UNIVERSIDADE ESTADUAL DE CAMPINAS
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Vanessa Felipe Vargas Moreno

INFLUÊNCIA DO DIÂMETRO LARGO DE IMPLANTES CURTOS E EXTRACURTOS NA DISTRIBUIÇÃO DE TENSÃO, DESEMPENHO CLÍNICO E BIOLÓGICO EM REABILITAÇÃO DE REGIÕES POSTERIORES

INFLUENCE OF THE WIDE DIAMETER OF SHORT AND EXTRA-SHORT IMPLANTS ON THE STRESS DISTRIBUTION, CLINICAL AND BIOLOGICAL PERFORMANCE FOR THE REHABILITATION OF POSTERIOR REGIONS

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Dissertação apresentada à Faculdade de Odontologia de Piracicaba da Universidade Estadual de Campinas como parte dos requisitos exigidos para a obtenção do título de Mestra em Clínica Odontológica, na Área de Prótese Dental.

Dissertation presented to the Piracicaba Dental School of the University of Campinas in partial fulfillment of the requirements for the degree of Master in Clinical Dentistry, in the Prosthodontics area.

Orientadora: Profa. Dra. Raissa Micaella Marcello Machado
Coorientadora: Profa. Dra. Altair Antoninha Del Bel Cury

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RESUMO

Implantes dentários curtos, >6 e <10 mm (IDCs) e extracurtos, ≤6 mm (IDECs), têm sido indicados para a reabilitação de rebordos severamente atrofiados, como alternativa às cirurgias de aumento vertical do rebordo. No entanto, a biomecânica deste tipo de reabilitação se torna desfavorável devido a menor superfície de contato osso/implante e a presença de maior proporção coroa/implante, o que resulta em um braço de alavanca vertical aumentado. Sendo assim, neste trabalho foi avaliado a influência do diâmetro largo (DL) na distribuição de tensões de IDECs, e identificar se o DL pode influenciar a biomecânica, o comportamento clínico e biológico dos implantes de comprimento reduzido. Para isto foram desenvolvidos dois estudos: I) estudo *in silico*, em que se avaliou, por meio da análise de elementos finitos, a influência do DL na distribuição de tensão de IDECs, com 5 mm de comprimento, reabilitados com coroas unitárias em região posterior de mandíbula atrófica, submetido a carga axial e oblíqua (30 graus), sendo avaliado quatro grupos: DRCA (implante de diâmetro regular, 4 mm, submetido à carga axial); DLCA (implante de diâmetro largo, 6 mm, submetido à carga axial); DRCO (implante de diâmetro regular, 4 mm, submetido à carga oblíqua); DLCO (implante de diâmetro largo, 6 mm, submetido à carga oblíqua); II) revisão sistemática com meta-análise, na qual foram incluídos estudos clínicos que utilizaram IDCs e/ou IDECs com DL, grupo intervenção e diâmetro regular (DR), grupo comparação, como retentores de coroas implantossuportadas. A partir do estudo I foi possível verificar que IDECs de DL possuem melhor distribuição de tensão no implante e no osso medular, entretanto no osso cortical a tensão foi maior principalmente quando submetido a forças oclusais oblíquas. Os resultados do estudo II mostraram que IDCs e IDECs de DL apresentam desempenho clínico e biológico semelhante ao DR, apresentando altas taxas de sobrevivência e baixo índice de complicações. Assim conclui-se que: I) O uso de IDECs de DL resulta em uma biomecânica favorável para o implante, mas tem um efeito potencialmente prejudicial ao osso cortical, principalmente sob carga oblíqua; II) O uso do DL de implantes de comprimento reduzido proporcionou comportamento clínico e biológico semelhante aos implantes de DR.

Palavras-chave: Arcada parcialmente edêntula. Prótese dentária fixada por implante. Revisão sistemática. Análise de elementos finitos.

ABSTRACT

Short, >6 e <10 mm (SDIs) and extra-short, ≤6 mm (ESDIs) dental implants have been indicated for the rehabilitation of severely atrophied ridges as an alternative to vertical bone augmentation surgeries. However, the biomechanics of this rehabilitation becomes unfavorable due to the smaller bone/implant contact surface and the presence of a higher crown/implant ratio, resulting in an increased vertical lever arm. Therefore, this dissertation evaluated the influence of wide diameter (WD) on the ESDIs' stress distribution and to identify its impact on the biomechanics, the clinical and biological performance of reduced length implants. For this, two studies were developed: I) *in silico* study by finite element analysis, that evaluated the WD influences on ESDIs, 5 mm in length, stress distribution as single crowns retainers in the posterior region of the atrophic mandible, being submitted to axial and oblique load (30 degrees), four groups being evaluated: RDAL (regular diameter implant, 4 mm, under axial load); WDAL (wide diameter implant, 6 mm, under axial load); RDOL (regular diameter implant, 4 mm, under oblique load); WDOL (wide diameter implant, 6 mm, under oblique load); II) systematic review with meta-analysis of clinical studies using WD SDIs and/or ESDIs, intervention group, and regular diameter (RD), comparison group, as crown retainers. The study I showed that WD SDIs and/or ESDIs have a better stress distribution at the implant and the cancellous bone. Although, it increased the stress in the cortical bone mainly when submitted to oblique occlusal forces. Study II showed that WD SDIs and/or ESDIs have similar biological and clinical performance compared to regular diameter, presenting high survival rates and low complications rate. Therefore, it is concluded that: I) WD ESDIs result in better biomechanical behavior for the implant, but it has a potentially damaging effect at the cortical bone, mainly under oblique load; II) the use of WD of reduced length implants showed a similar performance to RD implants.

Key-words: Jaw, edentulous, partially. Dental implant. Dental prosthesis, implant-supported. Systematic review. Finite element analysis.

LISTA DE ABREVIATURAS E SIGLAS

IDC	-	Implantes dentários curtos
SDI	-	Short dental implants
IDEC	-	Implantes dentários extracurtos
ESDI	-	Extra-short dental implants
DL	-	Diâmetro largo
WD	-	Wide diameter
DRCA	-	Implante de diâmetro regular (4 mm) submetido à carga axial
RDAL	-	Regular implant diameter under axial load
DLCA	-	Implante de diâmetro largo (6 mm) submetido à carga axial
WDAL	-	Wide diameter implant under axial load
DRCO	-	Implante de diâmetro regular (4 mm) submetido à carga oblíqua
RDOL	-	Regular diameter implant under oblique load
DLCO	-	Implante de diâmetro largo (6 mm) submetido à carga oblíqua
WDOL	-	Wide diameter implant under oblique load
DR	-	Diâmetro regular
RD	-	Regular diameter
C:I	-	Crow–to–implant ratio
AL	-	Axial load
OL	-	Oblique load
FEA	-	Finite element analysis

CAD	-	Computer-aided design
GPa	-	Young modulus
RR	-	Risk ratio
RCT	-	Randomized controlled clinical trial
JBI	-	Joanna Briggs Institute
GRADE	-	Grading of Recommendations Assessment, Development and Evaluation
N-RCT	-	Non-randomized clinical trial
CD	-	Combined data
NR	-	Not reported
95%-CI	-	95% confidence interval
CI	-	Confidence interval

LISTA DE SÍMBOLOS

δ	-	Poisson's ratio
σ_{Vm}	-	Equivalent von Mises stress
σ_{min}	-	Minimum principal stress
τ_{max}	-	Maximum shear stress
†	-	Data obtained after contacting the author by email
-	-	Data not evaluated

SUMÁRIO

1 INTRODUÇÃO

A reabilitação da região posterior com implantes dentários é desafiadora, uma vez que o processo de reabsorção do osso alveolar é progressivo. Além disso, o rebordo pode chegar à um nível de atrofia óssea severa, no qual a crista alveolar encontra-se próxima à estruturas anatômicas nobres, como o canal mandibular e seio maxilar (Atwood, 2001; Bordin et al., 2018; Marcello-Machado et al., 2017; Misch et al., 2006; Tallgren, 1972) dificultando a instalação de implantes de comprimento regular (Misch et al., 2006; Ravidà et al., 2019; Zadeh et al., 2018). Uma das alternativas para reabilitação desses casos é a utilização de implantes com comprimento reduzido, os quais recentemente foram classificados como implantes dentários curtos (>6 e <10 mm) ou extracurtos (≤6 mm) (Al-Johany et al., 2017). Estudos têm descrito essa alternativa como a mais segura devido à apresentar menores taxas de complicações, bem como menor custo e morbidade quando comparada às cirurgias de enxerto para reabilitação com implantes regulares (Lee et al., 2014; de N Dias et al., 2019). No entanto, os implantes de menor comprimento possuem superfície de contato entre osso/implante reduzida, o que pode levar a incertezas do seu prognóstico a longo prazo (Misch et al., 2006; Sotto-Maior et al., 2012, 2015). Considerando isto, e levando em conta que perdas ósseas peri-implantares apresentam uma média de 1 mm, variando de 0,1 a 2,67 mm após 10 anos de acompanhamento (Fischer K & Stenberg T, 2011; Moraschini V et al., 2015), a perda óssea ao redor de IDECs pode chegar a valores correspondentes à metade do comprimento desses implantes, comprometendo o seu desempenho.

Estudos mencionam que essa superfície de contato reduzida elevaria as tensões no osso (Mendonça et al., 2014; Misch et al., 2006; Rangert et al., 1996) e nos componentes protéticos (Misch et al., 2006; Sotto-Maior et al., 2012, 2015), tornando a biomecânica do conjunto desfavorável (Tawil et al., 2006; Tawil & Younan, 2004). Além disso, na maioria das vezes, os implantes dentários curtos e extracurtos são utilizados em associação com proporção coroa/implante aumentada. Pois, quanto maior o nível de reabsorção do rebordo, menor será o comprimento do implante utilizado, e maior será a coroa para a reabilitação da região. Consequentemente, maior será a proporção coroa/implante, ultrapassando os limites clínicos ideais (coroa/implante = 1:1) (Dykema et al., 1986; and Shillinberg et al., 1997; Jhanji & Sethi & Mittal, 2018) e criando uma maior concentração de tensões em áreas críticas,

independente do diâmetro e comprimento do implante (Bordin et al., 2018; Toniollo et al., 2017; Yilmaz et al., 2011). A fim de minimizar os riscos do menor comprimento associado a maior proporção coroa/implante, estudos recentes têm proposto o uso dos implantes com diâmetro largo (Arinc, 2018; Yamaguchi et al., 2018), o que aumentaria a área da estrutura interna do implante, e também a sua superfície de contato, obtendo assim uma maior superfície para uma melhor distribuição de tensões para o osso (Bordin et al., 2018; Ravidà et al., 2019; Yilmaz et al., 2011; Zadeh et al., 2018).

