgery, involves placing the implant using radiographs or computed tomography as a guide, based on the angle and position determined by the operator. This approach relies primarily on the surgeon's experience and direct visualization of the surgical field. Upon completion of the procedure, a postoperative radiograph is obtained to confirm the accurate placement of the implants (Afshari *et al*., 2022; Fávero Alves *et al*., 2023).

Implant placement using traditional techniques involves making a full-thickness flap for direct visualization of the alveolar ridge that ensures the insertion of the implant according to the patient's anatomy (Lemos *et al*., 2020). This technique has proven to be very successful in dental practice, thanks to its effectiveness experienced surgeons often resort to this technique to achieve a high level of success without leaving behind the guided technique (Khaohoen *et al*., 2024). However, osseointegration depends on factors such as systemic alterations, medication consumption and patient habits (Aghaloo *et al*., 2019, D'Ambrosio *et al*., 2023), in addition to the characteristics of the implant biomaterial and its surface such as topography and roughness, as well as adequate bone quantity and quality, absence of surgical complications such as overheating of the bone in the bone bed instrumentation, or contamination during surgery, occlusal overload and peri-implantitis (Zhu *et al*., 2021; Wang *et al*., 2023).

The success criteria for dental implants have been widely studied and debated over the years, with the standards proposed by Schnitman & Shulman (1979) being among the most frequently cited in the literature, who established three fundamental criteria that serve as a reference for evaluating implant effectiveness: 1) the absence of implant mobility is essential, as any detectable movement may indicate impending failure; 2) the lack of peri-implant radiolucency on radiographs serves as a critical indicator of implant health, reflecting proper integration with the surrounding bone; 3) vertical bone loss should not exceed 0.2 mm per year after the first year of functional loading, providing a measurable parameter for long-term stability. Additional considerations include the absence of inflammation, infection, or pain, and no damage to adjacent anatomical structures. Also recommend functional survival rates of 90 % at five years and 85 % at ten years, establishing clear benchmarks for assessing long-term implant performance.

On the other hand, Albrektsson *et al*. (2017) have made significant contributions to the understanding of success criteria in implant dentistry, Schnitman & Shulman (1979) emphasize the importance of implant stability, particularly in terms of freedom from mobility and the health of peri-implant tissues. Additionally, the absence of pain or infection related to the implant, along with the implant's ability to facilitate proper esthetic placement of the prosthesis, are crucial factors. Albrektsson *et al*. (2017) also sets similar success expectations, with survival rates of 85 % at five years and 80 % at ten years.These criteria play a fundamental role in guiding clinical practice and research in dental implantology, providing a robust framework for evaluating both the success and potential complications of dental implants. Ultimately, these standards ensure not only the viability of the implant but also patient satisfaction with their prosthetic restoration.

It is essential to consider the interplay between systemic and psychosocial factors in implant dentistry, as these may significantly influence implant failure. According to the criteria established by Misch *et al*. (2008), the implant failure indicators include pain upon palpation, percussion, or function; horizontal and/or vertical mobility; uncontrolled progressive bone loss; uncontrolled exudate; and peri-implant bone loss exceeding 50 %. These criteria facilitate the identification of clinical scenarios ranging from implants with mobility to those exhibiting substantial bone loss. Furthermore, Misch classifies implant failures according to their temporal occurrence: surgical, occurring during placement; early, within the first year; intermediate, between one and five years; late, after five years; and long-term, beyond ten years of function. A thorough understanding of these criteria and classifications is fundamental to improving implant success rates and ensuring optimal clinical outcomes for patients.

Despite advances in dental implant placement techniques, there remains a notable lack of robust scientific evidence comparing their relative success, as many studies fail to adequately distinguish between guided and conventional approaches (Rösing *et al*., 2019). Each patient presents unique clinical and anatomical considerations that must be carefully evaluated to ensure optimal treatment planning. While guided surgery may offer advantages in terms of

precision and reduced surgical trauma, its use should be justified based on individual patient needs (Do *et al*., 2020; Dutta *et al*., 2020). Accordingly, the present study aims to determine whether dental implants placed using surgical guidance demonstrate a significantly higher success rate compared to conventional placement, considering variables such as age, sex, and other sociodemographic factors, as well as clinical and radiographic parameters that define implant success.

