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Predictability of osseointegrated implants installed in guided bone regeneration areas: a retrospective study

Previsibilidade dos implantes osseointegráveis instalados em áreas de regeneração óssea guiada: um estudo retrospectivo

Previsibilidad de los implantes osteointegrados instalados en áreas de regeneración ósea guiada: un estudio retrospectivo

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ABSTRACT

Objective: To evaluate the predictability and success rate of implants installed in extraction sites, where the Guided Bone Regeneration (GBR) technique for bone preservation and implant placement was performed. **Methods:** This is a retrospective study, which included medical records of patients from the clinic of the Specialization in Implantology course from the educational institution, who underwent GBR in the tooth socket with indicated extraction, who delivered the tomographic exams, and had implants installed in these places, from 2007 to 2016. Forty-two participants were included in the research, totaling 55 sites divided into two groups: maxilla and mandible. **Results:** Two cases (3.7%) of non-bone formation were found after GBR, in the posterior region of the maxilla, with a success rate of 96.3% for predictability of implant placement in GBR sites. Of the 53 implants installed where there was sufficient bone formation, 3 (5.7%) did not return to the clinic and, therefore, 50 were evaluated, with 48 presenting clinical osseointegration with a success rate of 96%. **Conclusion:** There is predictability of GBR procedures in post-extraction sockets for the installation of osseointegrated implants.

Keywords: Guided Bone Regeneration, Osseointegrated Implants, Primary Stability, Secondary Stability.

RESUMO

Objetivo: Avaliar a previsibilidade e a taxa de sucesso dos implantes instalados em sítios de exodontia, onde foi realizada a técnica de Regeneração Óssea Guiada (ROG) para preservação óssea e instalação de implantes. **Métodos:** Trata-se de estudo retrospectivo, que incluiu prontuários de pacientes da clínica do curso de Especialização em Implantodontia de uma instituição de ensino submetidos à ROG no alvéolo de dente com extração indicada, que entregaram os exames tomográficos, e tiveram implantes instalados nestes locais, no período de 2007 a 2016. Quarenta e dois participantes foram incluídos na pesquisa, totalizando 55 locais divididos em dois grupos: maxila e mandíbula. **Resultados:** Foram encontrados 2 casos (3.7%) de não formação óssea após a ROG, ambos na região posterior da maxila, com taxa de sucesso de 96.3% para a previsibilidade da instalação de implantes em locais de ROG. Dos 53 implantes instalados onde houve formação óssea suficiente, 3 (5.7%) não retornaram à clínica e, portanto, 50 foram avaliados, sendo que 48 apresentavam osseointegração clínica com uma taxa de sucesso de 96%. **Conclusão:** Existe previsibilidade dos procedimentos de ROG em alvéolos pós-exodontia para a instalação de implantes osseointegráveis.

Palavras-chave: Implantes Osseointegráveis, Regeneração Óssea Guiada, Estabilidade Primária, Estabilidade Secundária.

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RESUMEN

Objetivo: Evaluar la previsibilidad y la tasa de éxito de los implantes instalados en sitios de extracción, donde se realizó la técnica de Regeneración Ósea Guiada (ROG) para la preservación ósea y la colocación de implantes. **Métodos**: Se trata de un estudio retrospectivo, que incluyó prontuarios de pacientes de la clínica del Curso de Especialización en Implantología de una institución educativa que fueron sometidos a ROG en el alvéolo con indicación de exodoncia, quienes entregaron la tomografía exámenes, y tenía implantes instalados en estos lugares de 2007 a 2016. Cuarenta y dos participantes fueron incluidos en la investigación, totalizando 55 lugares divididos en dos grupos: maxilar y mandíbula. **Resultados**: Se encontraron dos casos (3,7%) de no formación de hueso después de ROG en la región posterior del maxilar, con una tasa de éxito del 96,3% para la previsibilidad de la colocación de implantes en sitios ROG. De los 53 implantes instalados donde había suficiente formación ósea, 3 (5,7%) no regresaron a la clínica y, por lo tanto, se evaluaron 50, de los cuales 48 presentaron osteointegración clínica con una tasa de éxito del 96%. **Conclusión**: Existe previsibilidad de los procedimientos ROG en alvéolos post-extracción para la instalación de implantes osteointegrados.

