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DÉBORA DE ALMEIDA BIANCO

Evaluation of bone width around implants placed simultaneously with the split-crest technique: a retrospective longitudinal study

Avaliação da dimensão óssea ao redor de implantes colocados simultaneamente com técnica de crista dividida: estudo retrospectivo longitudinal

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Dissertação apresentada ao Programa de Pós-Graduação em Odontologia Integrada da Universidade Estadual de Maringá como parte dos requisitos para obtenção do título de Mestre em Odontologia Integrada.

Orientador: Prof. Dr. Maurício Guimarães Araújo

Co-orientadora: Profa. Dra. Flávia Matarazzo Martins

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Este trabalho de conclusão de Mestrado foi julgado e aprovado para obtenção do título de Mestre em Odontologia Integrada através da Universidade Estadual de Maringá

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Avaliação da dimensão óssea ao redor de implantes colocados simultaneamente com técnica de crista dividida: estudo retrospectivo longitudinal

RESUMO

Objetivo: O objetivo da presente dissertação foi investigar a espessura do rebordo alveolar e da parede óssea vestibular cicatrizada ao redor de implantes instalados simultaneamente a técnica de crista dividida (SCT) após pelo menos 5 anos de cicatrização em um estudo retrospectivo longitudinal.

Material e Métodos: Foram avaliados os prontuários de pacientes reabilitados com implantes instalados simultaneamente ao SCT o qual foi realizado em consultório particular no período de 2002 a 2012. Foram coletados dados dos pacientes, implantes e próteses e realizada uma análise descritiva das variáveis. A espessura da crista óssea foi medida antes da realização do SCT (WR1) no local do futuro implante e 2 mm abaixo da crista óssea através do uso de um paquímetro. A mesma medida foi obtida imediatamente após a instalação do implante (WR2). A espessura do rebordo cicatrizado, do osso vestibular e do osso lingual/palatino foram medidas, assim como a distância entre a borda da superfície polida do implante (SLA) e a crista óssea (BC) através de CBCT em diferentes períodos de acompanhamento.

Resultados: Dos 30 pacientes incluídos (56.2 ± 10.2 anos), 21 eram mulheres (70%) e 9 eram homens (30%). Cada participante apresentou um sítio cirúrgico, dessa forma foram realizados 30 procedimentos da SCT seguidos da instalação de 85 implantes. O tempo médio de acompanhamento foi de 11.5 ± 4.18 anos. Imediatamente após a realização da SCT, a crista tornou-se estatisticamente mais espessa **(**WR1: 2.91 mm vs. WR2: 5.89 mm). A média dos valores de WR nos diferentes tempos de acompanhamento foi semelhante à WR2 na maioria dos intervalos. A espessura óssea da parede vestibular

nos diferentes intervalos de acompanhamento variou de 0 a 1.74 mm. A espessura óssea nas paredes palatina/lingual variou de 0 a 1.67 mm. A média da distância entre SLA-BC variou de 0.23 a 4.02 mm ao longo dos intervalos de acompanhamento.

Conclusão: A SCT seguida da instalação de implantes pode aumentar significativamente a espessura do rebordo alveolar, a qual permanece em grande parte estável por vários anos. No entanto, no nível da borda do SLA, a margem da parede óssea vestibular é frequentemente reabsorvida.

Palavras-chave: Técnica de crista dividida, espessura óssea, CBCT, espessura óssea vestibular.

Evaluation of bone width around implants placed simultaneously with the split-crest technique: a retrospective longitudinal study

ABSTRACT

Objectives: This dissertation has the objective to investigate the width of the healed buccal bone wall and alveolar ridge at implants placed simultaneously with the split crest technique (SCT) after at least 5 years of the healing in a retrospective longitudinal study.
Material and methods: The records of patients rehabilitated with implants placed simultaneously with a SCT carried out at a private practice from 2002 to 2012 were assessed. Data on patients, implants, and prostheses were collected, and a descriptive analysis of the variables was performed. The width of the ridge (WR) was assessed immediately before (WR1) SCT at the future implant site and 2 mm below the crest with a caliper. The same measure was obtained after the implant placement (WR2). The width of the healed ridge, the thickness of the buccal and lingual/palatal bone, and the distance between the treated implant surface (SLA) border to the bone crest (BC) were also assessed by CBCT measurements at the different follow-up periods.
Results: Of the 30 patients included (56.2 ± 10.2 years), 21 were females (70%), and 9 males (30%). Each participant presented one surgical site. Thus 30 SCT procedures were performed with the installation of 85 implants. The mean follow-up time was 11.5 ± 4.18 years. Immediately following the SCT, the ridge became statistically wider (WR1: was 2.91 mm vs. WR2: 5.89 mm). The overall mean of WR values at the different follow-up time intervals was similar to WR2 at most of the intervals. The buccal bone thickness at the follow-up intervals varied from 0 to 1.74 mm. The bone wall thickness at the palatal/lingual walls at all intervals varied from 0 to 1.67 mm. The mean SLA-BC distance varied from 0.23 to 4.02 mm at all intervals.
Conclusion: Split-crest technique with concomitant implant placement may significantly increase the width of the alveolar ridge which remain in great part stable for several years. At the SLA border level, however, the buccal bone wall may be frequently lost.

Keywords: Split-crest technique, bone width, CBCT, buccal bone thickness

SUMMARY

LITERATURE REVIEW

Introduction

Alveolar ridge resorption has a variety of causes, such as periodontal diseases, traumatic tooth avulsion or long-term edentulism (Cawood & Howell, 1988; Schropp, Wenzel, Kostopoulos, & Karring, 2003). Tooth extraction is also a common reason for ridge resorption as the post-extraction alveolar site undergoes extensive bone remodeling and modeling (Araújo & Lindhe, 2005). Bone loss begins with a horizontal resorption that clinically may progresses to a height loss (Cawood & Howell, 1988; Oikarinen, Sàndor, Kainulainen, & Salonen-Kemppi, 2003).

The horizontal dimension typically exhibits the largest alveolar ridge reduction (Atwood, 1979), making it difficult or impossible to place implants in the appropriate location for a prosthetic solution (Hu et al., 2018). Ridge augmentation techniques are frequently used to increase bone volume in preparation for implant placement. Modalities include lateral augmentation using guided bone regeneration (Buser, Brägger, Lang, & Nyman, 1990), block grafting (Misch, 2009), distraction osteogenesis (Takahashi, Funaki, Shintani, & Haruoka, 2004) and Interpositional augmentation (Barros-Saint-Pasteur, 1966).

The split-crest technique (SCT) can also be utilized to increase bone width by splitting and expanding the existing residual ridge (Scipioni, Bruschi, & Calesini, 1994). This technique was proposed by Scipioni & Bruschi (1988) and consists in expanding the alveolar ridge with specific drills and chisels, resulting in a sufficient width for implant bed preparation. Bone graft or bone substitute materials such as autogenous (Guirado, Zamora, & Yuguero, 2007), allogenic (Langer, Langer, & Sullivan, 2012), or xenogeneic graft materials can be used to fill the space around the implants (Scarano et al., 2015a). This technique can be performed simultaneously with implant placement, resulting in a shorter treatment time (Blus & Szmukler-Moncler, 2006; Chiapasco, Ferrini, Casentini, Accardi, & Zaniboni, 2006; Engelke, Diederichs, Jacobs, & Deckwer, 1997; Koo, Dibart, & Weber, 2008; Langer et al., 2012; Scipioni et al., 1994; Sethi & Kaus, 2000).

The literature review below describes the available research on the horizontal ridge expansion outcomes following the SCT.

Search strategy

A bibliographic search was conducted in MEDLINE-PubMed to identify the current evidence supporting the present literature review. The PICOS methodology (Tacconelli, 2010) was used with the following MeSH terms and key words:

PICOS	Definition	MesH terms/ key words
P (Patient or population)	Patients treated with dental implants	Human OR dental implant OR dental implants OR
I (Intervention)	Dental implant placement following the split-crest technique	Split-crest technique OR split crest technique OR ridge expansion OR alveolar ridge split OR bone splitting
C (Comparison)	Not Applied	-
O (Outcomes)	Dimension of the total width of the healed ridge bone wall	Alveolar thickness OR bone width OR bone dimension
S (Study design)	Systematic reviews, randomized controlled clinical trials, prospective or restrospective studies and case series	clinical

Resulting in: ((((human) OR (dental implant)) OR (dental implants)) AND (((((split-crest technique) OR (split crest technique)) OR (ridge expansion)) OR (alveolar ridge split)) OR (bone splitting))) AND (((alveolar thickness) OR (bone width)) OR (bone dimension)).

The inclusion criteria were clinical studies of any design with implants placed simultaneously with split-crest technique in the jaws. Exclusion criteria were studies not published in English, in vitro or animal designs and lack of information. A total of 750

studies were identified in MEDLINE, of which 16 were included in this literature review. Five more studies were selected from hand searching screening. The primary outcome was the width of the healed ridge. Width of the ridge before and immediately after the SCT, the distance between the treated implant surface (SLA) to the bone crest and the buccal bone wall thickness were also recorded.

LONGITUDINAL STUDIES

Sixteen longitudinal studies were included in the present literature review. Detailed data collected from each study are shown in Table 1.