MATERIAL AND METHOD

This is a retrospective study, as it evaluates existing implant data obtained from secondary sources, such as patient clinical records. It also has an analytical design, as it seeks to test a research hypothesis regarding the potential relationship between implant success and the use of a surgical guide. Furthermore, the study is observational, since data were recorded without any intervention, within a defined period.

This research was conducted in accordance with the principles of the Declaration of Helsinki (1964) and Resolution 8430 of October 4, 1993. The study is classified as minimal-risk research, as it is a retrospective analysis of secondary data, involving a review of clinical records of patients who received dental implants with or without surgical guidance. The phenomenon was observed over time without any intervention or intentional modification of the study population. This project was approved by the Program Committee of Institución Universitaria Visión de las Américas (World Medical Association, 2013; Lopera, 2017).

The study universe of the present research is comprised by the census of medical records of patients, 234 in total who met the inclusion criteria, who underwent implant surgery, with or without surgical guidance in a private clinic in the city of Medellin during the period 2011 -2021, being a documentary study of secondary source, there was no direct intervention in the subjects or ethical risks.

The inclusion criteria taken into account were the medical records corresponding to the study period between 2011-2021, which had the necessary documentation and complete information in implant placement processes, such as radiographs after implant installation, clinical record of post-implant control and signed informed consents, In addition to patients with implants performed of the three brands of interest Straumann, Bicon and Phibo , the use of surgical guide and the implant performed freehand, as exclusion criteria were not taken into account the clinical histories of patients who had implants, which were not performed in the clinic but were rehabilitated in the clinic.

Data collection, processing, and statistical analysis were conducted on the established variables using information obtained from secondary sources, with the aim of evaluating the potential success of dental implants placed with and without a surgical guide across three commercial brands in a dental clinic in Medellin. Data were extracted and organized using Excel to facilitate statistical analysis. The association between the variables and implant success was assessed using the Pearson chi-square test in Jamovi software, with a significance level set at $p < 0.05$.

RESULTS

Characteristics of the study population

Of the 499 implants evaluated in 234 clinical histories of patients the information corresponding to sociodemographic categories, systemic diseases and success criteria was collected in an electronic spreadsheet, the population was sociodemographic ally characterized, in which it was defined that the average age was 63 years $\pm$ 11 , the minimum age was 30 years and the maximum age 89 years, in addition 55,6% of the total population corresponded to women; With respect to systemic diseases, the most common was heart disease (26,5 %), followed by diabetes (13,7 %). Regarding the consumption of medications, vitamins accounted for 20,9%, followed by cardiac medications, used by 15,4 %. On the other hand, 6,8% of the population uses medication for diabetes. Finally, regarding smoking, only 4,7 % of the population smoked (Table I).

Location of the implant site

Of the dental implants evaluated, it was found that there was a prevalence of placement in the upper maxilla 56 % in relation to the mandible 44%. Additionally, the most placed dental implant was the 36th followed by the 46th indicating a greater predominance in the posterior sector as opposed to the anterior. In which of 468 implants that were successful with respect to placement the most successful implant was the 36 most of them made with the Phibo brand (Fig. 1). On the other hand, it was found that of the 31 implants that failed with respect to location the implant that presented the highest failure rate was 35 in total with the three brands (Fig. 2).

Table I. Sociodemographic variables, systemic diseases and success criteria of the patients included in this study.

	Frequency	%
Sex		
Man	104	44.4
Woman	130	55.6
Cigarette consumption		
Yes	11	4.7
No	223	95.3
Medications		
Vitamins	49	20.9
Cardiac	36	15.4
Diabetics	16	6.8
Endocrine	26	11.1
None	95	40.6
Heart disease		
Yes	62	26.5
No	172	73.5
Endocrine diseases or diabetes		
Yes	32	13.7
No	202	86.3
More than one implant		
Yes	112	47.9
No	122	52.1
Use of guide		
Yes	448	89.8
No	51	10.2
Implant design allowed for placement of a crown or prosthesis		
Yes	496	99.4
No	3	0.6
The dental implant was rehabilitated		
Yes	324	64.9
No	175	35.1
There was evidence of peri-implant radiolucency evaluated on an undistorted radiograph		
Yes	28	5.6
No	471	94.4
Adjacent bone density		
Decreased	67	13.4
Homogeneous	331	66.3
Enhanced	101	20.2
Exhibition of threads		
Yes	23	4.6
No	476	95.4
Shape of the mesial bone crest		
Angled or vertical	247	49.5
Horizontal	252	50.5
Shape of the distal bone crest		
Angled or vertical	206	41.3
Horizontal	293	58.7