Palabras clave: Estabilidad Primaria, Estabilidad Secundaria**,** Implantes Oseointegrados*,* Regeneración Ósea Guiada.

INTRODUCTION

Implantology, since its discovery by Professor Per Ingvar Branemark in the sixties of the last century, has acquired high relevance in modern dentistry, because the titanium implant, in the shape of a screw, has the ability to replace, in a very satisfactory way, the missing teeth (BRÅNEMARK PI, et al., 1969). Oral rehabilitation with osseointegrated implants, replacing tooth roots, is among the best methods to restore aesthetics and masticatory function, with highly predictable results (CLEMENTINI M, et al., 2011; ADELL R, et al., 1981; BRANEMÅRK PI., et al., 1977; TALLARICO M, et al., 2018).

Osseointegration was defined by Branemark in 1969, as the direct, structural and functional connection between the living bone and the implant surface, submitted to occlusal load (BRÅNEMARK PI, et al., 1969). Clinically, osseointegration is an asymptomatic process in which a rigid fixation of alloplastic materials within the bone is achieved and maintained under functional load (ALBREKTSSON T and JOHANSSON C, 2001).

The primary stability of the implant is considered one of the prerequisites for osseointegration, being a purely mechanical parameter, determined at the time of implant installation and is associated, among other aspects, with the resistance between the bone and the implant under insertion (BARBERÁ-MILLÁN J, et al., 2021). While secondary stability is the progressive increase in stability related to biological events at the bone-implant interface, which can be seen in the second surgical procedure, achieved during implant reopening. Tertiary stability, on the other hand, refers to the maintenance of this stability with the implant in function (SHADID RM et al., 2014; SOEHREN SE and VAN SWOL RL, 1979).

However, after exodontia there is physiological alveolar bone loss, in height and thickness, both in the mandible and maxilla, which can interfere or prevent the installation of the osseointegrated implant (LUCAS RRS, et al., 2013). Studies have shown that the main bone changes occur in the first 3 months after tooth loss, during the healing period, and can be observed up to 1 year after tooth extraction, resulting in approximately a 50% reduction in the buccal-lingual ridge dimension (SCHROPP L, et al., 2003). The main clinical consequences of these physiological changes in the soft and hard tissues are the difficulty or impossibility of using therapies that aim to replace the lost dentition, either by limiting bone viability for implant installation or by compromising the aesthetic result after prosthesis placement (VIGNOLETTI F, et al., 2012).

To minimize this bone resorption and preserve the remaining alveolar ridge after exodontia, two main techniques are employed: immediate implant installation and the Guided Bone Regeneration (GBR) technique with or without the use of biomaterials (FERNANDES GVO, 2011). The biological principle of GBR was first described in 1957 by Murray et al, where they suggested that regeneration would be more predictable when bone tissue was isolated from connective tissue. With this, GBR is based on the concept of

osteopromotion, which refers to the use of physical means to promote a sealing of a bone defect in order to direct bone formation, through the use of a biological barrier (membrane), which can be resorbable or non-resorbable, where cells originating from the bone can migrate and proliferate without the interference of cells from other neighboring tissues (FERNANDES GVO, 2011; BARBOZA EP, CAÚLA AL, 2002; MELCHER AH, 2009; MISCH CE, 2009; MURRAY C, et al., 1957).

GBR has been used in order to maintain the volume of the alveolar bone and minimize horizontal and vertical changes in the bone ridge after tooth extraction, being a routine procedure to allow the future installation of osseointegrated implants (ELGALI I, et al., 2017; DARBY I, et al., 2009). It is estimated that 40% of osseointegrated implants require previous GBR procedures for the rehabilitation of the post-exodontia region (BORNSTEIN MM, et al., 2008).

Several studies indicate that the survival rate of implants installed in regions subjected to GBR are similar to those reported in edentulous ridges with bone availability (DONOS N, et al., 2008; CLEMENTINI M, et al., 2012; JENSEN SS e TERHEYDEN H, 2009), these rates being between 79% and 100% of success with few studies showing a survival of 90% after the first year of function (ELGALI I, et al., 2017; HAMMERLE CH, et al., 2002).