General data

The total number of patients in the studies ranged from 5 to 71, with a total of 404 patients (Albanese et al., 2019; Altiparmak, Akdeniz, Bayram, Gulsever, & Uckan, 2017; Anitua & Alkhraisat, 2016; Annibali, Bignozzi, Sammartino, La Monaca, & Cristalli, 2012; R. Bassetti, Bassetti, Mericske-Stern, & Enkling, 2013a; Blus & Szmukler-Moncler, 2006; Bruschi et al., 2017; Crespi, Bruschi, Gastaldi, Capparé, & Gherlone, 2015; Crespi, Capparè, & Gherlone, 2014; Crespi, Toti, Covani, Crespi, & Menchini-Fabris, 2021; de Souza et al., 2020; Ferrigno & Laureti, 2005; Garcez-Filho et al., 2015; González-García, Monje, & Moreno, 2011; Santagata, Guariniello, & Tartaro, 2015; Simion, Baldoni, & Zaffe, 1992). The total number of implants placed following the SCT was 1011, in 6 studies (Altiparmak et al., 2017; de Souza et al., 2020; Ferrigno & Laureti, 2005; Garcez-Filho et al., 2015; González-García et al., 2011; Santagata et al., 2015) implants were placed on the maxilla, in 9 studies (Albanese et al., 2019; Annibali et al., 2012; R. Bassetti et al., 2013a; Blus & Szmukler-Moncler, 2006; Bruschi et al., 2017; Crespi et al., 2015, 2014, 2021; Simion et al., 1992) they were placed both in the maxilla and the mandible, in 1 study (Altiparmak et al., 2017) it was placed only in the mandible. The bone width (BW) before the SCT was reported by thirteen studies and ranged from 2.7 to 4.6 mm (Albanese et al., 2019; Anitua & Alkhraisat, 2016; Annibali et al., 2012; R. Bassetti et al., 2013a; Blus & Szmukler-Moncler, 2006; Bruschi et al., 2017; Crespi et al., 2015, 2014,

2021; de Souza et al., 2020; Ferrigno & Laureti, 2005; Garcez-Filho et al., 2015; Santagata et al., 2015; Simion et al., 1992). Immediately after SCT the width ranged from 6 to 9 mm on the 7 studies that reported (Albanese et al., 2019; Anitua & Alkhraisat, 2016; Annibali et al., 2012; R. Bassetti et al., 2013a; Blus & Szmukler-Moncler, 2006; Crespi et al., 2015, 2014, 2021). Only 5 studies evaluated the bone width at the follow-up, and it ranged from 4.7 to 8.2 mm (Bruschi et al., 2017; Crespi et al., 2021; de Souza et al., 2020; Santagata et al., 2015; Simion et al., 1992). Only one study did not reported the BW in any time point (Altiparmak et al., 2017). Follow-up periods ranged from 6 months to 120 months. The buccal bone wall thickness was assess by only one study (Crespi et al., 2021) and presented a mean of 2.5 mm on the maxilla and 1.2 mm on the mandible. The SLA-BC distance was assessed at follow-up times in 9 studies and ranged from 0.1 to 2.5 mm (Albanese et al., 2019; Anitua & Alkhraisat, 2016; R. Bassetti, Bassetti, Mericske-Stern, & Enkling, 2013b; Bruschi et al., 2017; Crespi et al., 2015; de Souza et al., 2020; Garcez-Filho et al., 2015; González-García et al., 2011; Simion et al., 1992), and the implant survival ranged from 95 to 100% and was reported by all studies.

Table 1. Longitudinal studies.

Authors (year)	Study design	P/I (n)	Location of SCP	BW before SCT	BW immediately after SCT	BW at follow-up	Follow-up (months)	Buccal bone wall thickness	SLA-BC distance at follow-up	Implant survival	Author's conclusion
Albanese et al., (2019)	P	10/45	Maxilla/ Mandible	2.7 (SD: 1.1) mm	6 (SD: 1.6) mm	NR	12	NR	1.1 (SD: 1) mm	97.8%	SCT was predictable and showed a success rate of 97.8% at 12 months from implant surgery
Altiparmak et al., (2017)	R	24/43	Maxilla	NR	NR	NR	38.3	NR	NR	100%	The SCT showed to shorten the treatment period, decrease postoperative swelling and pain, eliminate the need for a second surgical site, reduce the treatment cost, and ease patient cooperation on the surgery
Anitua et al., (2016)	R	10/16	Mandible	4. 2 (SD: 1.4) mm	6.4 (SD: 1) mm	NR	60	NR	1.4 (SD: 1)	100%	The SCT was an effective technique for the treatment of the atrophic mandible and the placement of dental implants.
Annibali et al., (2012)	CS	5/19	Maxilla/ Mandible	4.6 (SD: 1.3) mm	9.1(SD: 1.2) mm	NR	12.2	NR	NR	100%	Survival and success rates of the implants placed in bone augmented using the SCT appeared to be similar to those of implants placed in bone augmented using the GBR techniques and in pristine sites.
Bassetti et al., (2013)	P	7/17	Maxilla/ Mandible	2.9 (SD: 0.4) mm	7.6 (SD: 0.8) mm	NR	30	NR	2 mm	100%	After SCT, during the healing phase and the first year of loading a slightly more pronounced marginal bone loss should be anticipated compared to implant insertion in native bone

Blus et al., (2006)	P	57/230	Maxilla/ Mandible	3.2 mm	6 mm	NR	30	NR	NR	96.5%	SCT with USBS is predictable and does not lead to bone overheating or bone injury.
Bruschi et al., (2017)	R	71/137	Maxilla/ Mandible	2.6 (SD: 0.7) mm	NR	6.9 (SD:1.8) mm	78	NR	0.1	98.5%	Marginal bone stability seems to be influenced by blood supply on different flap approaches, and it appears that a full-thickness flap should not be reflected when ridge splitting is done. The keratinized gingiva thickness, dental implants with a 2mm collar, and the axis of the implant perpendicular to the antagonist dental surface may justify the bone gain presented after almost three years of implant placement
Crespi et al., (2013)	P	46/118	Maxilla/ Mandible	2.8 (SD:0.7) mm	7.2 (SD:1.7) mm	NR	24	NR	NR	98.3%	SCT using an electrical mallet does not lead to bone injury and does not lead to bone overheating. This surgical technique is rendered safe, less technique sensitive, and comfortable.
Crespi et al., (2015)	P	36/93	Maxilla/ Mandible	3.0 (SD: 0.8) mm	6.6 (SD: 1.6) mm	NR	24	NR	1 (SD: 0.4)	98.9%	Immediate loading of implants placed in SCT presented a favorable clinical outcome at 2 years of follow-up.
Crespi et al., (2021)	R	38/72	Maxilla/ Mandible	Maxila: 3.7 (SD: 0.8) mm Mandible: 3.7 (SD: 1.0) mm	NR	Maxilla: 8.1 (SD: 0.8) mm Mandible: 7.2 (SD: 0.7) mm	60	Maxilla: 2.5 (SD: 0.5) mm Mandible: 1.2(SD: 0.3) mm	NR	95%	Posterior areas of the maxilla displayed a higher increase in alveolar width and volume than mandibular areas, and a lower cumulative survival rate was reported for the maxillary single implants
de Souza et al., (2021)	P	13/23	Maxilla	2.9 (SD: 0.3) mm	NR	6.3 (SD: 0.6) mm	18.3	NR	0.6 mm	100%	The SCT proved to be viable and predictable, enabling a significant increase in ridge thickness and a high percentage of implant survival

Ferrigno et al., (2005)	P	40/82	Maxilla	NR	NR	NR	18	NR	NR	ITI TE: 100% ITI Standand: 95%	ITI TE implants inserted in conjunction with SCT seem to be a promising therapy to treat selected anatomic situations involving insufficient maxillary bone thickness
Garcez-Filho et al., (2014)	R	21/40	Maxilla	3.2 mm	NR	NR	120	NR	1.9 (SD: 0.9) mm	95%	SCT may be considered a secure, less invasive, and less morbid alternative to treat narrow edentulous ridges when compared to autogenous bone grafts
Gonzalez-Garcia et al., (2010)	P	8/33	Maxilla	NR	NR	NR	28.3	NR	0.5 mm	100%	The SCT provides predictable results concerning primary stability and implant surveillance
Santagata et al., (2015)	P	13/33	Maxilla	4.6 mm	NR	8.2 mm *6 months	36	NR	NR	97.5 %	The SCT appeared to be relatively uncomplicated, and the success rates of implants placed in the expanded areas were within the limits of the proposed criteria
Simion et al., (1992)	CS	5/10	Maxilla/ Mandible	2.5 mm	NR	4.7 mm	6	NR	2.5 mm	100%	The results indicate that the SCT associated with an e-PTFE membrane could be a valid alternative to techniques requiring extra surgical ridge widening procedures.

Study design: P - prospective; R - retrospective; CS - case series

P/I (n) - patients/implants

BW before SCP: NR - not reported

Author's conclusion: GBR - guided bone regenaration; USBS - ultra-sonic bone surgery

SYSTEMATIC REVIEWS

Five systematic reviews reporting long-term clinical outcomes following the SCT were selected. Detailed data are shown in Table 2.

Bassetti et al. (2015) evaluated the clinical, radiological, and histological outcomes of the SCT outcomes with or without guided bone regeneration (GBR) with a follow-up range of 1-10 years from 18 human studies and 6 animal studies. Eighteen studies reported survival and 9 reported success rates ranged from 91.7 to 100% and 88.2 to 100%, respectively. In the publications assessing the crestal bone level changes the most bone loss was observed during healing phase. Only 1 publication compared bone level changes at buccal site with the mesial-distal sites and reported a slightly more pronounced bone loss buccally.

Elnayef et al. (2015) assessed the predictability, dimensional changes, and associated factors to successfully perform the SPT from 17 studies. The variables assessed were horizontal bone gain after SCT as well as its related predictability, complications, implant survival rate, and factors (e.g., PTF: partial thickness flap; FTF: full thickness flap). The implant survival rate of the included studies was 97% with the FTF approach and 95.7% with the PTF approach. The BW gain was 3.2 (SD:1.2) mm using FTF approach and 4.1 (SD: 3.1) mm using PTF approach. Buccal wall fracture that becomes detached from the periosteum (free bone fragment) represented the most frequent postoperative complication, followed by postoperative ridge resorption.