No entanto, ainda não está claro a influência do diâmetro largo de implantes extracurtos no comportamento biomecânico do conjunto implante-coroa utilizado para reabilitação de rebordos posteriores mandibulares com disponibilidade óssea vertical insuficiente para instalação de implantes de comprimento regular (>10 mm). Além disso, não se sabe quanto o diâmetro largo associado a uma proporção coroa/implante exarcebada, na presença de carga oblíqua, poderia influenciar a distribuição de tensão no implante, componentes protéticos e osso peri-implantar (Sotto-Maior et al., 2015; Elias et al., 2020). A respeito do comportamento deste conjunto, estudos clínicos e laboratoriais, não encontraram evidências de que a diferença no diâmetro do implante influencia a sobrevivência de implantes curtos (Bordin et al., 2018; Clelland et al., 2016; Lombardo et al., 2020). Uma revisão sistemática com meta-análise que somente avaliou a sobrevivência de implantes de diâmetro largo com diferentes comprimentos, reportou taxa de 92,67% para estudos retrospectivos e 97,76% para estudos prospectivos, em 5 anos de acompanhamento (Lee et al., 2016).

Estudo prévio já demonstrou que, do ponto de vista clínico e biológico, a proporção coroa/implante não é a principal razão para complicações biológicas ou falhas dos implantes (Ravidà et al., 2019). Além disso, ainda não há consenso na literatura sobre a influência do diâmetro largo na sobrevida, bem como no comportamento clínico e biológico de implantes curtos e extracurtos, e nem está estabelecido se a maior superfície de contato osso/implante influenciaria o sucesso desses implantes (Elias et al., 2020). Dessa forma, devido a falta de consenso e o uso cada vez mais difundido desses implantes, faz-se necessária a realização de mais estudos que esclareçam a previsibilidade do tratamento. Neste trabalho avaliou-se a influência do diâmetro largo na distribuição de tensões em região posterior de mandíbula atrófica, submetidos a carga axial e oblíqua. Além disso, por meio de

revisão sistemática com metanálise compilou evidências a respeito da influência do diâmetro largo no comportamento clínico e biológico dos implantes curtos e extracurtos usados para reabilitação de região posterior.

2 ARTIGOS

2.1 ARTIGO: Influence of diameter in the stress distribution of extra-short dental implants under axial and oblique load: a finite element analysis.

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(Anexo 1)

Influence of diameter in the stress distribution of extra-short dental implants under axial and oblique load: a finite element analysis

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ABSTRACT

Background: The use of extra-short dental implants with wide diameter could decrease the higher crown-to-implant ratio's implications in rehabilitating severely atrophic mandibular ridge. Therefore, this study evaluated the influence of a wide diameter on extra-short implants' stress distribution as a retainer for single implant-supported crowns in the atrophic mandible posterior region, under axial and 30º oblique load.

Materials and methods: Four 3D digital models of an atrophic mandible, using a single implant-retained crown with a 3:1 crown-to-implant ratio, were created for finite element analysis. The implant diameter used was either 4 mm (regular) or 6 mm (wide), both with 5 mm length. A 200 N axial or oblique load was applied to the first molar's occlusal surface. The equivalent von Mises stress was recorded for the abutment and implant, minimum principal stress and maximum shear stress for cortical and cancellous bone.

Results: The oblique load increased the stress in all components when compared to the axial load. Wide diameter implants showed a decrease of von Mises stress around 40% in both load directions at the implant and an increase of at least 3.6% at the abutment. Wide diameter implants exhibited better results for cancellous bone in both angulations. However, in the cortical bone, the minimum principal stress was at least 66% greater for wide than regular diameter implants, and the maximum shear stress more than 100% greater.

Conclusion: Extra-short dental implants with wide diameter result in better biomechanical behavior for the implant but have a potential risk of overloading the cortical bone and bone loss over time, mainly under oblique load.

Keywords

extra-short dental implants; short dental implants; implant-supported dental prosthesis; finite element analysis.

BACKGROUND

Implant-supported rehabilitation of the mandibular posterior region is challenging when severe mandibular bone resorption is present. The poor bone availability above the mandibular canal difficult the insertion of regular length implants [1–3]. Currently, there are different treatments for this clinical situation, including short dental implants, >6 to <10 mm in length (SDI), extra-short dental implants, ≤6 mm in length (ESDI) [4], or surgeries for vertical bone augmentation [3,5,6]. A recent systematic review showed at 1-year follow-up that SDIs have less morbidity, cost, and better survival rate (97%) than regular implants (92.6%) installed in a grafted bone area [7]. Besides, the proportion of patients with biological and mechanical complications was lower for SDIs, with an incidence of 6%, while 39% of complications were reported for regular implants [7]. Meanwhile, over a 5-year follow-up period, it was shown that there was no statistically significant difference in implant survival and success rates between SDIs and regular implants in the grafted area [5]. Also, ESDIs compared to regular implants have similar survival rates, 96.2%, and 99%, respectively, as well as the thecnical complications' incidence, 14.14% and 18.36%, respectively, after 3-years of follow-up [8].

However, a study that evaluated the long-term effectiveness of ESDI reported a survival rate of 94.1% at a five-year follow-up [1]. This rate can be explained by its unfavorable biomechanics [9,10] due to an increased crown-to-implant ratio (C:I) that creates a more significant vertical lever arm and a disadvantageous stress distribution [3,11,12]. These implants have a smaller bone/implant contact surface, which leads to increased stresses at the bone and prosthetic components [2,13,14]. Therefore, SDI and ESDI generally have a wide diameter (WD), increasing the surface and its bulk, which improves the stress dissipation [15–17], leading to better biomechanical behavior [18,19].

The treatment plan also requires checking the patients' occlusion and the antagonistic type affecting the implant success [19]. In a physiological occlusion predominantly occur axial loads (AL), in the mandibular posterior region, transmitted by the implant's long axis to the bone, resulting in an adequate stress dissipation [20,21]. However, when a non-physiological occlusion is present, the resultant occlusal force is an oblique load (OL), creating an unbalanced stress distribution [13,14]. Therefore, when the high C:I anchored by ESDI is used, the incidence of OL increases

the bending moment of the vertical lever arm, causing a non-homogeneous force dissipation, leading to poor prognosis, which may contribute to peri-implant bone loss [13,14,21]. Clinical and *in vitro* studies showed that the increased C:I only negatively influences the stress distribution when an OL is present [13,14,22].

Previous systematic reviews focused on C:I evaluation have shown no significant differences in biological complications and peri-implant health results [11,23–25], being 2.36:1 the higher C:I evaluated [24]. Meanwhile, a recent 4-year retrospective clinical trial concluded that the higher the C:I ratio (0.47 to 3.01), the less the marginal bone loss [26]. However, the biomechanical behavior of a challenging scenario where a 3:1 C:I crown supported by an ESDI, with 5 mm in length, at the severe reabsorbed mandibular posterior region, in the presence of OL, has not yet been investigated. That is critical since it can make the long-term success of this type of rehabilitation uncertain.

Besides, the benefits of using WD ESDI have not reached a consensus in the literature, since clinical and laboratory studies have not found differences in survival rates when assessing different diameters and lengths [3,27]. This fact contradicts the prerogative of better biomechanics due to its larger contact surface [18,19]. Therefore, there is a need for further studies, to evaluate the mechanical behavior [21] and its reliability satisfactorily to predict the rehabilitation behavior before future prospective clinical studies. Thus, using FEA, the present study evaluated the influence of WD on the stress distribution of ESDI as support for single implant-supported crowns in the posterior region of the atrophic mandible, with a 3:1 C:I ratio, under AL or OL.

MATERIALS AND METHODS

Through the computer-aided design (CAD) software (SolidWorks; Dassault-Systèmes SolidWorks Corp; Waltham, Massachusetts, USA) were created the 3D virtual models of a single crown, cement layer, cortical and cancellous bone. Also, CAD models of a universal abutment (4.5 x 2 x 6 mm) and two morse-taper implants of 4 x 5 mm (28.274 mm^3, bone/implant contact surface: 101.39 mm^2) and 6 x 5 mm (75.75 mm^3, bone/implant contact surface: 155.36 mm^2) were assessed virtually, which were obtained by the manufacturer (S.I.N Implant System, São Paulo, Brazil). Two study

factors were evaluated: I) implant diameter: 4 mm (RD: regular diameter, being this the control group) or 6 mm (WD) (Fig. 1); II) load angulation: AL or OL (30° off-axis) being applied at the mesiobuccal cusp [28] (Fig. 2). The bone model had a 12.94 mm height and 16.11 mm of thickness, and a 2 mm layer of cortical bone surrounding the cancellous bone [29] (Fig. 1). The crown, 13 mm in height with a 3:1 C:I [26] (Fig. 1) was virtually cemented on the abutment (70-µm layer), and four groups were created: RDAL (regular diameter implant under AL); WDAL (wide diameter implant under AL); RDOL (regular diameter implant under OL); WDOL (wide diameter implant under OL). The FEA models' validation [30] was performed by past literature for the location of force application and bone layers' dimensions and by past *in vivo* study for crown and C:I.

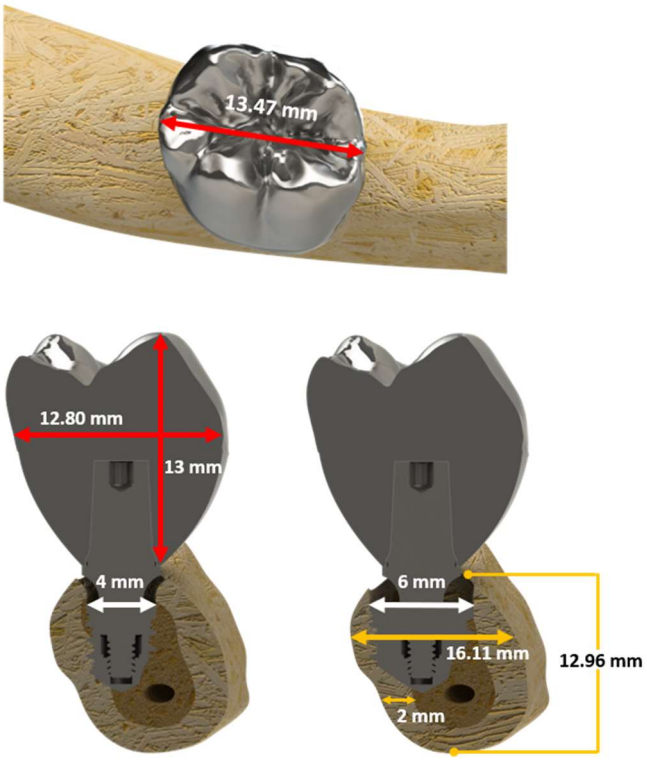

Figure 1: Implant diameter used for different groups are illustrated in white. The dimensions of the bone (yellow) and the crown (red) used are the same in all groups.