However, despite the predictability of the use of GBR and subsequent implant placement, there is a deficiency in the literature regarding the definition of the success rate related to the different stages of rehabilitation with osseointegrated implants after GBR, including primary, secondary and tertiary stabilities. Knowledge of success rates specifically related to clinical stages is extremely important to accurately recognize the specific influence of GBR on the final outcome of rehabilitation with osseointegrated implants, taking into account bone formation after GBR in the alveoli and primary loss. Implants installed in these places, thus minimizing possible failures related to osseointegration and contributing to the improvement of the success rate in implantology. The objective is to evaluate the predictability and success rate of implants installed in extraction sites, where the GBR technique for bone preservation and implant placement was performed.

METHODS

This is an observational and descriptive study, which was approved by the Research Ethics Committee of the of Hospital Universitario Antonio Pedro (HUAP) from the educational institution under opinion number 4,565,510, on March 1, 2021, CAAE: 40088120.0.0000.5243. The informed consent form was obtained and signed by the research participant of the study.

Research participants

The study was carried out through the analysis and collection of data from the medical records of the research participants who were treated at the clinic of the Specialization Course in Implantology, from January 2007 to December 2016, who underwent tooth extraction followed by Guided Bone Regeneration (GBR) procedures in the alveolus, with the aim of preserving the alveolar ridge for later installation of osseointegrated implant and prosthesis placement.

The sample included cases of tooth extraction followed by GBR contained in the medical records of people who agreed to participate in the research, and who signed the free and informed consent form. Data were analyzed based on a data collection form with the items necessary for understanding the research objectives.

The extraction sites followed by GBR contained in the sample were divided into 2 groups: maxilla and mandible. Secondary stability, assessed during implant reopening, was performed according to the criteria of Esposito et al. (1998) (24): in which success is associated with the absence of clinical signs and symptoms indicative of implant loss, in the period from implant placement to implant activation (early loss). The presence of mobility is indicative of total implant failure.

Inclusion / Exclusion Criteria

As inclusion criteria we had: 1) participants who underwent the extraction procedure where the GBR technique was performed immediately afterwards, who returned after the healing period and underwent the CT scan to assess the sufficient bone volume for implant placement; 2) participants who were able to have implants installed in the GBR sites with the two-stage technique and evaluated during the second surgical stage; 3) participants who had the prosthesis placed over the implant installed. As Exclusion criteria we had: 1) participants who underwent the GBR technique in the socket after tooth extraction and who did not return for CT scan; 2) participants with medical records with incomplete data in the clinical record; 3) Participants who had the prosthesis placed at the time of implant placement; 4) Participants who refused to participate in the research, mainly due to the COVID-19 pandemic.

Statistical analysis

The numerical variables were expressed as mean ± standard deviation, and the Normality Test (Shapiro-Wilk Test) was applied: t-test (normal sample) and the chi-square test (Nominal variables) were used to assess the variables. The p-value <0.05 was considered statistically significant with a 95% confidence interval. The Microsoft Office 2013 Excel program was used for data tabulation and the Prisma GraphPad 6.0 software (GraphPad Software, La Jolla, CA-EUA) for statistical calculations.

RESULTS

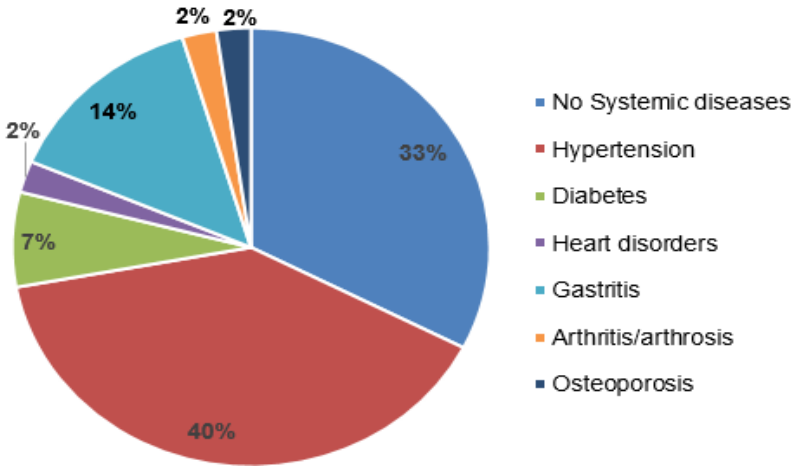
Respecting the inclusion criteria, a total of 42 research participants were evaluated among the patients treated at the FOUFF Implant Dentistry Specialization Course, who were included in the study, totalling 55 regions with guided bone regeneration (GBR) in the socket after extraction. 14 (35%) had a history of periodontitis, 9 (21%) had thin periodontium, 25 (59%) reported use of medication (antihypertensive, antiglycemic, herbal medicine) (**Table 1**), 28 (67%) had systemic diseases (hypertension, diabetes, gastritis, heart disorder, and arthrosis/arthritis) (**Graphic 1**).