Mestas et al. (2016) evaluated the survival rates of titanium dental implants placed using SCT for alveolar ridge expansion and the variables of the study were the number and/or percentage of implants reported lost from 9 studies. A total of 1178 patients received 3033 implants with ridge expansion. On average, the success rate was 96.6% and the survival rate was 96.8% with a mean follow-up of 58.3 months.

Starch and Jensen (2019) evaluated in 5 studies the hypothesis of no difference in implant treatment outcome after maxillary alveolar ridge expansion with SCP compared with lateral ridge augmentation with autogenous bone block graft. The primary outcome variable was the survival of prosthesis and implants. The findings indicated that both treatment modalities disclosed high survival rate of implants and prosthesis. As

secondary outcome, the implant stability, peri-implant marginal bone loss, gain in maxillary WR and biological and technical complications. Implant stability values, limited peri-implant marginal bone loss and gain in maxillary WR were reported. According to the results both techniques seemed to be useful for horizontal augmentation of maxillary alveolar deficiencies.

Waechter et al. (2016) reviewed data from 27 studies that reported bone volume gain with SCT with different surgical instruments for osteotomy. The findings of the review showed that average bone gain in the studies that used conventional surgical instruments (burs and chisels) was 3.6 mm, while in those that used piezoelectric ultrasound devices was 3.7 mm. It was concluded that the use of both techniques for osteotomy were effective for successful SCT.

Table 2. Systematic Reviews.

Author (year)	Journal	Nº of articles included	Objective	Variables	Results	Conclusion
Bassetti et al., (2015)	Clinical Oral Implants Research	18	To evaluate clinical and radiological outcomes of the SCT with or without GBR	Survival and success implant rates, dimensional bone changes	Survival (18 studies) and success (9 studies) rates ranged from 91.7 to 100% and 88.2 to 100%, respectively, with a mean follow-up of 1-10 years. Crestal bone level changes in some studies indicate slightly higher bone loss before and after loading. Only 1 publication compared bone level changes at buccal site with the mesial-distal sites and reported a slightly more pronounced bone loss buccally.	SCT seems to be a well-functioning one-stage alternative to extended two-stage horizontal grafting procedures
Elnayef et al., (2015)	The International Journal of Oral Maxillofacial Implants	17	To assess the predictability, dimensional changes, and associated factors to successfully perform the SCT	Horizontal bone gain after SCT as well as its related predictability, complications, implant survival rate, and factors (e.g., the FTF vs PTF approach)	The implant survival rate of the included studies' mean was 97.0% with the FTF approach and 95.7% PTF approach. The weighted mean of bone width gain was 3.19 (SD: 1.19) mm . For studies using PTF for SCP, only one study provided the mean of horizontal bone width gain (4.13 - SD: 3.13 mm). Buccal wall fracture represented the most frequent postoperative complication, followed by postoperative ridge resorption	The SCT might represent a predictable approach as demonstrated by a high implant survival rate, adequate horizontal bone gain, and minimal intra and postoperative complications.
Mestas et al., (2016)	The International Journal of Oral Maxillofacial Implants	9	To evaluate the survival rates of titanium dental implants placed using SCT for alveolar ridge expansion	Number and/or percentage of implants reported lost	A total of 1,178 patients received 3,033 implants following the SCT. On average, the success rate was 96.6%, and the survival rate was 96.8%, with a mean follow-up of 58.3 months.	The SCT appears to provide predictable alveolar ridge augmentation as well as high survival rates in the short and long term for implants in the maxilla or mandible

Starch-Jensen (2019)	Journal of Oral Maxillofacial Research	5	To test the hypothesis of no difference in implant treatment outcome after maxillary alveolar ridge expansion with SCT compared with lateral ridge augmentation with autogenous bone block graft	Primary outcome measures: survival of prosthesis, survival of implants Secondary outcomes: implant stability, peri-implant marginal bone loss, gain in maxillary alveolar ridge width, biologic and technical complications	Both treatment modalities disclosed a high survival rate of implants with few complications. The high survival rate of the prosthesis, implant stability values, limited peri-implant marginal bone loss, and gain in maxillary alveolar ridge width was reported with the SCT. Patient-reported outcome measures and length of treatment time were not assessed in any of the included studies.	The hypothesis of no difference in the final implant treatment outcome could neither be confirmed nor rejected. Both techniques seem to be useful for horizontal augmentation of maxillary alveolar deficiencies with a high survival rate of prosthesis and implants
Waechter et al., (2016)	Journal of Oral Maxillofacial Research	27	To determine the expected bone volume gain with SCT with different surgical instruments for osteotomy	Bone volume increase, surgical instruments used	A total of 4,115 implants were installed in 1,732 patients (average patient age 52 years). The overall implant survival rate was 97%. The average bone gain in studies that used conventional surgical instruments was 3.6 mm, while this was 3.7 mm in those that used ultrasound. The most significant problems identified during the qualitative analysis were related to the random selection of the population and the absence of statistical analysis.	The SCT appears to be a promising and effective technique to gain bone width, regardless of the surgical instruments used

Objective: GBR - guided bone regeneration

Variables: FTF - full-thickness flap; PTF - partial-thickness flap

CONCLUSION

SCT with concomitant implant placement shows high survival rates and, therefore, is a reliable and predictable alternative for ridge augmentation in narrow alveolar ridges. Evidence on the hard tissue stability, specially at the buccal site, for long period follow-up is however, limited.

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Evaluation of bone width around implants placed simultaneously with the split-crest technique: a retrospective longitudinal study

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INTRODUCTION

Bone resorption (vertically, horizontally, or a combination of both) is frequently found in patients with long-standing edentulism (Cawood & Howell, 1988; Schropp et al., 2003). Due to alveolar ridge resorption caused by post-extraction defects, periodontal diseases, traumatic tooth avulsion, or long-term edentulism, implant placement in an ideal position for a prosthetic solution is frequently compromised or impossible (Hu et al., 2018). As a result, augmentation techniques are frequently used to increase bone volume in preparation for implant placement.

Different ridge augmentation procedures such as lateral augmentation using guided bone regeneration (Buser et al., 1990), bone block grafting (Misch, 2009), distraction osteogenesis (Takahashi et al., 2004), and interpositional augmentation (Barros-Saint-Pasteur, 1966) have been suggested to reconstruct the resorbed posterior and anterior edentulous sites. Although guided bone regeneration is a predictable procedure for horizontal ridge augmentation, it strongly relies on the underlying bone's blood supply (Misch, 2016), which limits its use in an atrophic mandible with limited marrow between the buccal and lingual central plates. The same can be said for bone block grafting, which necessitates a second surgery site if autogenous bone is used (Buser, Dula, Hirt, & Schenk, 1996). Distraction osteogenesis and interpositional augmentation are also effective techniques, but complications may arise, resulting in the loss of large segments of bone (Guirado, Zamora, & Yuguero, 2007; Jensen, 2016).

In an attempt to overcome some of these limitations, the split-crest technique (SCT) with immediate implant placement was proposed by Scipioni & Bruschi (1988). In this technique, the ridge is expanded with specific drills and chisels, resulting in a sufficient width for implant bed preparation. Bone graft or bone substitute materials such as autogenous (Guirado et al., 2007), allogenic (Langer et al., 2012), or xenogeneic graft materials can be used to fill the space around the implants (Scarano et al., 2015b). This technique can be performed concurrently with implant placement, resulting in a shorter treatment time (Blus & Szmukler-Moncler, 2006; Chiapasco et al., 2006; Engelke et al., 1997; Koo et al., 2008; Langer et al., 2012; Scipioni et al., 1994; Sethi & Kaus, 2000). The

main advantages of such a technique are the fact that it does not require a donor area to remove the graft, provides a 4-wall bone defect and allows for the installation of dental implants in the same operative procedure, reducing morbidity, increasing wound stability, treatment time, the number of surgical procedures, and even the risk of complications to the patients, making it more easily accepted by them (Bassetti, Bassetti, & Bosshardt, 2016).

Because of the reduced morbidity (no bone harvesting from a second surgical region, no risk of membrane exposure, low risk of graft loss), the SCT with immediate implant placement (Scipioni et al., 1994; Sethi & Kaus, 2000) has caught the interest of many surgeons over the years. According to systematic reviews, horizontal reconstruction of alveolar deficiencies with the SCT appears to be a predictable and effective surgical technique with a high implant survival rate, gain in horizontal alveolar ridge width, and few biologic and technical complications (Bassetti et al., 2016; Elnayef et al., 2015; Mestas, Alarcón, & Chambrone, 2016; Waechter, Leite, Nascimento, Carmo Filho, & Faot, 2017).

Although this technique presents in the available literature high success rates and low rates of complications described, there are few studies that evaluate the healed buccal bone dimension for more than 5 years of follow-up. Thus, the aim of this study was to investigate the width of the healed buccal bone wall and alveolar ridge at implants placed simultaneously with SCT after at least 5 years of healing.

MATERIAL AND METHODS

Study design and population

This long-term retrospective study assessed the records of patients rehabilitated with implants placed simultaneously with a SCT. All surgeries were carried out at a private practice from 2002 to 2012. The Ethics Committee of Human Research of the State University of Maringá (UEM), Brazil, duly approved the study (protocol nº: 67415423.2.0000.0102). Because of the retrospective nature of this study, no informed consent was required. The study was conducted following the Helsinki Declaration, and manuscript preparation followed the STROBE guidelines (Vandenbroucke et al., 2007).

Inclusion and Exclusion Criteria

All clinical records of patients rehabilitated with implants placed simultaneously with the SCT from 2002 to 2012 were thoroughly examined.

All patient records that showed implants presenting (i) absence of mobility, (ii) pain, (iii) radiolucency, and (iv) peri-implant bone loss (>2mm) associated with (v) suppuration and/or bleeding on probing, possessing a cone beam computed tomography (CBCT) follow-up period of at least five years were selected for the study.