Source: own

Dental implant success rate by brand name

Likewise, the results of the three brands of implants evaluated in the study are presented, which show that of the 499 implants analyzed 53,5 % belong to the Phibo brand and the minority corresponding to 7,2% to the Straumann brand (Table II). It was observed that Phibo had a success rate of 93.6 %,

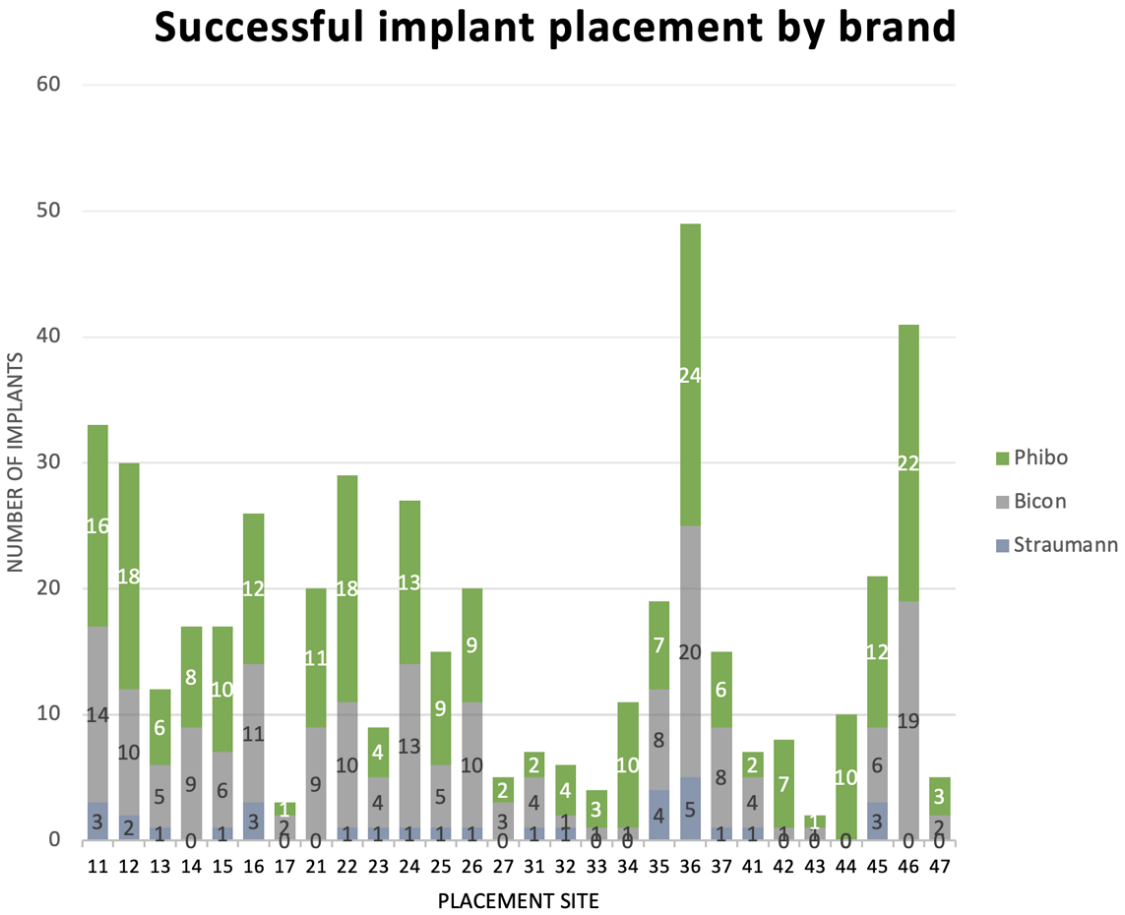

Fig. 1. Results according to successful implant location by brand evaluated in the study.