Table 1 - Clinical characteristics.

Parameters	N = 42	Percent (%)
Thin periodontium	9	21
Thick periodontium	33	79
Periodontitis History	14	35
Systemic diseases	28	67
Medication use	25	59
Smoker	5	12
Alcohol use	2	5

Source: Pinheiro MPF, et al., 2023.

Graphic 1 - Representative in the percentage of the presence of systemic diseases.



Source: Pinheiro MPF, et al., 2023.

The mean age of the participants was 59.4±8.24 years, being 27 women and 15 men. All (100%) of the alveoli were filled with biomaterials and covered with biological membranes. In the mandible, there was a predominance of filling with the Osteogen alloplastic biomaterial (75%) (p=0.008) (**Table 2**). Regarding bone ridge preservation, a total of 2 sites did not form bone (3.7%), located in the posterior region of the maxilla, and 100% of the regions undergoing bone regeneration in the mandible formed bone. However, there was no statistically significant difference in bone formation between mandible and maxilla. All sites that formed bone underwent the installation of osseointegrated implants, totaling 96.3% of the regions undergoing GBR with implants in primary stability.

In the evaluation related to the second surgical time (secondary stability), 3 (5.7%) research participants did not return for treatment, changing the total n to 50 evaluated regions, 26 in the maxilla and 24 in the mandible. Of the 50 sites included for analysis after the osseointegration period, 48 (96%) showed secondary stability after implant reopening, with 2 (4%) implants lost in the maxilla (primary loss). However, there was no statistically significant difference (p=0.26) between secondary stability in the maxilla and mandible. The 48 implants with secondary stability received the prosthesis on implant, with the predominant placement of the screw-retained prosthesis in the mandible in relation to the maxilla (0.02) (**Table 3**).

Table 2 - Clinical aspects and results in the first surgical procedure.

Parameters	Initial Total (n=55)	Maxilla (n=31)	Mandible (n=24)	p-value
Age	59.4±8.24	59.7±7.61	58.9±9.43	0.36
Tooth loss				
Cavity	12 (21.8%)	8 (25.8%)	4 (16.7%)	
Endodontics	8 (14.5%)	4 (12.9%)	4 (16.7%)	
Fracture	17 (31%)	10 (32.3%)	7 (29.16%)	0.07
Endo-periodic injury	8 (14.5%)	1 (3.2%)	7 (29.16%)	
Periodontitis	7 (12.8%)	5 (16.1%)	2 (8.3%)	
Furcation	3 (5.4%)	3 (9.7%)	0 (0.0%)	
Filling Material				
Osteogen (Intra-Lock)*1	30 (54.5%)	12 (38.7%)	18 (75%)	
Bio-Oss (Geistlich) *2	11 (20%)	10 (32.3%)	1 (4.16%)	
GenOx (Baumer) *3	8 (14.5%)	7 (22.6%)	1 (4.16%)	0008
Alobone (Osseocon) *4	5 (9.2%)	2 (6.4%)	3 (12.5%)	
Bonefill (Bionnovation) *5	1 (1.8%)	0 (0.0%)	1 (4.16%)	
Membrane				
Allumina (BiomacMed) *6	29 (52.8%)	12 (38.7%)	17 (70.84)	
Bio-Gide (Geistlich) *2	12 (21.8%)	11 (35.5%)	1 (4.16%)	
GenDerm (Baumer) *3	7 (12.8%)	5 (16.1%)	2 (8.3%)	
PRP	1 (1.8%)	0 (0.0%)	1 (4.16%)	0.07
CollaCote (Zimmer) *7	4 (7.2%)	2 (6.4%)	2 (8.3%)	
Lumina-Coat (Critéria) *3	1 (1.8%)	1(3,2%)	0 (0.0%)	
Vicryl	1 (1.8%)	0 (0.0%)	1 (4.16%)	
Bone formation	53 (96.3%)	29 (93.5%)	24 (100%)	0.31
Implant Installation (Primary Stability)	53 (96.3%)	29 (93.75%)	24 (100%)	0.31
Implant Platform				
HE	34(64,1%)	19 (65.5%)	15 (62.5%)	
HI	16 (30.2%)	8 (27.6%)	8 (33.4%)	**0**.84
CM	3 (5.7%)	2 (6.9%)	1 (4.1%)	