Patients presenting any of the following factors were excluded from the study: (i) incomplete clinical and CBCT records; and (ii) metal artifacts that prevented proper radiographic examination.

Surgical procedure

All the surgical procedures were performed by the same experienced operator (JGF). All patients presented an edentulous ridge characterized by a sufficient vertical bone height (greater than 10 mm) but an insufficient width (≤5 mm wide) for immediate implant installation (Garcez-Filho et al., 2015; Simion et al., 1992). Implants were placed following a modified SCT described previously by Garcez-Filho et al. (2015). In summary, one incision was placed at the top of the bone crest that extended mesiodistally over the chosen site. Two vertical incisions were placed at each end of the crestal incision and extended apically at a maximum depth of 5 mm beyond the mucogingival junction. A full-thickness flap was raised to expose 4 to 5 mm of bone crest at buccal and palatal aspects. At the buccal aspect, a horizontal incision was placed in the periosteum, and a split-thickness flap was elevated above the level of the previously denuded bone (5 mm most coronal). To allow for alveolar expansion, a horizontal osteotomy and two mesiodistal vertical osteotomies were carried out with the use of a conical ogival end diamond burr 3205 (Microdont® - São Paulo, SP, Brazil) and delimited the entire surgical area. In case of neighboring dentition, the vertical osteotomies were performed at least 1mm from the adjacent teeth. In order to obtain an incomplete or green-stick type fracture of the buccal bone wall, a thin chisel for bone expansion (Aseptic®, Woodinville, WA - USA) was

introduced into the horizontal osteotomy and the buccal bone wall was gently moved into the buccal direction until a 5 mm gap was achieved. The buccal bone was always connected to the periosteum, which partially covered the expanded bone wall.

The implant bed was prepared after splitting the bone ridge in order to place a Straumann® Standard Plus implant with SLA surface (3.3 mm or 4.1 mm in diameter; Straumann Dental System Implant®, Straumann, Waldenburg, Switzerland). The bed was prepared in accordance with the manufacturer's instructions. All implants achieved primary stability, and the interface between the SLA (treated implant surface) and the smooth surface (SLA border) was placed 2 mm below the buccal bone crest. The implant was connected to a healing abutment (3 mm high, Straumann Dental System Implant®, Straumann, Waldenburg, Switzerland). All implants placed had 8, 10, 12 or 14 mm in length and were anchored in at least 5 mm in depth of the lingual/palatal reminiscent native bone. A bone substitute material (Bio-Oss® small granules, Geistlich Pharma AB, Wolhusen, Switzerland) was grafted between the inner bone walls of the split-crest and adjacent to the implant surfaces. In addition, the bone substitute was also placed on the outer surface of the expanded buccal wall.

The flaps were repositioned and stabilized with interrupted sutures in such a way that a semi-submerged implant placement was achieved (Figure 1a, 1b, 1c and 1d describes a clinical case). The sutures were removed 10 days after the split-crest procedure. Prescription medication was given to patients: potassium diclofenac (50 mg), one pill every 8 hours for 3 days, amoxicillin (500 mg), one capsule every 8 hours for 7 days and mouthwash with chlorhexidine digluconate 0.12%, twice a day for 15 days. Six to eight weeks after implant placements, abutments were connected, and the prosthetic rehabilitations were delivered. The presence of occlusal contact on the ceramic crowns was confirmed with the aid of occlusal marking films. Following prosthesis insertion, the patients began a 6-monthly maintenance regimen that included oral hygiene instruction, prophylaxis, and supragingival scaling.

Clinical measurements

Immediately before ridge expansion, the width of the ridge (WR) at the future implant site and 2 mm below the crest was obtained by measuring the distance between the outer buccal and palatal walls with a caliper (WR1). Subsequently, after the ridge expansion and implant placement, the total width of the ridge (WR2) was obtained at the center of the implant site. The measurements were performed with the aid of a surgical thickness gauge (Milton®, nº 66-694 - Stainless, Germany). A mean value for the WR was calculated when more than one implant was placed in the area.

Cone-beam computed tomography (CBCT) measurements

All patients were referred for a CBCT scan at arches where the SCT and implant placement had been previously performed. The indications for the CBCT scans varied among root fractures, periapical lesions, and implant planning at the adjacent previous surgical sites. The CBCT scans were performed on the entire arch using the iCAT unit (Imaging Sciences International Inc., Hatfield, PA, USA). The images were captured using the iCAT software and then processed by a computer. The acquisition was performed (field of view: 6 × 8 cm) for 20 seconds with the following i-CAT tomography acquisition protocol: 0.3-mm voxel size; 14-bit grayscale; 0.5-mm focal spot; amorphous silicon flat-panel image detector; and single 360-degree rotation for image acquisition. Files from the Digital Imaging and Communication in Medicine (DICOM) project were imported into an open-source software (3D Slicer 4.10.1, www.slicer.org), and CBCT reconstructions were obtained. A cross-sectional view of each implant site on the buccal and palatal plane was obtained parallel to the implant's long axis. Following CBCT alignment to the site of interest, different linear measurements were performed on the images with open-free software (Image J 1.52a, National Institutes of Health, USA).

The primary variable of the present study was the width of the healed ridge. The same and previously calibrated examiner carried out all measurements: (i) width of the healed ridge (WR), measured at 0, 3 and 5mm below the SLA border; (ii) thickness of the buccal bone (BB), measured at 0, 3 and 5mm below the SLA border; (iii) thickness of the lingual/palatal bone (LB) measured at 0, 3 and 5mm below the SLA border and (iv) the distance between the SLA border to the bone crest (BC; SLA-BC). Intra-examiner double

assessments of the distance between SLA-BC of five randomly selected implant sites were obtained twice in an interval of 1 week. The intraclass correlation coefficient (ICC) obtained was 0.9 (CI 95%). (Figure 2 describes CBCT measurements).

Statistical analysis

For all clinical and tomographic parameters, descriptive analysis with mean values, standard deviations and median values was performed.

Assuming WR as the response variable and considering the follow-up time as a covariate, a generalized linear model was fitted based on the gamma family with a log link. The results were obtained using the function "glm" from R software (version 4.2.1) and are illustrated in Table 3.

In addition, frequency distribution was obtained for different variables and shown in Supplementary Tables 1, 2 and 3.

RESULTS

A total of 30 patients (21 females and 9 males), aged between 42 and 77 years (mean: 56.2 ± 10.2 years), fulfilled the inclusion criteria. Each participant presented one surgical site. Thus, 30 SCT were performed with the installation of 85 implants. There were, however, some patients who were evaluated more than once. The mean follow-up time was 11.5 ± 4.18 years. The longest follow-up was 18 years. All patient and implant study characteristics are presented in Table 1.

The mean width of the ridge at baseline (WR1) and immediately after the SCT (WR2) were, respectively, 3 (± 0.79) mm and 5.9 (± 0.89) mm. Immediately following the SCT, the ridge became statistically significantly wider ($p<0.001$). The overall mean of WR values at the different follow-up time intervals was similar to WR2 at most of the intervals (Table 2). At 0 mm, 3 mm, and 5 mm implant levels, the overall mean WR of the various time intervals were, respectively, 5.30 (± 1.77), 6.65 (±1.92) and 7.75 (± 2.15) mm (Table 2). By using a generalized linear model, it was found, however, that WR follow-up (WRF)

at some time-year intervals was statistically significant different from WR2 (For details, see Table 3).

The mean buccal bone thickness in patients at 5-year follow-up at 0, 3 and 5 mm below the SLA border were, respectively, 0.95 mm (±0,76), 1.50 mm (±0.75) and 2.02 mm (±1.27). The corresponding values at the remaining follow-up intervals varied from 0 to 1.74 mm (Table 4). The bone wall thickness at the palatal/lingual walls in all implant levels and time intervals varied from 0 to 1.67 mm (Table 4). The frequency distribution of the buccal and palatal/lingual bone wall width are presented in supplementary table 1 and supplementary table 2.

The mean SLA-BC distance, after five years of follow-up, was 1.62 mm (±1.84) (Table 5). The frequency distribution of the SLA-BC distance is presented in supplementary table 3.

DISCUSSION

The current long-term observational study reported on hard tissue stability around 85 implants placed simultaneously with a SCT for horizontal ridge augmentation for up to 18-year follow-up. The findings documented that the SCT significantly increased the width of the alveolar ridge, which remained relatively stable for several years. Furthermore, it also showed that frequently, at the SLA border, the buccal bone was lacking, while at 3 and 5 mm below, it was ≥ 1mm thick.

In the present study, the ridge at the SLA border was, on average, 3 mm wide at baseline and increased to 6 mm immediately after the augmentation procedure. After a period of at least 5 years of healing, the ridge remained about 6 mm wide. The literature showed a similar mean increase of the alveolar ridge width following SCT, ranging from 3 to 6 mm (Al-Dubai, Abdel-Rahman, Ahmed, & Tawfik, 2022; Anitua & Alkhraisat, 2016; Blus & Szmukler-Moncler, 2006; Bruschi et al., 2017; Crespi et al., 2014; Garcez-Filho et al., 2015; Scarano et al., 2015a; Starch-Jensen & Becktor, 2019). Elamrousy et al. (2021) evaluated the alveolar bone width after SCT with 2 different bone grafts. The authors observed after 6 months of healing that the alveolar ridge width increased from 3-6 mm.

It has been reported that the mean width of the pristine alveolar process at the esthetic zone of the maxilla (from second premolar to central incisor) was about 9 mm (Botelho, Perussolo, Misawa, Zadeh, & Araújo, 2020; Misawa, Lindhe, & Araújo, 2016). Thus, in the various clinical studies reported above, the SCT can predictably increase the ridge width but often fails to increase the ridge to its pristine dimension.