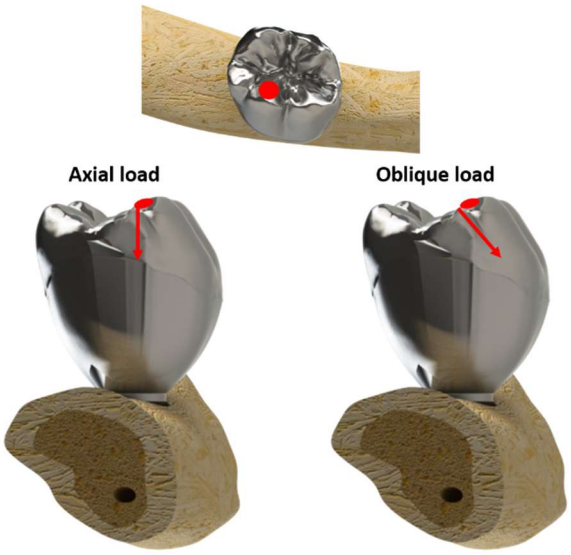

Figure 2: Load angulation applied at the mesiobuccal cusp for different groups, axial load and 30º oblique load.

After assembly, the virtual models were exported to finite element software (ANSYS Workbench 15.0; ANSYS Inc; Canonsburg, Pennsylvania, USA) for a mathematical solution. A tetrahedral mesh was generated with an element size of 0.6 mm after convergence analysis with 5% tolerance. The Young modulus (GPa) and Poisson's ratio (δ) of each material were set in the software according to table 1. All components were considered homogenous, isotropic, and linearly elastic. Also, the contact conditions between implant/abutment were assumed as no separation, and the contacts crown/abutment and implant/bone were assumed as bonded.

Table 1: Mechanical properties of materials

Material	Young Modulus (GPa)	Poisson's ratio (δ)
Titanium Grade IV [31,32]	110	0.33
Co-Cr alloy [33]	220	0.3
Cortical bone [19]	13.7	0.3
Cancellous bone [19]	1.370	0.3
Resin cement [34]	18.3	0.33

Then, the models were fixed in two lateral portions of the bone segment and were submitted to a 200N load on the occlusal surface of the first molar [13] (Fig. 2).

The equivalent von Mises stress (σ_{vM}) was used for the implant and the abutment [13,19,31]. Minimum principal stress (σ_{min}), and maximum shear stress (τ_{max}) [13,35] were used for both cortical and cancellous bone.

RESULTS

Results for the FEA assessment are presented in table 2. Regardless of diameter, there was a significant increase in stress in all components, over 200%, under OL when compared to AL results. Also, the stress was greater on the abutment and cortical bone and less on the cancellous bone and implant for WD groups. A significant increase in stress was observed in cortical bone for WD groups compared to RD groups, being higher 66.3% for σ_{min} and 99.8% for τ_{max} under AL and higher 125.7% for σ_{min} and 201.7% for τ_{max} under OL (Table 2). For the AL groups, the peak stress concentration was in the area in contact with the apical region of the implant, being the maximum values found at σ_{min} of 72.34 MPa (WDAL) (Fig. 3) and τ_{max} of 42.02 MPa (WDAL) (Fig.4). Meanwhile, in the OL groups, the highest stress concentration was in the cervical third of the bone, and the maximum values at σ_{min} 266.7 MPa (WDOL) (Fig. 3) and at τ_{max} 130.88 MPa (WDOL) (Fig. 4).

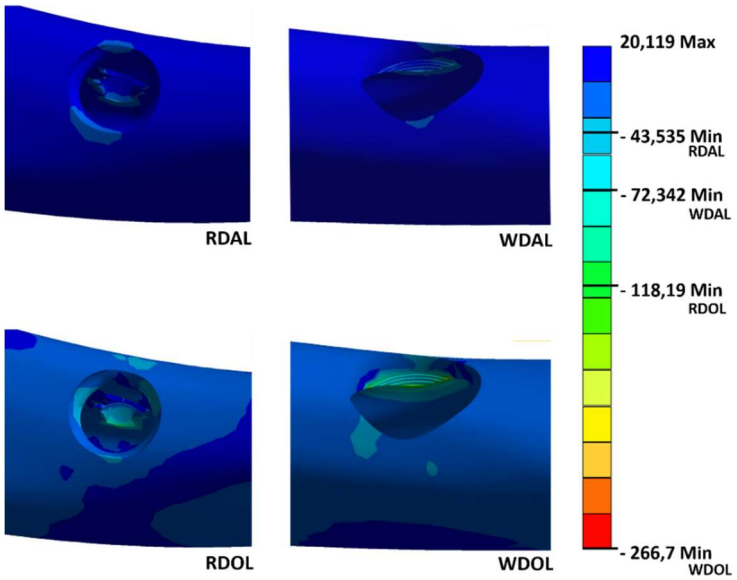

Figure 3: Minimum principal stress peak concentration for cortical bone (MPa) for all groups. Blue to red color represents stress values from higher to lower, respectively.

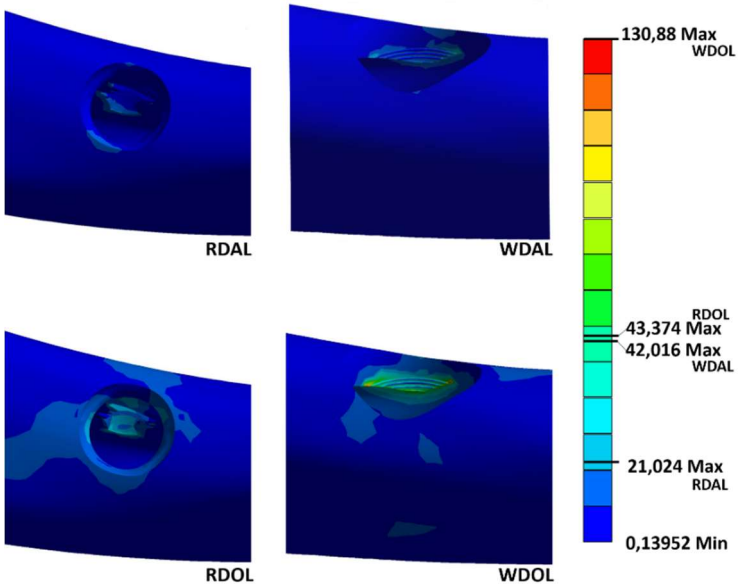

Figure 4: Maximum shear stress peak concentration for cortical bone (MPa) for all groups. Blue to red color represents stress values from lower to higher, respectively.

The analysis of σ_{min} and τ_{max} showed decrease stress in the cancellous bone for WD groups, about 44.9% for σ_{min} and 55.9% for τ_{max} under AL and 73.2% for σ_{min} and 71.9% for τ_{max} under OL (Table 2). Also, the images showed a peak stress concentration in the cervical third of the bone in all groups, and the minimum value of the σ_{min} was 9.79 MPa (WDAL) and of the τ_{max} 7.32 MPa (WDAL) (Fig. 5 and Fig. 6). Besides, the σVm evaluation images showed that in all groups, the peak stress area was at the abutment collar level (Fig.7) and in the corresponding region of the implant (Fig. 8). The analysis demonstrated that with the WD, a low increase occurred in the abutment stress of 3.6% under AL (WDAL: 202.94 MPa) and 12.7% under OL (WDOL: 1157.4 MPa) (Table 2). However, a decrease in the implant of 38.7% was observed under AL (WDAL: 185.98 MPa) and 38.2% under OL (WDOL: 873 MPa) (Table 2).

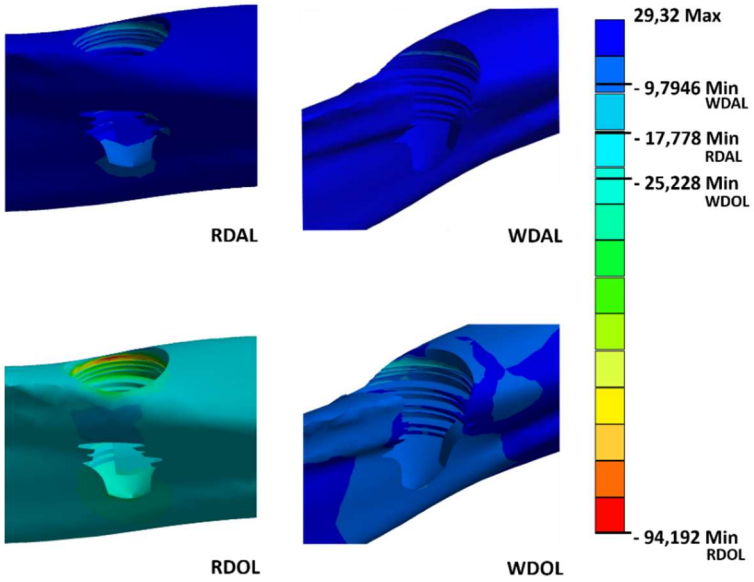

Figure 5: Minimum principal stress peak concentration for cancellous bone (MPa). Blue to red color represents stress values from higher to lower, respectively.

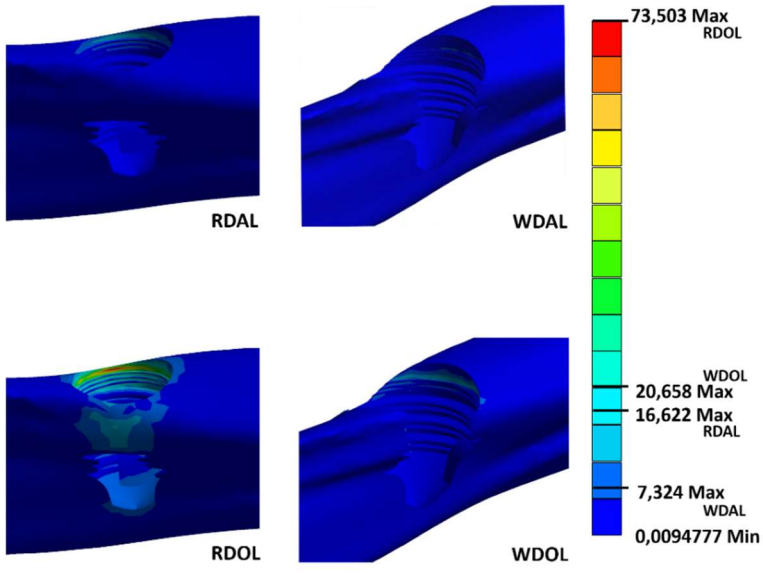

Figure 6: Maximum shear stress peak concentration in the cancellous bone (MPa). Blue to red color represents stress values from lower to higher, respectively.