Legend: *1- São Paulo, Brazil; *2- Wolhusen, Switzerland; *3- São Paulo, Brazil; *4- Rio de Janeiro, Brazil; *5- São Paulo, Brazil; *6- Minas Gerais, Brazil; *7- Florida, USA.
Source: Pinheiro MPF, et al., 2023.

Table 3 - Main results obtained in the second surgical time (secondary stability), with a total of 50 regions.

Parameters	Initial Total (n=50)	Maxilla (n=26)	Mandible (n=24)	p-value
Secondary Stability	48 (96%)	24 (92.3%)	24 (100%)	0.26
Placement of the prosthesis	48 (96%)	24 (92.3%)	24 (100%)	0.26
Type of Prosthesis				0.02
Cemented	9 (18.8%)	8 (33.4%)	1 (4.2%)	
Screwed	39 (81.2%)	16 (66.6%)	23 (95.8%)	

Source: Pinheiro MPF, et al., 2023.

DISCUSSION

Currently, the GBR procedure is considered highly predictable to achieve bone formation, allowing the installation of osseointegrated implants (ELGALI I, et al., 2017). GBR is used to preserve ridge volume by placing the graft material in a tooth socket after extraction, with or without the application of a barrier membrane or soft tissue. In guided bone regeneration, a barrier membrane is used to direct the growth of new bone and gingival tissue. This preservation procedure is often used in dental practice owing to its conceptual attractiveness and technical simplicity with continuous evaluation (OGAWA T, et al., 2022). However, rehabilitation with osseointegrated implants corresponds to different stages that include not only implant installation and primary stability, but also adequate osseointegration (secondary stability) and the ability to sustain a functioning prosthesis (tertiary stability).

Our main results showed that (i) 96.3% of the sites submitted to the post-extraction GBR procedure had bone neoformation confirmed by computed tomography; (ii) 96% of implants installed in bone formation sites showed secondary stability; (iii) 100% of the participants who returned for treatment received implant-supported prostheses in the previous region of GBR.

Clinical reports in the literature suggest that dental implants installed in the mandible have higher survival rates than those installed in the maxilla, especially in the posterior region of the maxilla (TURKYILMAZ I e MCGLUMPHY EA, 2008). These findings are in agreement with our results, which showed loss of two implants in the posterior region of the maxilla, after the osseointegration period, during the implant reopening procedure.

Various studies have shown a positive correlation between implant failure and low bone density. This systematic review and meta-analysis reported that low bone density seriously affects primary implant stability and survival. Also reported 35% implant loss in Type IV bone compared with Types I, II, and III, which have shown an implant loss of only 3% (RADI IA, et al., 2018).

Classically, the predominant bone densities in the maxilla, mainly in the posterior region, are types III and IV, according to the Mish Classification (MISCH CE et al., 1999) and, although several studies have shown no association between bone density and implant loss, other studies have shown a high failure rate in regions with these bone densities, which can be explained because this bone is basically medullary, thus compromising secondary stability, whereas primary stability is present in the clinical analysis during implant installation, the low density may have allowed micromovements to occur during the osseointegration period, thus replacing osseointegration with fibrointegration, characterized by implant mobility (MORASCHINI V, et al., 2015).

In our study, we used as success criteria the parameters described by Esposito et. al. 1998 (ESPOSITO M, et al., 1998), which include the absence of clinical signs and symptoms indicative of implant loss, these being all symptomatic mobile implants to implants showing more than 0.2 mm of peri-implant bone loss after the first year of loading, or bleeding pockets exceeding 5 mm of probing depth, in the period from implant placement to implant activation (early loss). With that, the two implants that failed located in the maxilla, presented mobility, were removed. These findings also suggest that the GBR procedure in post-extraction sockets follows the principle of bone formation guided not only by cellular selectivity, but includes the predominant bone density profile of the post-extraction region, which will be characteristic of the regenerated

region, even after the period of bone neoformation. This fact also corroborates the absence of bone formation after GBR that occurred in two cases located in the posterior region of the maxilla, in our study, characterized by low bone density which may be associated with high and rapid bone resorption, following the physiological alveolar resorption process, in height and thickness, even in the presence of a biological barrier. It is known that bone resorption progresses faster in the maxilla due to the greater vascular supply (SOEHREN SE e VAN SWOL RL. 1979).