At different intervals of healing (5-18 years), the mean width of the alveolar ridge varied from about 5, 7 and 8 mm, respectively, at 0, 3 and 5 mm below the SLA border. These findings are similar to several clinical studies (Al-Dubai et al., 2022; Anitua & Alkhraisat, 2016; Anitua, Begoña, & Orive, 2013; Blus & Szmukler-Moncler, 2006; de Souza et al., 2020; Elamrousy et al., 2021; Gurler, Delilbasi, Garip, & Tufekcioglu, 2017; Holtzclaw, Toscano, & Rosen, 2010; Santagata et al., 2015; Scarano et al., 2015a; Scavia, Roncucci, Bianco, & Maddalone, 2020) that measured the width of the alveolar ridge after shorter time intervals (3-6 months of healing). These studies reported a ridge from 6 mm to 10 mm wide. In addition, Crespi et al. (2021) evaluated the outcome of SCT after 5 years of healing and reported that the mean width of the ridge was about 7-8 mm. The above results suggest that the SCT may predictably augment the ridge for long periods.

At the SLA border, the width of the alveolar ridge in the present study was compared to the width obtained immediately after the SCT (WR2). The findings showed a frequent reduction of the bone width after the various time intervals. At the 5 to 7-year time intervals, the reduction was about 0.2 to 0.7 mm, while at the 16 to 18-year time interval, the corresponding width reduction ranged from 1.7 to 3.1 mm. Such ridge reduction has also been described after other ridge augmentation procedures (Kuchler et al, Benic et al 2012). Kuchler et al (2016) measured the buccal bone wall width at 2 mm apical to the implant shoulder 10 years after immediate implant placement with simultaneous guided bone regeneration and showed a reduction of 0.9 mm (ranged from 0.0 to 2.8 mm) of the buccal bone dimension. The above results were similar to Benic et al (2012), which showed the mean thickness of the buccal bone measured at the most coronal aspect of the alveolar crest as determined at implant placement measured about

0.4 mm with 71% of the cases presenting 0 mm. Thus, at the most coronal portion of the ridge, a certain amount of bone loss should be expected after ridge augmentation procedures.

The mean buccal bone thickness after 5 years of healing at 0, 3 and 5 mm below the SLA border was, respectively, 1.0, 1.5 and 2.0 mm. The frequency distribution analyses showed, however, that at the SLA border, the percentage of sites devoid of buccal bone tended to increase over time, from 0-43% at 5 to 9-year intervals to 50-100% at ≥ 10-year time intervals. The corresponding values at the 3 and 5 mm implant levels at the various time intervals were, however, markedly different. Most of the implant surfaces exhibited a buccal bone ≥1 mm. This finding is in accordance with a clinical study performed with a similar methodology (Crespi et al., 2021). The authors measured the buccal bone width at 1 mm apical to the most coronal bone margin and reported that the bone was about 2.0 mm wide. In a histological preclinical study, Monje et al (2019) demonstrated that a minimum of 1.5 mm of buccal bone thickness was recommended to reduce the risk of post-operative bone loss and soft tissue recession. Accordingly, Koh et al (2011) showed in a randomized pilot study that the number of exposed implant threads was strongly correlated with the keratinized tissue thickness, buccal plate thickness, and horizontal defect depth. Thus, it is suggested that the increasing frequency of implant sites lacking buccal bone observed at the coronal portions of the ridge in later time intervals observations may be related to the initial bone thickness.

At the more apical portions of the implant sites, 3 and 5 mm below the SLA border, the current study found that the buccal and palatal bone walls were frequently thicker as the healing period increased. Glickman and Smulow, in 1965, suggested the term "buttressing bone formation" for those situations where bone formation occurs with the purpose of reinforcing bone trabeculae in response to trauma from occlusion or under circumstances which occlusal forces are not severe enough to produce trauma from occlusion but generated altered occlusal forces. Such an earlier concept was supported by the so-called Wolff's Law (1892), which stated that bone tissue grows and is modified

in response to the mechanical pressures it receives. In addition, higher mechanical loads (0.25% to 0.40% of deformation) cause bone hypertrophy with increased lamellar bone, and pathologically higher loads (more than 0.40% deformation) cause woven bone formation (Marx & Garg, 1998). Thus, the thicker bone walls observed in later periods of observation at the 3 and 5 mm implant levels may be due to increased mechanical load at the bone tissue.

The mean SLA-BC distance was assessed at the buccal aspect of the implant by a CBCT scan, and the mean was 1.7 mm following several years of healing (5-18 years). According to Albrektsson and Isidor (1994), implant treatment can be deemed successful if the peri-implant bone loss is 1.5 mm or less within the first year after loading and if bone loss is no more than 0.2 per year over the following years. The SLA-BC distance after 1 year was not examined in the current investigation; however, the results after 5 years showed that the mean distance was 1.6 mm. Thus, the mean vertical bone loss appears to satisfy Albrektsson and Isidor's success criteria. These findings corroborate the data from Albanese et al (2019) that evaluated the outcome of SCT and implant placement. The authors used CBCT scans to measure the distance SLA-BC after 1 year of healing. It was found that the mean loss was 1.2 mm. Other studies presented in the literature that evaluated the SLA-BC distance used periapical or panoramic radiographs for analysis. They showed a mean SLA-BC distance at the interproximal aspect that ranged from 0.5 mm to 2 mm at the first year after implant loading (Albanese et al., 2019; Bruschi et al., 2017; Crespi et al., 2015; de Souza et al., 2020; Gurler et al., 2017; Jensen, Cullum, & Baer, 2009), and 0.5 mm to 1.68 mm (Bassetti, Bassetti, Mericske-Stern, & Enkling, 2013; Crespi et al., 2015; Ferrigno & Laureti, 2005; González-García, Monje, & Moreno, 2011) after 2 years follow-up. Garcez-Filho (2015) also evaluated the SLA-BC distance after 6 months and 10 years and observed that the distance increased between the 2-time intervals by about 1.5 mm.

The SCT is considered a predictable approach that demonstrates a high implant survival rate with the additional advantage of immediate implant placement, which shortens the treatment and reduces the costs (Bassetti et al., 2016; Elnayef et al., 2015;

Garcez-Filho et al., 2015; Mestas et al., 2016; Waechter et al., 2017). This technique is, however, considered time-consuming and enhances the risk of injuries to the lips, tongue, and surrounding soft tissues when using the classical method with bone chisels and rotating saws. In addition, it requires significant technical skills and a long learning curve (Anitua & Alkhraisat, 2016; Blus & Szmukler-Moncler, 2006; Waechter et al., 2017).

The current study presents some limitations. The sample was relatively small. The measurements taken at different intervals were not always performed on the same patients. The initial measurements were made intra-operatively and not with CBCT scans. CBCT scans in the same patients at baseline and at various time intervals would have been ideal to confirm the dimensional changes that had occurred, particularly at buccal sites. No measurements of esthetic and patient-related outcomes were performed, which would have contributed to the understanding of the long-term benefit of the SCT with implant placement. Further prospective longitudinal studies with larger samples to evaluate dimensional, esthetic and patient-related outcomes are needed.

CONCLUSIONS

Split-crest technique with concomitant implant placement may significantly increase the width of the alveolar ridge, which remains in great part stable for several years. At the SLA border level, however, the buccal bone wall may be frequently lost.

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TABLES & CHART.

Table. 1 Patient and implant study characteristics**.**

Variable		Count	%	Mean	Median	Std. Dev.
Subjects		30				
Age				56,23	55	10,20
Gender	**Female**	21	70%			
	Male	9	30%			
Implants		85				
Implant Location	**Anterior**	43	51%			
	Posterior	42	49%			
Implant Length	**8mm**	31	37%			
	10mm	46	54%			
	12mm	6	7%			
	14mm	2	2%			
Implant Diameter	**3.3 mm**	71	84%			
	4.1 mm	14	16%			
Implant Surface	**SLA**	52	61%			
	SLActive	33	39%			

Table 2. Mean width of the ridge at the follow-up intervals (WRF) at the SLA border (0), 3 and 5 mm below.

Follow-up	N	Width of the ridge								
		0 mm			3 mm			5 mm		
		Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
5	16	5.81	5.21	1.76	6.46	6.46	6.46	6.94	6.94	6.94
6	10	5.16	5.11	0.90	6.23	6.23	6.23	7.85	7.85	7.85
7	31	6.21	5.87	1.98	7.35	7.35	7.35	8.55	8.55	8.55
8	11	6.66	6.65	1.20	7.04	7.04	7.04	7.64	7.64	7.64
9	1	5.92	5.92	--	6.33	6.33	6.33	8.19	8.19	8.19
10	5	4.73	5.20	1.23	6.92	6.92	6.92	7.59	7.59	7.59
11	3	3.87	3.30	0.98	6.80	6.80	6.80	7.90	7.90	7.90
12	4	4.94	4.94	1.44	6.58	6.58	6.58	7.51	7.51	7.51
13	4	3.80	3.80	0.58	5.85	5.85	5.85	6.75	6.75	6.75
14	4	3.95	3.70	0.85	4.58	4.58	4.58	6.48	6.48	6.48
15	3	3.97	3.30	1.15	6.63	6.63	6.63	7.10	7.10	7.10
16	11	4.27	4.10	1.27	6.40	6.40	6.40	7.92	7.92	7.92
17	8	3.36	3.30	0.18	5.20	5.20	5.20	6.60	6.60	6.60
18	5	5.26	4.10	2.00	7.88	7.88	7.88	9.34	9.34	9.34
Total	116*	5.30	5.05	1.77	6.65	6.60	1.92	7.75	7.90	2.15

*Of the 85 implants 31 were evaluated at 2 different follow-up intervals.

Table 3. Difference between WR2 and WRF at the different times intervals at the SLA border (0 mm).