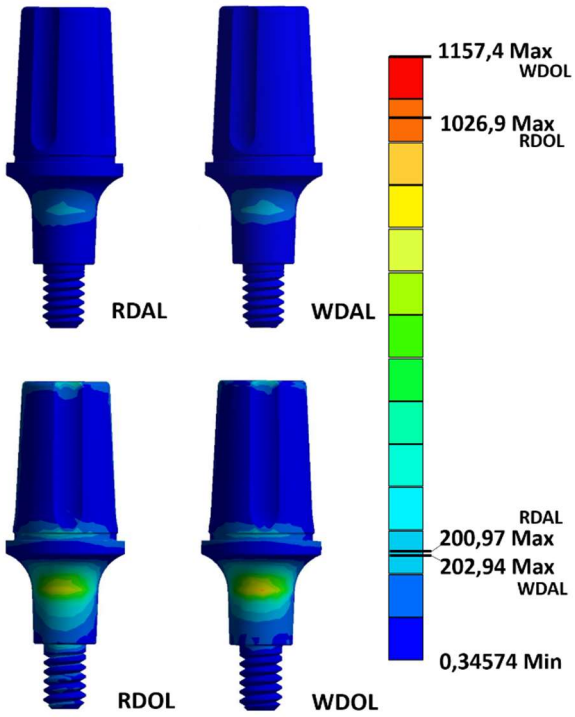

Figure 7: Von-Mises stress peak concentration (MPa) in the abutment. Blue to red color represents stress values from lower to higher, respectively.

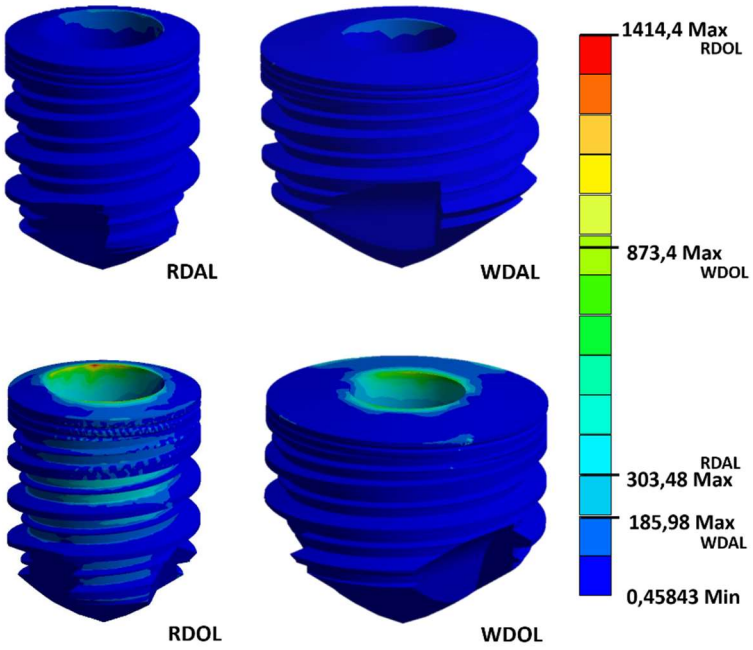

Figure 8: Von-Mises stress peak concentration (MPa) in the implant. Blue to red color represents stress values from lower to higher, respectively.

Table 2: Von-Mises criteria (MPa) for implants and abutment, minimum principal stress and shear stress for cortical and cancellous bone (MPa), and the differences between the groups and direction of the load.

	Axial load			Oblique load of 30º			Axial load x Oblique load of 30º	
	RDAL	WDAL	% stress	RDOL	WDOL	% stress	RDAL/RDOL %	WDAL/WDOL %
Abutment (σ_{vM})	200.97	202.94	*3.6%	1026.9	1157.4	*12.7%	*511.0%	*570.3%
Implant (σ_{vM})	303.48	185.98	#38.7%	1414.4	873.4	#38.2%	*466.1%	*469.6%
Cortical bone (τ_{max})	21.02	42.02	*99.8%	43.37	130.88	*201.7%	*206.3%	*311.5%
Cortical bone (σ_{min})	43.53	72.34	*66.3%	118.19	266.7	*125.7%	*271.5%	*368.7%
Cancellous bone (τ_{max})	16.62	7.324	#55.9%	73.5	20.66	#71.9%	*442.2%	*282.1%
Cancellous bone (σ_{min})	17.78	9.795	#44.9%	94.19	25.23	#73.2%	*529.8%	*257.6%

Notes. (*) Increased stress; (#) Stress decreased.

DISCUSSION

There is no consensus in the literature about the benefits of using WD ESDI in cases of severe mandibular bone resorption in the posterior region [21]. Also, recent studies showed that a high C:I ratio only increases the stress concentration when OL is present [13,36,37], being traumatic occlusion the primary cause of biomechanical complications [13,22,36,38]. Thus, by FEA, the present study evaluated the influence of WD on ESDI's stress distribution as support for single implant-supported crowns in the posterior region of the atrophic mandible, under AL and OL. It was observed that WD ESDI showed decrease of stress at the implant and the cancellous bone, while at the abutment and the cortical a increase was shown. Besides, when submitted to OL, there was an increase in stress in all components and groups by more than 200%, corroborating with previous studies [13,22,36,38].

In this study, the stress distribution on the peri-implant bone was different when a WD was used. A significant increase (up to 66%) in the stress can be observed in the cortical bone when τ_{max} and σ_{min} were evaluated, independently of load angulation. This is crucial since the stress exceeded the critical threshold of compressive (50 MPa) and tensile stress (34.72 MPa) at WDAL, RDOL, and WDOL, which would induce the bone resorption [39,40]. Also, in WD groups under OL load, the figures show a stress peak in the cervical third of the bone of at least 311.5% higher than the findings of the AL groups, which could be explained by the use of the WD implant providing a 34.73% higher bone/implant contact and wear on the cortical bone. These results corroborate with Elias et. al [36], which evaluated the influence of the prosthetic crown height in SDI and found a higher stress concentration in the OL groups.

Meanwhile, in the WD groups, a decrease in the stress was observed in the cancellous bone, bringing the MPa values found within the limits of compressive and tensile stress at WDOL [39,40] may be related to its Young modulus. The value that is lower than that of the cortical bone is that the greater the Young modulus, the stiffer the material, the greater the stress accumulation [19], and more resistance to deformation [41]. In the present study, when the WD implant was evaluated, the contact between the implant and cortical bone was increased, leading to higher stress on the cortical bone and a reduction on the cancellous bone, which can explain the results [19,42]. This enhanced contact with the cortical bone may negatively influence

the bone remodeling around the implants since the cortical bone is less vascularized than the cancellous bone, which leads to interference of blood supply that directly affects the bone resorption response [43].

The consequences of higher stress concentration on the cortical bone associated with its decrease on the cancellous bone remain uncertain since low-stress values around the implant resulting in a bone loss due to disuse atrophy, while high stress cause microfracture at the bone resulting either in bone loss or fatigue failure of the implant [41,43]. Also, since WD in ESDI increases the stress at the implant/cortical bone interface, being MPa values over the compressive and tensile limits of the bone [39,40], it represents a potential biological risk for marginal bone loss that might be even higher under OL. Besides, the mechanical loading conditions regulate the morphology of the bone [44], and it is still unknown how much bone/implant contact is necessary for the success of ESDIs [36].

The results of von Mises stress showed, in all groups, a higher stress concentration at the surface of the abutment collar level and at the implant platform where it touches the abutment collar. In both loads, the WD showed an increase of 12.7% in stress at the abutment and a reduction of at least 38.2% in the implant. This enhanced stress at WD implants might be explained by its structure 62% bulkier than RD implants. Since the stress increased over 400% at implant and abutment at the OL groups, clinically, increase the risk of the implant, and abutment failure once was exceeded the limits of tensile yield strength 0.2% (483 MPa) and ultimate tensile strength (550 MPa) of the titanium grade IV [45]. Suggesting that should be avoided the use of ESDI when it is impossible to eliminate OL during mandibular excursive movements, for example, in a parafunction scenario.

Clinically the masticatory forces are not acting in just one way and, impossible to isolate the force direction. So, it is essential to perform *in silico* studies, which allow the researcher to evaluate and study every direction of occlusal forces like was performed in this study. Besides, the present study is a numerical theoretical analysis, and its results should be validated with an *in vitro* study assessing implant failure mode in the same conditions of this study. In addition, other simulations could be performed to estimate possible statistical differences, for example, using different prostheses, abutments, and materials with different elastic modulus since they could reach a different result because of its dampers chewing loads [19]. Finally, performing randomized clinical trials including patients with severe bone atrophy in the posterior

region of the mandible with different types of occlusal patterns and a minimum of 1 mm cortical bone wall to surrounds the implant.

CONCLUSION

Extra-short dental implants with wide diameter result in better biomechanical behavior for the implant but have a potential risk of overloading the cortical bone and bone loss over time, mainly under oblique load.

LIST OF ABBREVIATIONS

ESDI: extra-short dental implants;
SDI: short dental implants;
C:I: crow–to–implant ratio;
WD: wide diameter;
AL: axial load;
OL: oblique load;
FEA: finite element analysis;
CAD: computer-aided design;
RD: regular diameter;
GPa: young modulus;
δ: Poisson's ratio;
RDAL: regular implant diameter under axial load;
WDAL: wide diameter implant under axial load;
RDOL: regular diameter implant under oblique load;
WDOL: wide diameter implant under oblique load;
σ_{vM}: equivalent von Mises stress;
σ_{min}: minimum principal stress;
τ_{max}: maximum shear stress.

DECLARATIONS

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and material

All data generated or analyzed during this study are included in this published article.

Competing interests

The authors declare that they have no competing interests.

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Author's contributions

Vanessa Felipe Vargas Moreno drafted the work, got the CAD's donation, lead the writing, performed the finite element analysis/ methodology, interpreted the data, reviewed and edited. Rafael Soares Gomes conceptualized, performed the finite element analysis/ methodology and reviewed and edited. Michele Costa de Oliveira Ribeiro conceptualized, interpreted the data, reviewed and edited. Mariana Itaborai Moreira Freitas conceptualized, interpreted the data, reviewed and edited. Altair Antoninha Del Bel Cury conceptualized, reviewed and edited. Raissa Micaella Marcello Machado supervised, lead the project administration, reviewed and edited. All authors read and approved the final manuscript.

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2.2 ARTIGO: Clinical and biological performance of wide diameter for short and extra-short dental implants as crowns retainers: a systematic review with meta-analysis

Clinical and biological performance of wide diameter for short and extra-short dental implants as crowns retainers: a systematic review with meta-analysis

Running title: Wide diameter short and extra-short dental implants

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ABSTRACT

Objective: To investigate the influence of wide diameter (WD) on the clinical and biological performance of reduced length implants (<10mm), short (SDI), and extra-short dental implants (ESDI) used for maxillary posterior region rehabilitation with single and/or fixed partial denture.