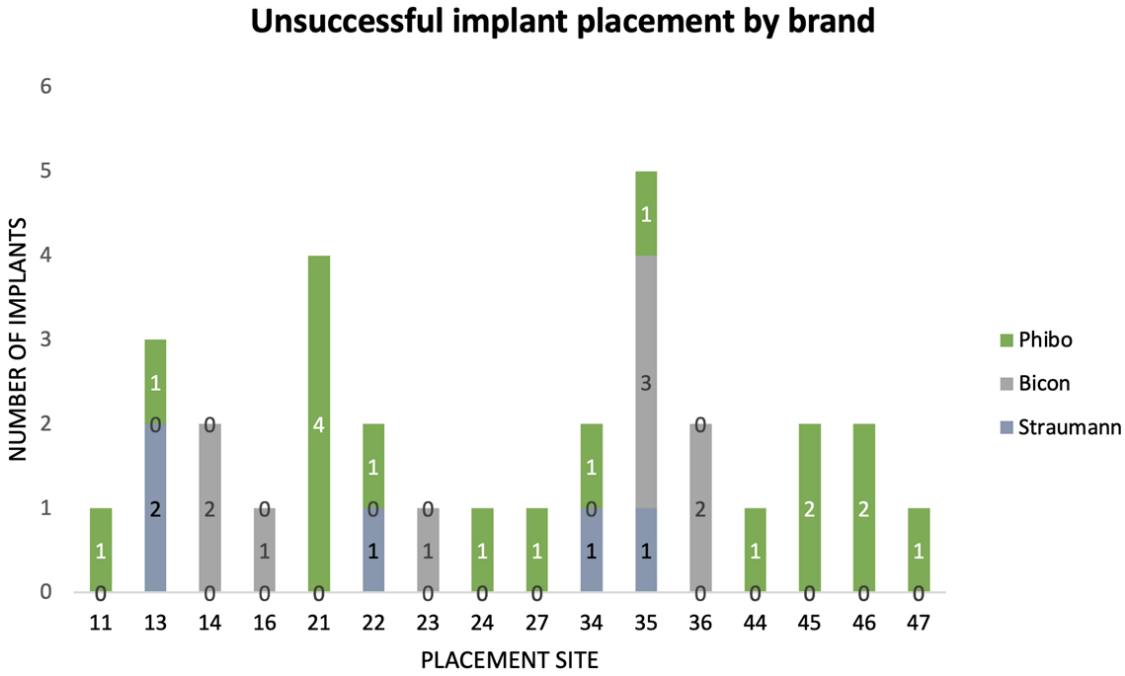

Fig. 2. Results according to the location of the unsuccessful implant by brand evaluated in the study.

Bicon 94,4% and Straumann 93,8% respectively; out of a total of 499 dental implants in 234 patients, there were 31 failures, resulting in a success rate of 93,8% both with and without surgical guidance.

Table II. Implant brands evaluated in the study

	Frequency	%
Straumann	36	7.2
Bicon	196	39.3
Phibo	267	53.5
Total	499	100.0

Implant success and use of surgical guide

In the study of 234 patients, the relationship between the success of dental implants and the use of surgical guides was evaluated. A marked preference for surgical guides was observed, since 89,8% of the procedures were performed using this technique. On the other hand, only 10,2 % of the cases were performedwithout a guide, which could increase the risk of complications. Regarding the number of implants per patient 47,9 % required more than one, suggesting a trend towards more complex treatments. Regarding the success of the treatments, of the 448 implants placed with surgical guidance only 30 failed representing a success rate of 93,3 %. Although, the statistical analysis using the chi-square test did not show a statistically significant difference between the group of implants placed with and without surgical guidance, the results suggest a tendency toward greater success in the implants placed with guidance (Fig. 3).

Failed implants and related variables

Of a total of 499 implants evaluated 64,9 % were successfully rehabilitated, while 35,1 % failed. The fact that 87,1 % of the failed implants showed radiolucency, a critical indicator of implant health suggests a low rate of bone stability in these cases. On the other hand, only 12,9 % of the successful implants showed this sign, which is highly significant. Regarding adjacent bone density 66,3 % showed homogeneous density, which is favorable for implant integration. The exposure of threads was minimal, affecting only 4,6 %. Regarding the shape of the osseous ridge, 50,5 % were found to have a mesial horizontal ridge, while 58,7 % presented a distal horizontal osseous ridge. It is noteworthy that among the failed implants, only 3,2 % corresponded to patients who were smokers, which could indicate that other factors play a more significant role in dental implant failure (Fig. 4).