0 mm						
Follow-up	**N**	**Difference**	**95% Conf. Int.**		**p value**	**Signif.**
			Lower	**Upper**		
5	16	0.15	-1.64	0.76	0.72	
6	10	0.66	0.44	1.57	0.04	*
7	31	0.17	-0.37	0.64	0.55	
8	11	-0.77	-1.77	0.35	0.10	
9	1	---	---	---	---	---
10	5	0.10	-0.90	1.70	1.00	
11	3	2.70	1.00	2.70	0.05	*
12	4	2.42	-0.58	5.70	0.11	
13	4	2.20	1.70	2.70	0.02	*
14	4	1.93	0.90	2.70	0.20	*
15	3	2.70	0.70	2.70	0.05	*
16	11	1.70	0.90	1.90	0.00	*
17	8	3.09	2.70	3.70	0.00	*
18	5	1.70	-1.80	2.90	0.59	

OBS: Negative sign on the difference indicates that WRF is greater than WR2.

TABLE 4. Mean width of the buccal and palatal/lingual bone wall at the follow-up intervals (WRF) at the SLA border (0), 3 and 5 mm below.

Buccal bone wall width										
Follow-up	**N**	**0 mm**			**3 mm**			**5 mm**		
		Mean	**Median**	**SD**	**Mean**	**Median**	**SD**	**Mean**	**Median**	**SD**
5	16	0.95	1.06	0.76	1.50	1.73	0.75	2.02	2.16	1.27
6	10	0.73	0.66	0.78	1.35	1.50	0.82	2.14	2.30	1.05
7	31	1.27	1.03	1.35	1.81	1.50	1.43	2.62	2.16	1.57
8	11	1.74	1.82	0.92	1.83	1.90	0.55	2.14	2.42	0.94
9	1	0.00	0.00	--	0.00	0.00	--	1.50	1.50	--
10	5	0.90	0.80	0.94	2.80	3.10	0.98	3.21	3.30	1.15
11	3	0.00	0.00	0.00	1.37	1.50	0.71	2.03	1.90	0.61
12	4	0.74	0.64	0.88	1.88	1.71	1.46	2.41	1.81	2.08
13	4	0.00	0.00	0.00	1.00	1.25	0.69	1.48	1.70	1.08
14	4	0.00	0.00	0.00	0.18	0.00	0.35	1.53	1.70	1.39
15	3	0.20	0.00	0.35	1.43	1.40	0.55	1.53	1.50	0.15
16	11	0.41	0.00	1.02	1.44	0.00	2.10	2.30	1.60	2.17
17	8	0.00	0.00	0.00	1.20	1.50	0.90	2.14	2.35	1.77
18	5	1.42	1.60	1.38	2.34	1.90	2.18	3.18	3.20	2.44
Total	116	0.87	0.66	1.08	1.60	1.50	1.28	2.30	2.10	1.50
Palatal/lingual bone wall width										
Follow-up	**N**	**0 mm**			**3 mm**			**5 mm**		
		Mean	**Median**	**SD**	**Mean**	**Median**	**SD**	**Mean**	**Median**	**SD**
5	16	1.64	1.39	1.27	1.75	1.71	0.99	1.75	1.32	1.29
6	10	1.32	1.18	0.47	1.58	1.70	0.79	2.41	2.59	1.00
7	31	1.67	1.63	0.97	2.23	2.10	1.12	2.64	3.05	1.02
8	11	1.62	1.65	0.56	1.91	2.00	0.55	2.20	2.21	0.70
9	1	2.62	2.62	--	3.03	3.03	--	3.39	3.39	--

10	5	0.32	0.00	0.72	0.88	0.90	0.88	1.06	1.30	0.71
11	3	0.53	0.00	0.92	1.83	1.90	0.31	2.40	2.50	0.17
12	4	0.82	0.86	0.66	1.37	1.39	0.73	1.86	2.10	0.57
13	4	0.00	0.00	0.00	1.58	1.90	1.16	2.58	2.65	0.83
14	4	0.33	0.00	0.65	0.80	0.85	0.63	1.23	1.25	0.67
15	3	0.43	0.00	0.75	1.57	1.60	0.25	1.97	2.00	0.06
16	11	0.40	0.00	0.57	1.41	1.50	1.25	1.90	2.10	1.22
17	8	0.09	0.00	0.25	0.97	1.10	0.93	1.51	1.75	1.19
18	5	0.74	0.00	1.03	1.80	2.30	1.17	2.50	3.10	1.45
Total	116*	1.12	1.07	1.03	1.72	1.77	1.03	2.14	2.2	1.09

*Of the 85 implants 31 were evaluated at two different follow-up intervals.

Table 5. Frequency distribution of the buccal bone wall width at different levels at the 5 to 18-year follow-up intervals.

		0mm			
Follow-up	**N**	**0 mm**	**>0<1 mm**	**≥1<2 mm**	**>2 mm**
5	16	31%	13%	50%	6%
6	10	40%	30%	20%	10%
7	31	26%	19%	36%	19%
8	11	9%	9%	46%	36%
9	1	100%	0%	0%	0%
10	5	40%	20%	20%	20%
11	3	100%	0%	0%	0%
12	4	50%	0%	50%	0%
13	4	100%	0%	0%	0%
14	4	100%	0%	0%	0%
15	3	77%	33%	0%	0%
16	11	82%	0%	9%	9%
17	8	100%	0%	0%	0%
18	5	40%	0%	20%	40%
Total	116*	47%	12%	27%	14%
		3mm			
Follow-up	**N**	**0 mm**	**>0<1 mm**	**≥1<2 mm**	**>2 mm**
5	16	12%	6%	63%	19
6	10	10%	20%	50%	20%
7	31	10%	16%	48%	26%
8	11	0%	0%	64%	36%
9	1	100%	0%	0%	0%
10	5	0%	0%	20%	60%
11	3	0%	33%	33%	33%
12	4	0%	25%	25%	50%
13	4	25%	0%	75%	0%
14	4	75%	25%	0%	0%
15	3	0%	33%	33%	33%
16	11	55%	9%	9%	27%
17	8	26%	12%	50%	12%
18	5	20%	20%	20%	40%
Total	116	17%	13%	43%	27%
		5mm			
Follow-up	**N**	**0 mm**	**>0<1 mm**	**≥1<2 mm**	**>2 mm**
5	16	13%	6%	25%	56%
6	10	0%	10%	30%	60%

7	31	0%	16%	23%	61%
8	11	0%	27%	9%	64%
9	1	0%	0%	100%	0%
10	5	0%	0%	20%	60%
11	3	0%	0%	67%	33%
12	4	0%	50%	0%	50%
13	4	25%	0%	25%	50%
14	4	100%	0%	0%	0%
15	3	0%	0%	0%	100%
16	11	28%	0%	36%	36%
17	8	25%	0%	12%	63%
18	5	9%	11%	25%	55%
Total	116*	21%	25%	28%	26%

*Of the 85 implants 31 were evaluated at two different follow-up intervals.

Table 6. Frequency distribution of the palatal/lingual bone wall width at different bone levels at the 5 to 18-year follow-up intervals.

			0mm		
Follow-up	**N**	**0 mm**	**>0<1 mm**	**≥1<2 mm**	**>2 mm**
5	16	6%	37%	20%	37%
6	10	0%	40%	50%	10%
7	31	7%	16%	48%	29%
8	11	0%	9%	55%	36%
9	1	0%	0%	0%	100%
10	5	80%	0%	20%	0%
11	3	67%	0%	33%	0%
12	4	25%	25%	50%	0%
13	4	100%	0%	0%	0%
14	4	75%	0%	25%	0%
15	3	67%	0%	33%	0%
16	11	64%	9%	27%	0%
17	8	87%	13%	0%	0%
18	5	60%	0%	20%	20%
Total	116*	31%	16%	34%	19%
			3mm		
Follow-up	**N**	**0 mm**	**>0<1 mm**	**≥1<2 mm**	**>2 mm**
5	16	0%	31%	31%	38%
6	10	0%	20%	40%	40%
7	31	0%	13%	29%	58%
8	11	0%	9%	36%	55%
9	1	0%	0%	0%	100%
10	5	40%	20%	40%	0%
11	3	0%	0%	66%	33%
12	4	0%	50%	0%	50%
13	4	25%	0%	25%	50%
14	4	25%	25%	50%	0%
15	3	0%	0%	100%	0%
16	11	36%	0%	36%	28%
17	8	37%	13%	37%	13%
18	5	20%	0%	20%	60%
Total	116	10%	15%	34%	41%
			5mm		
Follow-up	**N**	**0 mm**	**>0<1 mm**	**≥1<2 mm**	**>2 mm**
5	16	0%	37%	19%	44%

6	10	0%	10%	30%	60%
7	31	0%	3%	26%	71%
8	11	0%	9%	9%	82%
9	1	0%	0%	0%	100%
10	5	20%	20%	60%	0%
11	3	0%	0%	0%	100%
12	4	0%	0%	25%	75%
13	4	0%	0%	25%	75%
14	4	0%	50%	50%	0%
15	3	0%	0%	33%	67%
16	11	18%	9%	0%	73%
17	8	25%	12%	25%	38%
18	5	20%	0%	0%	80%
Total	116*	5%	12%	22%	61%

*Of the 85 implants 31 were evaluated at two different follow-up intervals.

Table 7. Mean distance from the SLA border (0 mm) and BC. (Mean, median, SD)

Follow-up	Mean	Median	SD
5	1.62	0.90	1.84
6	1.52	0.95	1.30
7	1.23	1.08	1.00
8	1.10	1.08	0.40
9	4.02	4.02	-
10	1.11	1.10	1.21
11	1.40	1.60	0.92
12	1.65	1.65	0.92
13	1.53	1.85	1.07
14	1.63	1.55	1.42
15	0.23	0.30	0.21
16	3.20	3.50	2.74
17	3.25	1.90	3.32
18	1.80	0.00	2.91
Total	1.70	1.10	1.84

Table 8. Frequency distribution of the SLA-BC values according to different ranges of distances at the 5 to 18-year follow-up intervals.