Material and methods: This study was registered on PROSPERO (CRD42020189262). A search in six databases was conducted to select randomized controlled trials, non-randomized clinical trials, and retrospectives studies. Meta-analyses of implant survival and prostheses success were evaluated. The risk of bias was determined using Joanna Briggs Institute appraisal tools, and the GRADE approach was used to the certainty of the evidence.

Results: Eighteen articles were included, 713 implants were installed with WD, and 847 were installed with regular diameter (RD). Three studies presented a low risk, eight an unclear risk, while seven a high risk of bias. Meta-analyses showed no statistical difference, independently of follow-up time for implant survival, until one year (RR 1.05 [0.92; 1.19]; p = 0.50; I2 = 51%), one to five years (RR 1.02 [0.99; 1.05]; p = 0.24; I2 = 0%) and more than five years (RR 1.01 [0.93; 1.11]; p = 0.75; I2 = 40%); and for prostheses success (RR 0.99 [0.97; 1.02]; p = 0.70; I2 = 0%). One study reported prosthetic complications: two crown shipping/fracture (WD) and one abutment loosening (RD). The most common biological complication was excessive bone loss (WD implants n = 4; RD implants n = 5).

Conclusion: When associated with SDI and ESDI, WD behaves similarly to RD regarding clinical and biological performance in maxillary posterior region rehabilitations, since both present high survival rates and prostheses success rate and low incidence of complications.

Key words: jaw, edentulous, partially; dental implant; dental prosthesis, implant-supported; systematic review.

INTRODUCTION

Reduced length dental implants, such as short dental implants, >6 to <10mm in length (SDI), and extra-short dental implants, ≤6mm in length (ESDI) (Al-Johany et al., 2017), are a strategy for maxillary posterior regions' rehabilitations with severe bone resorption. This type of rehabilitation is an alternative with less morbidity and similar survival rates or peri-implant bone loss (Mezzomo, Miller, Triches, Alonso, & Shinkai, 2014; Monje, Chan, et al., 2013; Monje et al., 2014; Palacios, Garcia, Caramês, Quirynen, & da Silva Marques, 2018) compared to surgeries for vertical bone augmentation (Bordin, Bergamo, Bonfante, Fardin, & Coelho, 2018; de N Dias, Pecorari, Martins, Del Fabbro, & Casati, 2019; Ravidà, Barootchi, et al., 2019; Ravidà, Wang, et al., 2019; Zadeh et al., 2018). These implants are commonly associated with rehabilitations with a higher crown-to-implant ratio (C:I), resulting in unfavorable biomechanics and non-homogenous load distribution to the bone (Bordin et al., 2018; Misch et al., 2006; Sotto-Maior, Senna, Silva-Neto, de Arruda Nóbilo, & Cury, 2015). The biomechanics behavior of SDI and/or ESDI can be improved using implants with a wide diameter (WD) to increase their structural area and the bone-implant contact surface, leading to a better stress distribution (Arinc, 2018; Yamaguchi et al., 2018).

However, it is still unknown if increasing the bone/implant contact can influence the success of ESDIs (Elias et al., 2020). Also, there is no consensus that confirms that WD implants present better clinical and biological performance than regular diameter (RD) implants. A recent three-year retrospective study showed a similar survival rate for SDI and ESDI with WD (5 mm) and RD (4 to 4.5 mm), 97.01%, and 97.76%, respectively (Lombardo, Signoriello, Simancas-Pallares, Marincola, & Nocini, 2020). A randomized controlled clinical trial (RCT) with three-year follow-up showed survival rates of 100% for 5 mm and 95.23% for 4 mm diameter implants (Clelland, Chaudhry, Rashid, & McGlumphy, 2016). Meanwhile, a systematic review with meta-analysis that evaluated the wide diameter, independently of implant length, found an estimated 5-year survival rate of at least 92.67% (Lee, Chen, Starr, & Chuang, 2016).

There is a lack of literature evidence in clinical trials (Clelland et al., 2016; Lombardo, Signoriello, et al., 2020; Monje, Fu, et al., 2013), and the use of the WD reduced length implants has increased. Thus, to clarify doubts about the WD, this systematic review with meta-analysis was performed to obtain qualitative and

quantitative data about WD's influence on the clinical and biological behavior of SDI and/or ESDI used for the maxillary posterior region rehabilitations with a single and fixed partial denture.

MATERIALS AND METHODS

Study Registration and reporting format

This systematic review was registered in the International Prospective Register of Systematic Reviews (PROSPERO), number CRD42020189262, and conducted following the PRISMA 2020 statement (Page et al., 2021).

PICO question and Search Strategy

This review sought to answer the following question: Has the WD influence the clinical and biological behavior of SDIs and/or ESDIs used to rehabilitate posterior regions? This systematic review was elaborated following the PICO format (Stone, 2002), being these the eligibility criteria:

- Patients: Partially edentulous patients rehabilitated with single and/or fixed partial denture retained by SDIs and/or ESDIs in the posterior region of the mandible and/or the maxilla.
- Intervention: Installation of SDIs and/or ESDIs, with WD (≥4.8 mm) in the posterior region.
- Comparison: Installation of SDIs and/or ESDIs, with RD (≥3.75 to <4.8 mm) in the posterior region.
- Outcome: primary outcomes - Implant survival rate, implant success rate and prostheses success rate; secondary outcomes - peri-implant complications and prosthetic complications.

For that, an electronic literature search was performed by two independent reviewers, V.F.V.M. and M.C.O.R., at the databases MEDLINE/PubMed, Web of Science, Embase, Scopus, and Cochrane using a match of boolean operators with Medical Subject Headings, synonymous and free terms, according to the rules of each database (Table 1). A search on ClinicalTrials.gov was done to find ongoing studies on this subject, and a manual search was performed using the references of the selected studies to identify additional studies. The publication date was not restricted,

andarticles published until this search performance date (June 22th, 2020) were included.

Table 1 - Search Strategy

MEDLINE (Pubmed)
((dental implant* OR implants, dental OR implant, dental)) AND jaw, edentulous, partially) AND (short OR extra-short OR extremely short implant*)) AND (diameter OR wide diameter OR large diameter)) OR (regular diameter OR regular diameter implant*)) OR (standard diameter OR standard diameter implant*)) AND clinical trial
Cochrane
dental implant* OR implants, dental OR implant, dental in All Text AND jaw, edentulous, partially in All Text AND short OR extra-short OR extremely short implant* in All Text AND diameter OR wide diameter OR large diameter in All Text OR (regular diameter OR regular diameter implant*) OR (standard diameter OR standard diameter implant*)
Scopus
(ALL (dental AND implant* OR implants AND dental OR implant AND dental) AND ALL (jaw AND edentulous AND partially) AND ALL (short OR extra- short OR extremely AND short AND implant*) AND ALL (diameter OR wide AND diameter OR large AND diameter) OR ALL regular AND diameter OR regular AND diameter AND implant*) OR ALL (standard AND diameter OR standard AND diameter AND implant*) AND ALL (clinical AND trial))
Web of Science
ALL=((dental AND implant*) AND jaw, edentulous, partially AND ((short OR extra- short OR (extremely AND short) AND implant*)) AND ((wide AND diameter) OR (large AND diameter) AND implant*) OR (regular AND diameter AND implant*) OR (standard AND diameter AND implant*) AND (clinical AND trial)
Embase
dental AND edentulousness AND (short OR 'extra short' OR (extremely AND short)) AND (wide AND diameter OR (large AND diameter)) AND implant* OR ((regular AND diameter OR (standard AND diameter)) AND implant*)) AND clinical AND trial
ClinicalTrials.gov
Partial – edentulism (short OR extra-short OR extremely short implant*) AND dental implant*

To select and defined the studies, inclusion, and exclusion criteria were established:

- Inclusion criteria: clinical trials that evaluated SDIs and/or ESDIs as single crown and fixed partial denture retainers in the partially edentulous patients' in the posterior region; the sample size had to be more than five patients; outcomes that contain at least one of the variables: implant survival rate, implant success rate, prostheses success rate, marginal bone level, peri-implant health, prosthetic and peri-implant complications.
- Exclusion criteria: studies that did not specify the dimensions of the implant; studies that evaluated only dental implants with ≥ 10 mm in length; studies that did not assess regular and wide diameter implants together; studies in full edentulous;

studies with combine data (narrow and/or regular and/or wide diameter; anterior and posterior region; full and partially edentulous); *in vitro*, *in silico* and animal studies, systematic review, literature review and book chapter; studies not accessed in full; case series and case reports.

Study selection and data extraction process

The review process was composed of three phases: title and abstract screening, full-text evaluation, and data extraction. Initially, the study selection, by title and abstract, was performed independently by two reviewers (V.F.V.M., M.C.O.R.), according to pre-established inclusion and exclusion criteria. Then, full-text reading was conducted by the same evaluators to confirm studies' eligibility. The disagreements were solved through discussion with a third reviewer (R.M.M.M.). If the study had insufficient data, an e-mail and/or social media contact to the corresponding author was performed.

Different implant diameters were used in the included studies, and these variations resulted in the comparisons of this review. The following data was collected from the included studies: author; year of publication; country; type of study; type of implant (brand, dimensions, total number); loading type; follow-up; outcomes: implant success rate, implant survival rate, prostheses success rate, peri-implant or prosthetic complications, evaluation of peri-implant health as bleeding on probing, probing depth, or plaque index, and marginal bone level.

Risk of Bias

A quality assessment for risk of bias was executed independently by two evaluators (V.F.V.M., M.C.O.R.), and disagreements were mediated by a third evaluator (R.M.M.M.). Studies were assessed using a clinical appraisal tool for experimental studies by Joanna Briggs Institute (JBI) (Tufanaru, Munn, Aromataris, Campbell, & Hopp, 2020). The risk of bias of randomized controlled trials (RCT) was evaluated by the JBI checklist for RCTs. The risk of bias of non-randomized clinical trials (N-RCT) and retrospective studies (comparison of interventions) was evaluated using a JBI checklist for quasi-experimental studies. Because of the nature of the studies being about implant installation, it was impossible to apply the question about multiple measurements of the outcome both pre and post the intervention/exposure, so this section was evaluated as not applicable. Each study was classified as low risk

(if present, is unlikely to alter the results) if all domains fit this result, unclear risk (raise some doubt about the result), if at least one domain fit this result, or high risk (may seriously affect the results) if at least one domain fits this result.