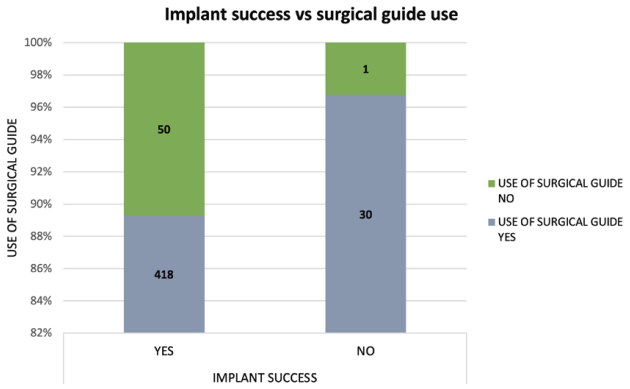

Fig. 3. Results when evaluating the success of implants vs, the use of surgical guidance.

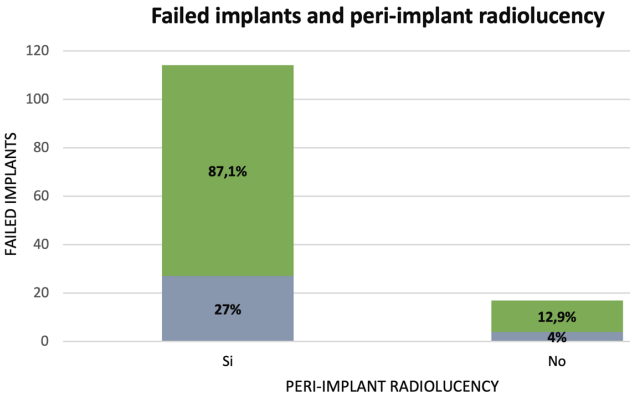

Fig. 4. Results according to failed implants in relation to peri-implant radiolucency.

DISCUSSION

The primary objective of this study was to evaluate the success rate of dental implants placed with and without surgical guidance in a defined population, as well as to identify factors associated with implant success. The results demonstrated an overall success rate of 93.8 % for the 499 implants analyzed across 234 clinical records, which is consistent with success rates reported in the literature, typically ranging from 95 % to 98 % (Kim *et al*., 2022).

In a study conducted by Krisam *et al*. (2019), the mean patient age was 60.6 years, with a female predominance of 58.5 %. In contrast, the present study reported a mean age of 63 years and 55.6 % female, suggesting a slightly older but comparable demographic, emphasizing the potential influence of gender on oral health. Regarding systemic conditions, observed 10 % of patients with diabetes and 26% with a history of periodontitis, whereas in the present analysis, 26.5 % of patients had heart disease and 13.7 % had diabetes or other endocrine disorders, which

may impact implant outcomes. Concerning implant success, Krisam *et al*. (2019) reported a 4.8% failure rate prior to restoration, particularly in short implants or sites requiring bone augmentation. In the current study, 3.2% of implant failures occurred in patients who smoked. While no direct influence of surgical guides has been definitively proven, their use may be associated with improved outcomes in implant placement.

Chiriboga-Malo *et al*. (2023) emphasize the complex interplay between sociodemographic factors and the stability of dental implants. Variables such as sex, age, smoking, and the presence of periodontal disease significantly influence treatment outcomes. Their study demonstrated that men exhibited a higher mean stability coefficient (51–91) compared to women (30–90), suggesting a potential gender effect on clinical results. Age was also identified as a critical factor, particularly in women, due to progressive bone volume loss over time. Smoking contributed substantially to implant complications, being associated with 46 % of failures. However, implant failure is not solely determined by sociodemographic characteristics; technical factors also play a key role. Implants placed in the maxilla showed higher failure rates, likely due to lower bone density, while specific implant brands, such as M4, exhibited failure rates as high as 68 %. Furthermore, the macro- and micro-design of the implant, the surgical technique employed, and the functional load during the healing period are all critical determinants of stability. These results highlight the necessity of a comprehensive evaluation that integrates patient-related, anatomical, and technical considerations to optimize outcomes in implant therapy. These findings align with the results of our study, where similar patterns were observed within the analyzed population.