Follow-up	N	0 mm	>0<1 mm	≥1<2 mm	>2 mm
5	16	12%	50%	19%	19%
6	10	50%	30%	10%	10%
7	31	10%	36%	32%	22%
8	11	9%	27%	64%	0%
9	1	0%	0%	0%	100%
10	5	40%	0%	20%	40%
11	3	0%	33%	33%	33%
12	4	50%	0%	25%	25%
13	4	25%	0%	25%	50%
14	4	25%	0%	50%	25%
15	3	33%	77%	0%	0%
16	11	18%	9%	18%	55%
17	8	12%	0%	50%	38%
18	5	60%	0%	0%	40%
Total	116*	21%	25%	28%	26%

*Of the 85 implants 31 were evaluated at two different follow-up intervals.

FIGURES.

Figure 1. A) Clinical image from the region of the right mandible illustrating the keratinized mucosa of the edentulous ridge ready to receive midcrestal incision and panoramic radiograph illustrating the alveolar bone height to allow adequate expansion of the buccal bone plate. B) Clinical image from the right mandible immediately after a full thickness flap and subsequently horizontal osteotomy which will allow an adequate expansion of the buccal plate. C) Clinical image illustrating the implants installed and the bone substitute grafted between the inner bone walls of the SCP and the implant surfaces. D) Clinical image illustrating the healed keratinized mucosa and final prosthesis, and the corresponding CBCT of the region after 10 years of loading.

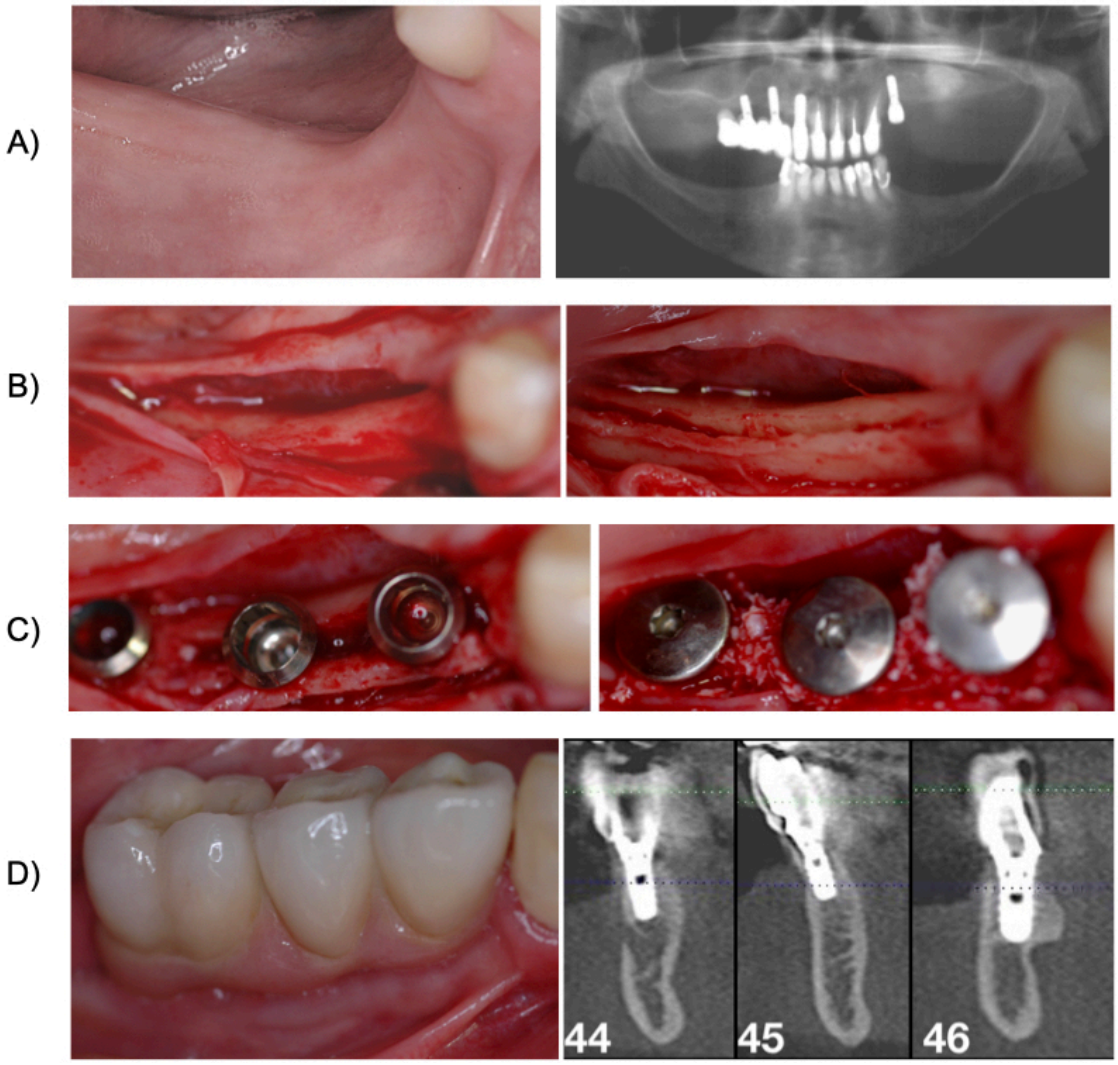
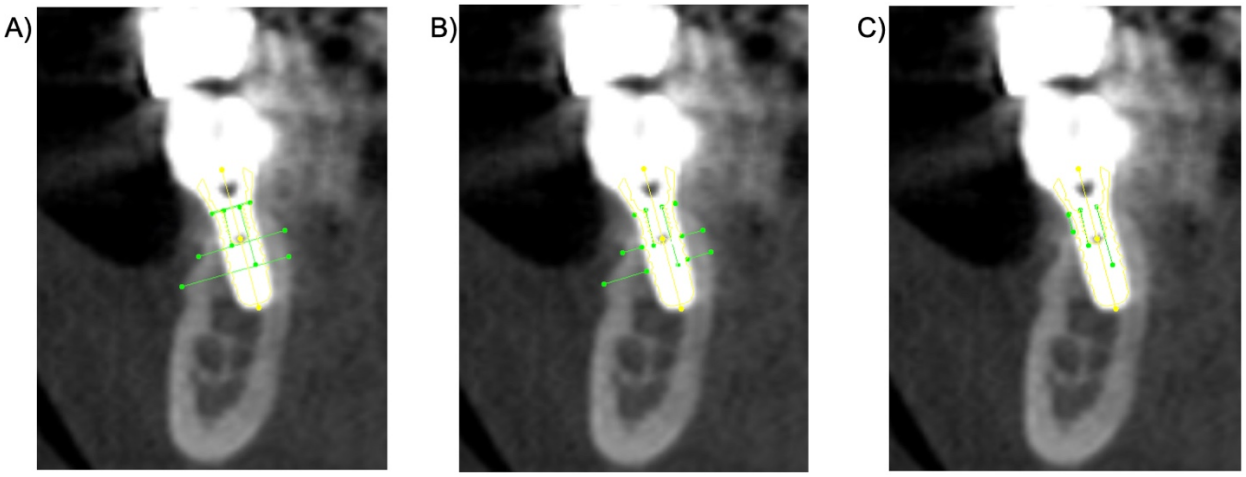


Figure 2. CBCT measurements. A) width of the healed ridge (WR), measured at 0, 3 and 5mm below the SLA border; B) thickness of the buccal bone and lingual/palatal bone, measured at 0, 3 and 5mm below the SLA border; C) the distance between the SLA border to the bone crest (BC;SLA-BC).



APPENDIX.

Clinical Oral Implants Research Guidelines

Author Guidelines

The study specific criteria were selected. Full-text guideline is available at: https://onlinelibrary.wiley.com/page/journal/16000501/homepage/forauthors.html

Clinical Oral Implants Research conveys scientific progress in the field of implant dentistry and its related areas to clinicians, teachers and researchers concerned with the application of this information for the benefit of patients in need of oral implants. The journal addresses itself to clinicians, general practitioners, periodontists, oral and maxillofacial surgeons and prosthodontists, as well as to teachers, academicians and scholars involved in the education of professionals and in the scientific promotion of the field of implant dentistry.

MANUSCRIPT CATEGORIES AND REQUIREMENTS

- **Original research articles** of high scientific merit in the field of surgical and prosthetic aspects of clinical oral implant dentistry including material sciences, physiology of wound healing, prevention and treatment of pathologic processes jeopardizing the longevity of implants, clinical trials on implant systems, stomatognathic physiology related to oral implants, oral tissue regeneration related to oral implants, digital technologies in the field of implant dentistry, new developments in therapeutic concepts and prosthetic rehabilitation.
- **Clinical Oral Implants Research** also publishes preclinical *in vivo* and *in vitro* research of high scientific merit which has translational relevance to clinical oral implant dentistry.
  Clinical Oral Implants Research encourages complete reporting of all data in one manuscript as opposed to reporting data (for example clinical and radiographic data) in multiple manuscripts.
- **Review articles** by experts on new developments in basic sciences related to implant dentistry and clinically applied concepts. Reviews are by invitation only from the Editor-in-Chief.
- **Perspective articles** on topical areas related to implant dentistry and clinically applied concepts by invitation only from the Editor-in-Chief.
- **Case reports** and case series, but only if they provide or document new fundamental knowledge and if they use language understandable to the clinician.
- **Novel developments** if they provide a technical novelty for any implant system
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vii. Abstract, MeSH term keywords and word count;
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Acknowledgments

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A sample of the most common entries in reference lists appears below. Please note that a DOI should be provided for all references where available. For more information about APA referencing style, please refer to the **APA FAQ**. Please note that for journal articles, issue numbers are not included unless each issue in the volume begins with page one.