Statistical Analysis

For quantitative analysis, only RCTs and N-RCTs were considered. The numerical data from dichotomous variables, survival rate and prostheses success rate, were used to performed two meta-analyses to estimate the risk ratio (RR) and the possible statistical differences between the WD and RD implants. The subgroup meta-analyses were conducted in the function of the follow-up time (until one year; one to five years; more than five years) in the survival rate meta-analysis. It was impossible to perform a subgroup analysis about prostheses' success because of the low number of studies that presented this data. The data about implant success and marginal bone level were scarce and present different evaluation forms, which makes it impossible to conduct the meta-analyses. The random-effects model was applied due to the number of the included studies in the analysis, and the heterogeneity was tested (I2 index). The analysis was performed at RevMan software (Review Manager v. 5.3, The Cochrane Collaboration; Copenhagen, Denmark) with a 5% significance level.

Assessment of certainty of evidence

The certainty of the evidence was determined for each outcome to acknowledge the results in the meta-analyses, using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach (Ryan & Hill, 2016). The evidence profile varies from very low to high. RCTs and N-RCTs began as high evidence, and the quality of the body of evidence decreased to moderate, low, or very low if serious or very serious issues related to risk of bias, inconsistency, indirectness, imprecision and publication bias were presented.

RESULTS

Study Selection

The initial search in June 2020 yielded 22858 potential studies, and the strategy details used are described in the PRISMA flowchart (Figure 1). The systematic search found: 2060 on MEDLINE/ Pubmed, 17206 on Cochrane (Trials file), 508 on Web of Science, 532 on Scopus, and 2552 on Embase. After the removal of duplicates (n=2939), remained 19919 articles remained. And then, the screening by title and abstract narrowed it down to 262 records, which were read in full by two reviewers (V.F.V.M., M.C.O.R.). Also, the search on Clinicaltrials.gov yielded ten studies, but none fulfilled the inclusion criteria. A total of 18 studies were included for data extraction and qualitative synthesis, of these ten was found by electronic search and eight by manual search (Attard & Zarb, 2003; Bahat, 2000; Clelland et al., 2016; Koo et al., 2010; Lombardo, Marincola, Signoriello, Corrocher, & Nocini, 2020; Lombardo et al., 2017; Lombardo, Signoriello, et al., 2020; Mangano et al., 2014; Mendonça, Francischone, Senna, Matos de Oliveira, & Sotto-Maior, 2014; Renouard & Nisand, 2005; Rossi et al., 2018, 2015, 2017; Rossi, Ricci, Marchetti, Lang, & Botticelli, 2010; Sohn, Kim, Lee, Jung, & Shin, 2010; Sohn et al., 2014; Weerapong, Sirimongkolwattana, Sastraruji, & Khongkhunthian, 2019). For quantitative synthesis, only nine papers could be used (Attard & Zarb, 2003; Bahat, 2000; Clelland et al., 2016; Mangano et al., 2014; Rossi et al., 2018, 2015, 2017, 2010; Weerapong et al., 2019) (Figure 1). The characteristics and extracted variables of all included studies are detailed in tables 2 and 3.

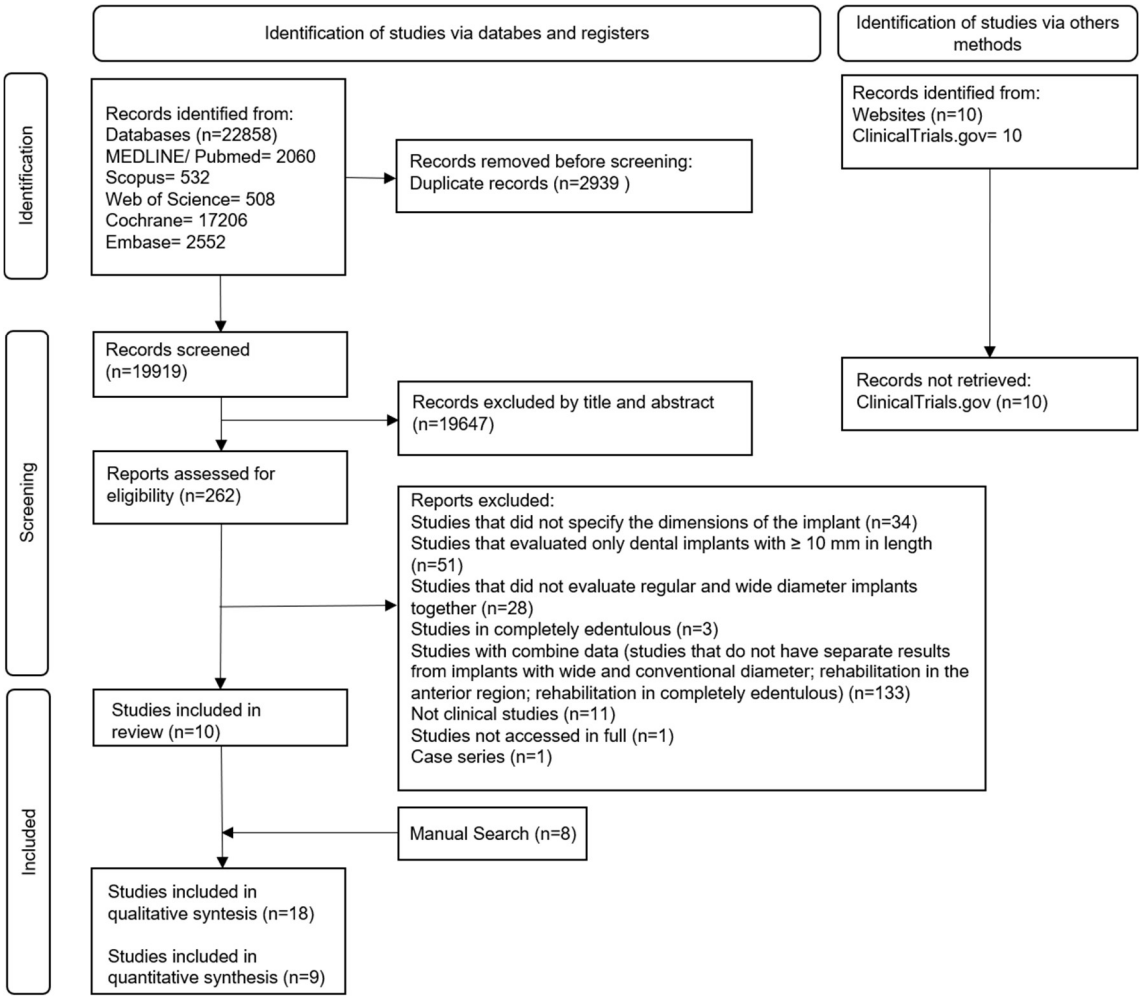

Figure 1: PRISMA Flow chart of the study search strategy and selection process.

General results

The eighteen papers were published between the years 2000 and 2020, with follow-up ranging from one to sixteen years. From these, nine were retrospective longitudinal clinical trials (Kim, Ku, Kim, Yun, & Kim, 2018; Koo et al., 2010; Lombardo, Marincola, et al., 2020; Lombardo et al., 2017; Lombardo, Signoriello, et al., 2020; Mendonça et al., 2014; Renouard & Nisand, 2005; Sohn et al., 2010, 2014), seven were prospective N-RCT (Attard & Zarb, 2003; Bahat, 2000; Mangano et al., 2014; Rossi et al., 2018, 2015, 2017, 2010) and two were RCT (Clelland et al., 2016; Weerapong et al., 2019) (Table 2).

Table 2 - Characteristics of the included studies: patients, implants, and outcomes

Authors/ Year/ Country	Type of study	Sample Average Age (AA)	Implant characteristics Brand/ Location/Dimensions	Total implants WD	RD
Bahat 2000 NR	Non-randomized clinical trial	CD Age range= 18 to +81	Brånemark System implants (Nobel Biocare, Göteborg, Sweden). Maxilla. Lenght: 6, 7, 8 and 8.5mm / Diameter: 3.75, 4 and 5mm	16	87
Attard & Zarb 2003 Canada	Non-randomized clinical trial	CD AA=50.97±13.27	Brånemark System implants (Nobel Biocare, Göteborg, Sweden). CD Lenght: 7 and 8.5mm / Diameter: 3.75, 4 and 5mm	17	31
Renouard & Nisand 2005 NR	Retrospective Longitudinal	88 AA= 58.6	Brånemark System implants (Nobel Biocare, Göteborg, Sweden). Maxilla. Lenght: 6, 7 and 8.5mm / Diameter: 3.75, 4 and 5mm	42	54
Sohn et al 2010 South Korea	Retrospective Longitudinal	43 AA=CD	Endopore (Innova Life Sciences, Toronto, Ontario, Canada). Mandible Lenght: 5, 7 and 9mm / Diameter: 4.1 and 5mm.	22	59
Rossi et al 2010 Italy	Non-randomized clinical trial	35 AA=51	Straumann SLActive (Straumann AG, Waldenburg, Switzerland). CD Lenght: 6mm / Diameter: 4.1 and 4.8mm	21	19
Koo et al 2010 South Korea	Retrospective Longitudinal	CD AA=47	Mark III, Ti-Unitite anodized surface (Nobel Biocare, Göteborg, Sweden). Maxilla, Mandible. Lenght: 7 and 8.5mm / Diameter: 3.75, 4 and 5mm	63	59
Sohn et al 2014 South Korea	Retrospective Longitudinal	42 AA=-	Endopore Dental Implant System, Innova Corporation Maxilla Lenght: 7 and 9mm / Diameter: 4.1 and 5mm	22	30
Mangano et al 2014 Italy	Non-randomized clinical trial	CD AA= 49.1±11.5	Leone Implant System®, Florence, Italy. CD Lenght: 8mm / Diameter: 4.1 and 4.8mm	114	96
Mendonça et al 2014 Brazil	Retrospective Longitudinal	CD Age range to= 45 to 81	Does not specify the brand. Maxilla, Mandible. Lenght: 7 and 8.5mm / Diameter: 4.1 and 5mm	83	129
Rossi et al 2015 Italy	Non-randomized clinical trial	35 AA=51	Straumann SLActive (Straumann AG, Waldenburg, Switzerland) CD Lenght: 6mm / Diameter: 4.1 and 4.8mm	21	19
Clelland et al 2016 USA	Randomized clinical trial	CD Age range to=49 to 76	OsseoSpeed (Dentsply Implants) Maxilla. Mandible Lenght: 6, 8 and 9mm / Diameter: 4 and 5mm	8	42
Lombardo et al 2017 Italy	Retrospective Longitudinal	CD AA=52.4±9.6	Bicon Dental Implants, Boston, MA, USA. Maxilla Lenght: 5, 5.7, 6 and 8mm / Diameter: 4, 4.5, 5 and 6mm	38	39
Rossi et al 2017 Italy	Non-randomized clinical trial	20 AA=55	Standard Plus, SLActive, (Straumann AG, Basel, Switzerland). CD Lenght: 6mm / Diameter: 4.1 and 4.8mm	11	29
Rossi et al 2018 Italy	Non-randomized clinical trial	35 AA=51	Straumann SLActive (Straumann AG, Waldenburg, Switzerland) CD Lenght: 6mm / Diameter: 4.1 and 4.8mm	21	19