Fouda (2020) conducted research that revealed that the maxilla is the site where the highest number of dental implants are placed reaching a total of 39,468, compared to 38,762 in the mandible. This study also highlighted that the upper jaw presents a failure rate of 3,14%, with 1,239 failed implants of which 6,2% were in the anterior area. On the other hand, in the mandible the failure rate is lower with a rate of 1,96% and 759 failures suggesting a greater vulnerability of implants in the anterior maxilla (Fouda, 2020). These findings coincide with those of our study, in which we also found a prevalence of implants in the maxilla 56% with implant number 36 being the most used followed by 46 indicating a clear predominance in the posterior versus the anterior zone. These data highlight the importance of considering the location of implants in dental planning, as this can significantly influence success or failure rates.

According to research by Lázaro-Abdulkarim *et al*. (2022) analyzed the failure of dental implants highlighting several critical factors affecting its success finding that 10,8% of patients experienced failures being more frequent in men (12,6%) than in women (9,1%). Implant location is also crucial with a higher failure rate in the anterior zone (OR = 1,35), while implants in the posterior maxilla showed a better success rate (OR = 0,66). Implant brand is another significant aspect: Nobel Biocare and Straumann implants have failure rates of 2,8 % and 4,7 %, respectively, compared with 5,4 % for MIS implants. Bone density also plays a key role; type IV bone showed lower success rates ranging from 50% to 94%. The use of surgical guides improves accuracy in implant placement, potentially increasing success rates. Only 3,4 % of implants were placed with immediate loading suggesting that most are implanted with delayed loading for better integration (Lázaro-Abdulkarim *et al*., 2022). These findings emphasize the complexity of success in dental implant treatments, agreeing in some respects with our study.

García-García *et al*. (2016) evaluated differences between peri-implant bone level measurements obtained via periapical radiographs and those recorded intraoperatively in patients with peri-implantitis. Their results demonstrated a significant discrepancy, with radiographic measurements averaging 4.0 ± 2.2 mm, whereas intraoperative measurements averaged 5.3 ± 2.3 mm, resulting in a mean difference of 1.3 mm. Regarding defect classification and concordance, the agreement between radiographic and intraoperative evaluations was limited, particularly for intraosseous defects, which showed only 10 % concordance, while supracrestal defects achieved moderate agreement at 60 %. These findings indicate that radiographic assessment tends to underestimate actual bone loss, potentially affecting the accuracy of peri-implant bone evaluation. The study underscores the importance of thorough intraoperative assessment to avoid misdiagnosis and ensure long-term implant success. Consistent with our research, this study highlights the critical role of accurately assessing peri-implant bone levels, while cautioning that radiographs alone may underestimate the extent of bone loss.

It is important to acknowledge several limitations of this study that may influence the interpretation of the findings. First, its retrospective design makes the results highly dependent on the quality and accuracy of existing clinical records, which may introduce biases in data collection and compromise the validity of the conclusions. Additionally, the inclusion criteria based on the availability of complete information may have excluded relevant cases, thereby affecting the representativeness of the sample. Another notable limitation is the challenge of fully controlling for confounding variables that could have influenced the outcomes, such as patient lifestyle factors, the surgeon's level of experience, and the specific surgical techniques employed. Moreover, because the study was conducted in a single clinic in Medellín, the findings may not be generalizable to other populations or geographic regions outside Colombia, limiting their applicability to different clinical settings. The study period ending in 2021 also represents a constraint, as more recent advancements in implant techniques and materials that may affect current outcomes were not considered. Finally, the lack of detailed information regarding the type of surgical guide used and other implant-related factors such as connection type, diameter, and length precludes precise comparisons among the three implant brands evaluated, given their inherent differences.

To enhance the quality of future research on dental implants, it is essential to conduct prospective studies that include patients from multiple clinics and diverse clinical backgrounds, along with detailed documentation of the specific implant systems used. Such approaches would allow for more representative findings that are applicable across various clinical contexts. Additionally, incorporating a broader analysis of factors influencing implant success such as oral health history, the presence of complex medical conditions, immediate versus delayed loading protocols, malocclusion, bruxism, crowding, loss of vertical dimension, and other relevant clinical characteristics would be highly beneficial. Including these variables could enable real-time monitoring of implant performance, improve the evaluation of surgical guide effectiveness in different clinical scenarios, and contribute to a deeper understanding of the multifactorial nature underlying successful implant placement.