Journal article

Beers, S. R. , & De Bellis, M. D. (2002). Neuropsychological function in children with maltreatment-related posttraumatic stress disorder. The American Journal of Psychiatry, 159, 483–486. doi:**10.1176/appi.ajp.159.3.483**

Book edition

Bradley-Johnson, S. (1994). Psychoeducational assessment of students who are visually impaired or blind: Infancy through high school (2nd ed.). Austin, TX: Pro-ed.

Internet Document

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UNIVERSIDADE ESTADUAL DE MARINGÁ

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Avaliação da dimensão óssea ao redor de implantes colocados simultaneamente com a técnica de split-crest: um estudo longitudinal

Pesquisador: Mauricio Guimarães Araújo

Área Temática:

Versão: 1

CAAE: 67415423.2.0000.0104

Instituição Proponente: Universidade Estadual de Maringá

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 5.956.424

Apresentação do Projeto:

Apresentação do Projeto:

Título da Pesquisa: Avaliação da dimensão óssea ao redor de implantes colocados simultaneamente com a técnica de split-crest: um estudo longitudinal

INTRODUÇÃO:

A reabsorção óssea extrema (vertical, horizontal ou uma combinação de ambos) é comum em pacientes com edentulismo de longa data (CAWOOD; HOWELL, 1988; SCHROPP; KOSTOPOULOS; KARRING, 2003). Devido à reabsorção do rebordo alveolar causada por defeitos pós-extração, doenças periodontais, avulsão dentária traumática ou edentulismo prolongado, a colocação do implante em uma posição ideal para uma solução protética é frequentemente comprometida ou impossível (HU, et al., 2018) Como resultado, as técnicas de aumento são freqüentemente usadas para aumentar o volume ósseo na preparação para a colocação do implante.Classicamente, quatro diferentes procedimentos de aumento horizontal podem ser usados para ampliar os rebordos mandibulares posteriores estreitos desdentados: aumento lateral usando regeneração óssea guiada (BUSER, et al., 1990), enxerto em bloco (MISCH, 2009), distração osteogênica (TAKAHASHI, et al., 2004) e aumento interposicional (SCIPIONI; BRUSCHI; CALESINI, 1994). Embora a regeneração óssea guiada seja um procedimento previsível para o aumento horizontal do rebordo,

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sua dependência do suprimento sanguíneo do osso subjacente (MISCH, 2016) limita seu uso em uma mandíbula atrófica com medula limitada entre as paredes vestibular e lingual. O mesmo pode ser dito para o enxerto em bloco, que necessita de um segundo local de cirurgia se for usado osso autógeno (BUSER, et al., 1996). A distração osteogênica é uma técnica eficaz para aumento horizontal do rebordo; no entanto, complicações podem resultar na perda de grandes segmentos de osso (JENSEN, 2016).Na tentativa de superar algumas dessas limitações, uma técnica de osteotomia sagital com colocação imediata de implantes foi proposta por Scipioni & Bruschi (1986). Nesta técnica o rebordo é expandido com brocas e cinzéis específicos, resultando em uma largura suficiente para o preparo do leito de implantação. Enxertos ósseos ou materiais substitutos ósseos, como materiais de enxerto autógenos (GUIRADO; ZAMORA; YUGUERO, 2007), alogênicos (LANGER; LANGER; SULLIVAN, 2012) ou xenógenos, podem ser usados para preencher o espaço ao redor dos implantes (SCARANA, et al., 2015). Essa técnica pode ser realizada concomitantemente à colocação do implante, resultando em menor tempo de tratamento (SCIPIONI; BRUSCHI; CALESINI, 1994; LANGER; LANGER; SULLIVAN, 2012; BLUS; SZUMKLER-MONCLER, 2006; ENGELKE, et al., 1997; KOO; DIBART; WEBER, 2008; SETHI; KAUS, 2000; CHIAPASCO, et al., 2006). As principais vantagens dessa técnica são o fato de não necessitar de área doadora para a retirada do enxerto, permitir a instalação de implantes dentários no mesmo ato operatório, reduzindo a morbidade, o tempo de tratamento, o número de procedimentos cirúrgicos e até o risco de complicações aos pacientes, tornando-o mais facilmente aceito por eles (BASSETTI; BASSETTI; BOSSHARDT, 2015).Devido à morbidade reduzida (sem retirada de osso de uma segunda região cirúrgica, sem risco de exposição da membrana, baixo risco de perda do enxerto), a técnica de osteotomia sagital com colocação imediata do implante (SCIPIONI; BRUSCHI; CALESINI, 1994; ; SETHI; KAUS, 2000) despertou o interesse de muitos cirurgiões nos últimos anos. De acordo com revisões sistemáticas e metanálises, a reconstrução horizontal de deficiências alveolares com a técnica de crista dividida parece ser uma técnica cirúrgica previsível e eficaz com alta taxa de sobrevivência do implante, ganho na largura do rebordo alveolar horizontal e poucas complicações biológicas e técnicas (BASSETTI; BASSETTI; BOSSHARDT, 2015; BUSER; WEBER; LANG, 1990; WAECHTER, et al., 2017; ELNAYEF, et al., 2015; MESTAS; ALARCÓN; CHAMBRONE, 2016). Embora essa técnica apresente altas taxas de sucesso e baixas taxas de complicações descritas na literatura, há poucos estudos que mostram a estabilidade de tecidos duros e moles com mais de cinco anos de acompanhamento.

Registros de pacientes mostrando implantes que apresentavam (i) idade maior ou igual a 18 anos

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(ii) ausência de mobilidade no implante, (iii) dor, (iv) radiolucidez e (v) perda óssea peri-implantar (>2mm) associada a (vi) ausência de supuração e/ou sangramento à sondagem, possuindo um (vii) período de acompanhamento de tomografia computadorizada de feixe cônico (CBCT) de pelo menos cinco anos.

Objetivo da Pesquisa:
Objetivo da Pesquisa:

Hipótese:
Manutenção da parede óssea vestibular em lingual nos milímetros 3 e 5 com diminuição da espessura com o passar do tempo

Objetivo Primário:
Investigar a dimensão total das paredes ósseas do rebordo cicatrizado ao redor de implantes colocados simultaneamente com a técnica de split- crest nos maxilares com um acompanhamento tomográfico de no mínimo 5 anos

Avaliação dos Riscos e Benefícios:
Avaliação dos Riscos e Benefícios:
RISCOS

Como se trata de uma análise documental, existem riscos como o vazamento de informações por meio de ataques cibernéticos ao computador que está sendo utilizado, ataques hacker via internet, roubo de HD e/ou computador com as informações. Para diminuir os riscos das informações serem compartilhadas de maneira a comprometer a confidencialidade dos pacientes, iremos anonimizar a amostra, somente um pesquisador acessará os prontuários, a tabulação e manipulação dos dados será feita de maneira offline, os arquivos não serão compartilhados via internet, os HDs e um Pen -drive contendo os registro serão armazenados com o pesquisador responsável e somente ele terá acesso através de senha designada pelo mesmo.

BENEFÍCIOS

Avaliar a estabilidade das paredes ósseas ao redor dos implantes instalados simultaneamente à

técnica de crista dividida ao longo dos anos, o que favorece o paciente, uma vez que se o procedimento se mostrar estável ao longo dos anos indicará sucesso na forma de tratamento escolhida.

Comentários e Considerações sobre a Pesquisa:

Trata-se de um estudo de fontes secundárias, com solicitação de dispensa de TCLE, documentação de apresentação obrigatória presente; folha de rosto e autorizações presentes; instrumento de coleta visualizado; cronograma de execução e orçamento financeiro adequados. Apresenta discussão dos riscos e benefícios.

Considerações sobre os Termos de apresentação obrigatória:

Foram revisados os seguintes documentos com suas respectivas datas de envio:
PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_2079865.pdf– Submissão 17/02/2023
folha_de_rosto.pdf – Submissão 16/02/2023
Tabela_Coleta_Dados.pdf– Submissão 03/02/2023
termodecompromissoprofmauricio.pdf– Submissão 31/01/2023
cartaanuencia.pdf - Submissão 31/01/2023
termodecompromisso.pdf - Submissão 31/01/2023
DispensaTCLE.doc - Submissão 26/01/2023
projetodepesquisa.docx - Submissão 26/01/2023

Recomendações:

Vide campo "Conclusões ou Pendências e Lista de Inadequações".

Conclusões ou Pendências e Lista de Inadequações:

Não foram observados óbices éticos nos documentos do estudo. Assim, De acordo com a análise realizada e as informações constantes nos arquivos anexados, baseado na legislação vigente, esse Comitê Permanente de Ética em Pesquisa Envolvendo Seres Humanos se manifesta pela aprovação do projeto de pesquisa em tela. Alerta-se a respeito da necessidade de apresentação de relatório final no prazo de 30 dias após o término do projeto.

Considerações Finais a critério do CEP:

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_2079865.pdf	17/02/2023 10:39:58		Aceito
Folha de Rosto	folha_de_rosto.pdf	16/02/2023 10:38:19	DEBORA DE A BIANCO	Aceito
Outros	Tabela_Coleta_Dados.pdf	03/02/2023 11:49:21	DEBORA DE A BIANCO	Aceito
Declaração de Pesquisadores	termodecompromissoprofmauricio.pdf	31/01/2023 15:16:24	DEBORA DE A BIANCO	Aceito
Declaração de Pesquisadores	cartaanuencia.pdf	31/01/2023 15:14:29	DEBORA DE A BIANCO	Aceito
Declaração de Pesquisadores	termodecompromisso.pdf	31/01/2023 15:13:04	DEBORA DE A BIANCO	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	DispensaTCLE.doc	26/01/2023 15:22:10	DEBORA DE A BIANCO	Aceito
Projeto Detalhado / Brochura Investigador	projetodepesquisa.docx	26/01/2023 14:39:23	DEBORA DE A BIANCO	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

MARINGA, 21 de Março de 2023

Assinado por:
Maria Emília Grassi Busto Miguel
(Coordenador(a))