Kim et al 2018 South Korea	Retrospective Longitudinal	128 AA=52.6±11.2	Implantium Superline implants (Dentium, Suwon, Korea). CD Lenght: 7 and 8mm / Diameter: 4, 4.5, 5 and 6mm	138	16
Weerapong et al 2019 Thailand	Randomized clinical trial	23 AA= 50.50	PW + Dental Implant System. Mandible. Lenght: 6mm / Diameter: 4.2 and 5mm	17 †	6 †
Lombardo et al 2020 Italy	Retrospective Longitudinal	98 AA= 54.07±10.67	Bicon Dental Implants, Boston, MA, USA. Mandible Lenght: 5, 6 and 8mm / Diameter: 4, 4.5 and 5mm	67	134
Lombardo et al 2020 Italy	Retrospective Longitudinal	31 AA= 53.59 ±10.48	Bicon Dental Implants, Boston, MA, USA. Maxilla Lenght: 5, 6 and 8mm Diameter: 4, 4.5 and 5mm	34	17

(WD) Wide diameter group

(RD) Regular diameter group

(CD) Combined data

(NR) Not reported

(†) Data obtained after contacting the author by email

Table 3 - Characteristics of the included studies: variables analyzed

Authors/ Year/ Load	Implant Success		Implant Survival		Prostheses Success		Marginal Bone Level (mm)		Total Implant Loss		Complications
	WD	RD	WD	RD	WD	RD	WD	RD	WD	RD	
Bahat 2000 Conventional 12 years	CD	CD	93.75%	86.20%	-	-	CD	CD	1	12	Surgical: Yes, NR. Prosthetic: Yes, NR. Peri-implant: Yes, NR.
Attard & Zarb. 2003 Conventional 8.11 ± 4.71 years	-	-	76.47%	96.77%	CD	CD	-	-	4	1	Surgical: No. Prosthetic: Yes, CD. Peri-implant: Yes, NR.
Renouard & Nisand, 2005 Conventional 37.6 months after loading	-	-	92.85% healing-loading; 97.61% loading-1 year: 92.85% 1-2 years: 92.85% 2-3 years: 92.85% 3-4 years: 92.85%	96.29% healing-loading: 96.29% loading-1 year: 96.29% 1-2 years: 96.29% 2-3 years: 96.29% 3-4 years: 96.29%	-	-	CD	CD	3	2	Surgical: No. Prosthetic: No. Peri-implant: Yes, CD.
Sohn et al., 2010 Conventional 55.8 months	-	-	95.45%	100%	-	-	-	-	1	0	Surgical: No. Prosthetic: No. Peri-implant: No.
Rossi et al., 2010 Early 2 years	-	-	100%	89.47%	100%	100%	CD	CD	0	2	Surgical: Yes, NR. Prosthetic: Yes, 0. Peri-implant: Yes, 0.
Koo et al., 2010 Conventional 5 years	-	-	100%	100%	-	-	-	-	0	0	Surgical: No Prosthetic: No. Peri-implant: No.

Sohn et al., 2014 Conventional 72.8 months	-	-	96.6%	86.36%	-	-	CD	CD	3	1	Surgical: No. Prosthetic: No. Peri-implant: No.
Mangano et al., 2014 Conventional 5.6 ± 2.7 years	98.24%	96.87%	99.1%	97.8%	98.24%	98.95%	CD	CD	1	2	Surgical: Yes, NR. Prosthetic: Yes, 3. -WD= 2 crown shipping/fracture. -RD=1 abutment loosening; Peri-implant: Yes, 2. - Bone loss ≥ 1.5mm ≤ 2.5mm after 1 year of function: WD=1, Mand.; RD =1, Max.
Mendonça et al., 2014 Conventional 9.7-3.7 years	92.77%	93.79%	92.77%	93.79%	-	-	Length: 8.5mm maxilla: splinted: -1.00±0.00 non-splinted: 2.17±0.94 8.5mm mandible: splinted: -0.98±0.94 non-splinted: 1.40±1.51 7mm mandible: splinted: -1.06±0.73 non-splinted: 1.21±0.70	Length: 8.5mm maxilla: splinted: -0.45±0.25 - non-splinted: -0.25±0.25 8.5mm mandible: splinted: -1.12±0.72 - non-splinted: -1.34±0.88 7mm mandible: splinted: -1.52±1.06 - non-splinted: -0.88±0.65	6	8	Surgical: No. Prosthetic: No. Peri-implant: Yes, NR.
Rossi et al., 2015 Early 5 years	-	-	100%	89.47%	100%	100%	CD	CD	0	2	Surgical: Yes, NR. Prosthetic: Yes, 0. Peri-implant: Yes, CD.
Clelland et al. 2016 Conventional 3 years	-	-	100%	95.23%	CD	CD	CD	CD	0	2	Surgical: No. Prosthetic: Yes, CD. Peri-implant: No.
Lombardo et al., 2017 Conventional 24.4 ± 12.2 months	-	-	97.36%	92.30%	-	-	CD	CD	1	3	Surgical: No. Prosthetic: No. Peri-implant: Yes, 1. -RD: Severe bone loss due to peri-implantitis.
Rossi et al. 2017 Conventional 5 years	-	-	90.9%	89.65%	CD	CD	CD	CD	1	3	Surgical: Yes, NR. Prosthetic: Yes, CD. Peri-implant: Yes, CD.

Rossi et al. 2018 Early 10 years	-	-	95.23%	89.47%	100%	100%	-0.7±0.8	-0.9±0.5	1	2	Surgical: Yes, NR. Prosthetic: Yes, 0. Peri-implant: Yes, 1. -WD: implant loss due to peri-implantitis that did not respond to the non-surgical treatment.
Kim et al., 2018 Conventional 51.35 ± 24.97 months	92.75%	100%	94.92%	100%	CD	CD	Diameter: 1 year – final 5mm: -0.29-0.80 6mm: -0.25-0.72 7mm: -0.28-0.63	Diameter: 1 year – final 4mm: -0.26-0.73 4.5mm: -0.21-0.79	7	0	Surgical: No. Prosthetic: Yes, CD. Peri-implant: Yes, CD.
Weerapong et al., 2019 Imediated 1 year	-	-	94.11% †	83.33% †	-	-	CD	CD	1	1	Surgical: No. Prosthetic: No. Peri-implant: Yes, NR.
Lombardo et al., 2020 Conventional 3 years	-	-	97.01%	97.76%	100%	100%	Diameter: 5mm: -0.31(1.09) 6mm: -0.3(0.98) †	Diameter: 4mm: -0.75(0.97) 4.5mm: -0.73(0.99) †	2	3	Surgical: No. Prosthetic: Yes, 0. Peri-implant: Yes, 5. - Late failures due to excessive bone loss: WD=2; RD=3
Lombardo et al., 2020 Conventional 3 years	-	-	97.05%	94.11%	100%	100%	CD	CD	1	1	Surgical: Yes, NR. Prosthetic: Yes, 0. Peri-implant: Yes, 2. - Late failures due to excessive bone loss: WD=1; RD=1

(WD) Wide diameter group

(RD) Regular diameter group

(CD) Combined Data

(-) Data not evaluated

(NR) Not Reported

(†) Data obtained after contacting the author by email

The WD group analyzed 713 implants and the RD group a total of 847. For analysis, the studies that present the same sample in different follow-up times were counted only once (Rossi et al., 2018, 2015, 2010) (Table 1). Concerning loading, 14 studies evaluated the implants under conventional load (Attard & Zarb, 2003; Bahat, 2000; Clelland et al., 2016; Kim et al., 2018; Koo et al., 2010; Lombardo, Marincola, et al., 2020; Lombardo et al., 2017; Lombardo, Signoriello, et al., 2020; Mangano et al., 2014; Mendonça et al., 2014; Renouard & Nisand, 2005; Rossi et al., 2017; Sohn et al., 2010, 2014), three early (Rossi et al., 2018, 2015, 2010) and one immediate (Weerapong et al., 2019).

All studies presented results of implant survival. In WD, it ranged from 76.47% to 100%, and in RD went from 83.33% to 100% (Table 3). Among these, only one study specifies this rate by follow-up time (Renouard & Nisand, 2005). Meanwhile, only three studies described the implant success according to the diameter (Kim et al., 2018; Mangano et al., 2014; Mendonça et al., 2014), in WD ranged from 92.75% to 98.24% and in RD from 93.79% to 100%. The prostheses success was described in six studies and ranged from 98.23% to 100% in WD and from 98.93% to 100% in RD (Lombardo, Marincola, et al., 2020; Lombardo, Signoriello, et al., 2020; Mangano et al., 2014; Rossi et al., 2018, 2015, 2010). The marginal bone level has been informed only for four studies, but not according to diameter (table 3) (Kim et al., 2018; Lombardo, Signoriello, et al., 2020; Mendonça et al., 2014; Rossi et al., 2018).

Only one study reported prosthetic complications, being two crown shipping/fracture (WD) and one abutment loosening (RD) (Mangano et al., 2014) (Table 3). Five studies described a total of 12 peri-implant complications, being two bone loss ≥1.5mm ≤ 2.5mm (WD=1; RD=1) (Mangano et al., 2014), nine excessive bone loss (WD=4; RD=5) (Lombardo, Marincola, et al., 2020; Lombardo et al., 2017; Lombardo, Signoriello, et al., 2020; Rossi et al., 2018), and one peri-implantitis (WD=1) (Rossi et al., 2018) (Table 3).

Risk of bias

The risk of bias is presented in figures 2 and 3 (Review Manager, version 5.4.1; The Cochrane collaboration). The quality assessment of RCTs (figure 2) demonstrated an unclear risk of bias due to a lack of information about the randomization process (Clelland et al., 2016) and blinding the participants (Weerapong et al., 2019). Meanwhile, retrospective and N-RCTs risk of bias assessment (figure 3)

revealed in three studies a low risk of bias (Lombardo, Marincola, et al., 2020; Lombardo, Signoriello, et al., 2020; Mendonça et al., 2014), in six studies an unclear risk (Attard & Zarb, 2003; Kim et al., 2018; Lombardo et al., 2017; Renouard & Nisand, 2005; Rossi et al., 2017; Sohn et al., 2010), in seven a high risk (Bahat, 2000; Koo et al., 2010; Mangano et al., 2014; Rossi et al., 2018, 2015, 2010; Sohn et al., 2014). The major problems were unclear information about cofounders and appropriate statistical analysis.