In contrast, our work demonstrated a high predictability for sufficient bone formation for implant placement in sites that underwent a GBR procedure after tooth extraction. It was also possible to observe the high success rate (96.3%) with osseointegrated implants installed in the places where the GBR procedures were performed, demonstrated in the results obtained during the second surgical procedure and in the act of placing the prosthesis, thus the rate of primary (or early) loss of osseointegration is very low.

Based on the findings of this meta-analysis and systematic review, implants placed after GBR have a significantly higher success rate than implants placed immediately (XINBO YU, et al., 2022). Literature seem to demonstrate that GBR procedure is reliable techniques, providing sufficient bone volume to allow implant placement in the case of vertical and/or horizontal defects of partially or totally edentulous patients. (CLEMENTINI M, et al., 2013).

Biomaterials can be used to fill the post-extraction socket in GBR procedures and are classified according to their function and origin. The most used work through osteoinduction and/or osteoconduction. Osteoinduction is the stimulation of bone growth via mesenchymal cells that differentiate into osteoblasts, with the help of growth factors. Osteoconduction, on the other hand, involves the formation of progenitor cells in and around the filling material. As for the origin, they can be classified as autogenic, allogenic, xenogenic, and alloplastic (KALSI AS, et al., 2019). It has been clearly described that biocompatibility is the most important requirement to take into account when choosing a membrane, but other factors such as space maintaining capacity, cell oclusiveness, easy handling and bioactivation friendly materials are the ones that will fulfill our necessities (CABALLÉ-SERRANO J, et al., 2018).

In our study we used biomaterials in all GBR procedures, which were chosen randomly, based on the principle that this combination can preserve even more the alveolar ridge, being an effective method to reduce the process of physiological resorption after exodontia (MAJZOUB J, et al., 2019). Alloplastic biomaterials were the most used, considering both arches, with a significant predominance in the mandible, and in the maxilla the distribution of xenogenic and alloplastic biomaterials was more balanced, with a slight predominance of xenogenic biomaterials. The membranes used were absorbable and non-absorbable, with a predominance of the latter in the sum of the two arches and in the mandible, where the difference was more pronounced. However, the type of biomaterial had no influence on implant loss or lack of secondary stability.

In this study, although we did not aim to evaluate the tertiary stability of the implant, it is important to note that all sites with secondary stability were able to receive implant-supported prostheses, cemented or screwed, further reinforcing the predictability of success in implant dentistry procedures after GBR in dental alveoli.

Oral rehabilitation with osseointegrated implants, replacing tooth roots, is among the best methods to restore aesthetics and masticatory function, with highly predictable results (CLEMENTINI M, et al., 2011; ADELL R, et al., 1981; BRANEMÅRK PI, et al., 1977; TALLARICO M, et al., 2017). We can state, based on our results, that rehabilitation with osseointegrated implants after GBR procedures remains highly predictable to restore esthetics and masticatory function. However, future longitudinal studies are needed to analyze tertiary stability and implant longevity in function after GBR procedures and implant placement.

CONCLUSION

The main reasons that led to dental extractions were tooth fractures, combined with cases of extensive caries and endo-periodontal lesions, especially in the posterior regions of the two arches, and in the

mandible was the total loss in this region. Alloplastic biomaterials were the most used compared to xenogeneic ones, adding the two arches, with higher prevalence in the mandible. The success rate was identical for the two types of biomaterials used. In two sites it was not possible to install implants after GBR with a predictability rate of 96.3%. Regarding the implants that could be evaluated during the second surgical procedure and in the placement of the prosthesis (primary failure), a success rate of 96% was obtained. Regarding the types of prostheses placed, the 48 implants with secondary stability received the prosthesis on implant, with the predominant placement of screw-type prosthesis in the mandible in relation to the maxilla (0.02).

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