CONCLUSION

This study did not identify a statistically significant difference in the success rate of dental implants placed with or without surgical guidance. Nevertheless, the data show a trend toward higher success in procedures performed with surgical guidance, with an overall implant success rate of 93.8 % and a predominant use of guidance in 89.8 % of cases. These findings underscore the relevance of surgical planning in dental implant placement. Although no definitive association was established between the use of surgical guides and implant success, the widespread preference for this technique and its high success rate suggest that it may contribute positively to rehabilitation outcomes. Additionally, other clinical and radiographic factors such as bone density and the presence of radiolucency demonstrated meaningful correlations with implant success and failure. Collectively, these results highlight the importance of considering multiple variables in treatment planning and assessment, which may help improve clinical outcomes in future research.

ACKNOWLEDGMENTS. We would like to express our deepest gratitude to the teachers for their experience, understanding and patience that contributed to our experience in the complex and rewarding path of research. To our parents and undergraduate classmates for their unconditional support and inspiration and to the William Posada private practice dental clinic for allowing us to conduct the research.

AUTHOR CONTRIBUTIONS: Conceptualization: Eilien Tovío Martínez, Luis Fabian Benitez Moreno, Ana Maria Valencia, Leonela Deyalit Murillo Maldonado, Manuela Zapata Restrepo, Maria Jose Salazar Puerta, Suldeny Betancur Tobón, Santiago Sosa López. Formal Analysis: Luis Fabian Benitez Moreno. Investigation: Ana María Valencia, Manuela Zapata Restrepo, Leonela Deyalit Murillo Maldonado, Maria Jose Salazar Puerta, Suldeny Betancur Tobon, Santiago Sosa Lopez. Methodology: Eilien Tovío Martínez, Luis Fabian Benitez Moreno, Ana María Valencia Metaute Manuela Zapata Restrepo, Leonela Deyalit Murillo Maldonado, Maria Jose Salazar Puerta, Suldeny Betancur Tobón, Santiago Sosa López. Project Administration: Eilien Tovío Martínez, Luis Fabian Benitez Moreno. Writing - Original Draft: Ana María Valencia Metaute, Manuela Zapata Restrepo, Leonela Deyalit Murillo Maldonado, Maria José Salazar Puerta, Eilien Tovío Martínez, Luis Fabian Benitez Moreno. Writing - Review & Editing: Eilien Tovío Martínez, Luis Fabian Benitez Moreno, Ana María Valencia Metaute, Manuela Zapata Restrepo, Leonela Deyalit Murillo Maldonado, Maria Jose Salazar Puerta, Suldeny Betancur Tobón, Santiago Sosa López.

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RESUMEN: Los implantes dentales son una alternativa de rehabilitación oral basado en la colocación de elementos de titanio endooóseos que reemplazan las raíces de los dientes perdidos. El proceso que permite su funcionamiento se denomina osteointegración, y consiste en la formación de una unión sólida entre el titanio y el tejido óseo. El objetivo de este estudio fue evaluar la tasa de éxito a largo plazo de implantes dentales colocados con guía quirúrgica y sin guía quirúrgica, utilizando tres marcas comerciales diferentes, en una clínica odontológica de Medellín durante el periodo 2011–2021. Se llevó a cabo un estudio observacional retrospectivo en 234 pacientes, en el cual se analizaron características sociodemográficas y radiográficas, además de criterios de éxito. Los datos se recopilaron en Excel y se procesaron mediante la prueba de chi-cuadrado en Jamovi. En total, se evaluaron 499 implantes colocados en 234 pacientes. Las enfermedades sistémicas más frecuentes fueron cardiopatías y diabetes. El 56 % de los implantes se colocaron en el maxilar, siendo el diente 36 el que mostró mayor éxito. Se empleó guía quirúrgica en el 89,8 % de los casos, con tasas de éxito del 93,3 % en implantes guiados y del 98 % en implantes no guiados, sin diferencias estadísticamente significativas. En conjunto, el 64,9 % de los implantes fueron rehabilitados con éxito. La radiolucidez estuvo presente en el 87,1 % de los fracasos, mientras que solo el 3,2 % ocurrió en pacientes fumadores, lo que sugiere la influencia de otros factores clínicos. Aunque no se encontraron diferencias significativas entre los grupos, se observó una tendencia favorable al uso de guías. La alta frecuencia de utilización de estas herramientas resalta su posible impacto positivo en la rehabilitación, así como la importancia de los factores clínicos y radiográficos en la planificación del tratamiento implantológico.

PALABRAS CLAVE: Cirugía asistida por ordenador, implantes dentales, maxilar, cirugía oral, osteointegración.

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