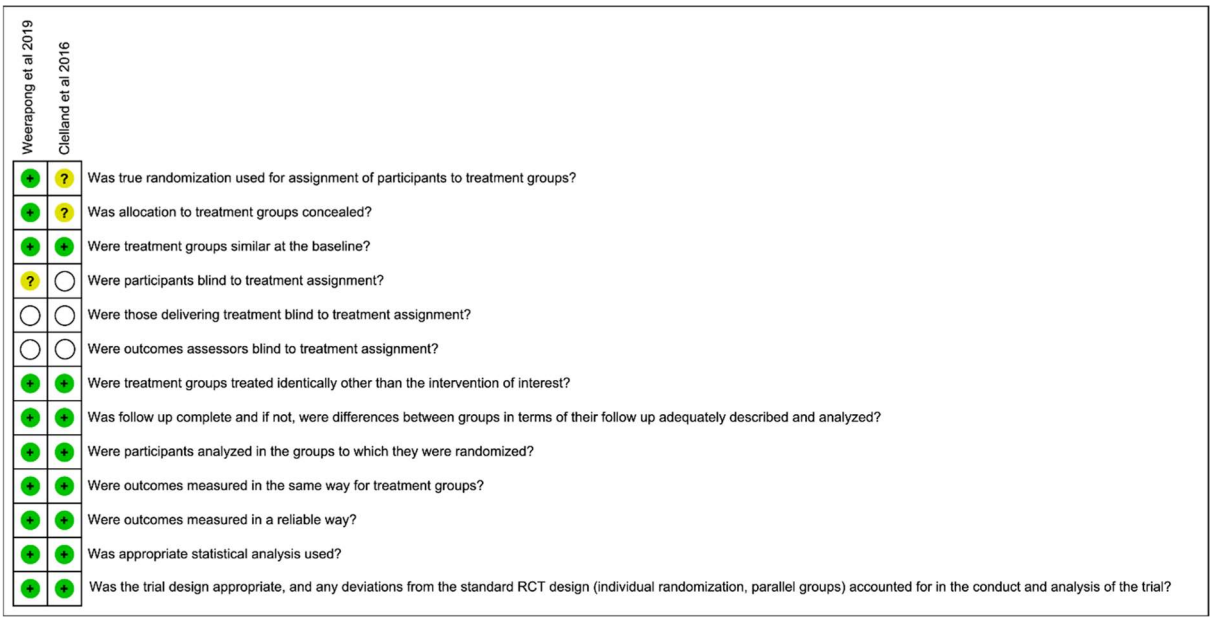

Figure 2: Summary of risk of bias in randomized controlled studies. Risk of bias explanation: low (green), high (red), unclear (yellow), or not/applicable (white).

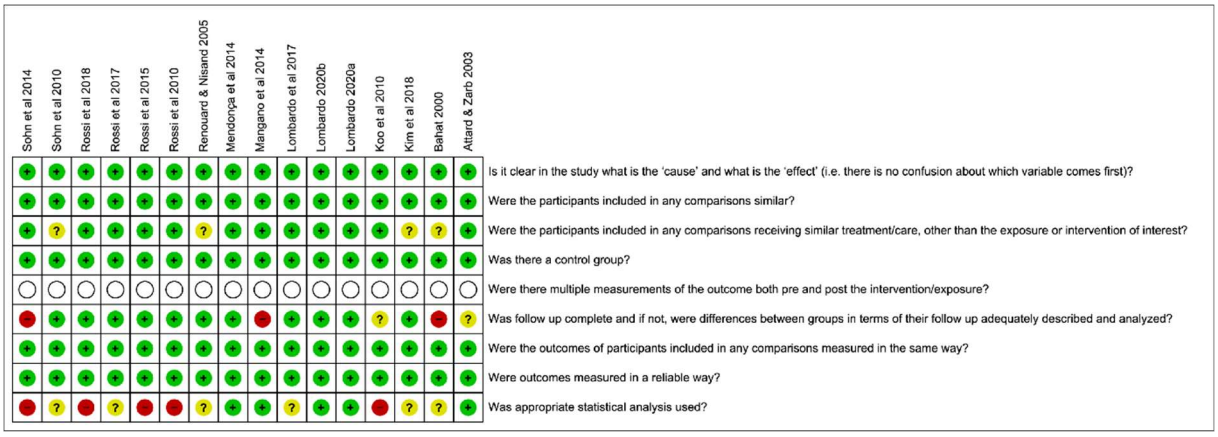

Figure 3: Summary of risk of bias in non-randomized and retrospectives studies. Risk of bias explanation: low (green), high (red), unclear (yellow) or not/applicable (white).

Meta-analysis

The summarized aggregated results of each quantitative analysis are represented by forest plots graphics, where RR was applied with a 95% confidence interval (95%-CI). Nine studies were included at the implant survival meta-analysis (Attard & Zarb, 2003; Bahat, 2000; Clelland et al., 2016; Mangano et al., 2014; Rossi et al., 2018, 2015, 2017, 2010; Weerapong et al., 2019) (Figure 4) and showed no statistical difference between the groups (WD and RD) according to the follow-up time when compared until one year (RR 1.05 [0.92; 1.19]; p = 0.50; I2 = 51%), one to five years (RR 1.02 [0.99; 1.05]; p = 0.24 ; I2 = 0%) and more than five years (RR 1.01 [0.93; 1.11]; p = 0.75; I2 = 40%), with moderate certainty of evidence (Table 4). Meanwhile, only four studies (Mangano et al., 2014; Rossi et al., 2018, 2015, 2010) accessed the prostheses success (RR 0.99 [0.97; 1.02]; p = 0.70; I2 = 0%) (Figure 5), and also showed no statistical difference and a moderate certainty of evidence (Table 4). It was impossible to perform a publication bias test as recommended by Egger et (Egger, Smith, Schneider, & Minder, 1997) due to the insufficient number of studies.

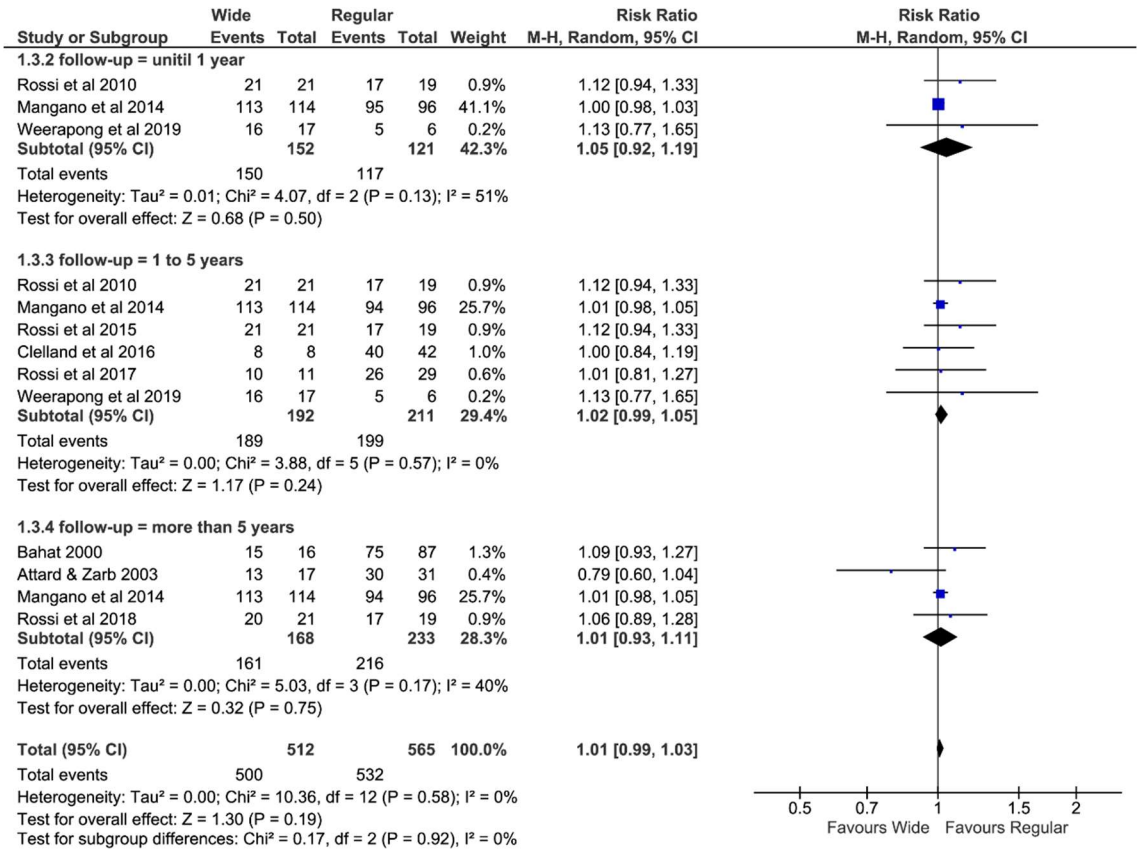

Figure 4: Forest plots for the survival rates of WD and RD groups according to the follow-up: until 1 year; 1 to 5 years; more than 5 years.

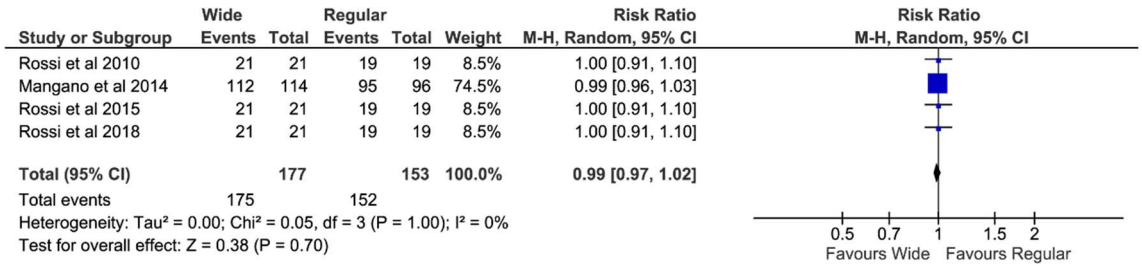

Figure 5: Forest plot for prostheses success rates of WD and RD groups.

Table 4 - Evidence profile of wide diameter and regular diameter in dental implants.

Certainty assessment							Summary of findings				
№ of participants (studies) Follow-up	Risk of Bias	Inconsistency	Indirectness	Imprecision	Publication Bias	Overall certainty of evidence	Study event rates (%) With RD	Study event rates (%) With WD	Relative effect (95% CI)	Antecipated absolute effects Risk with RD	Antecipated absolute effects Risk difference with WD
Implant Survival											
997 (2 RCT and 7 N-RCTs)	serious [a]	not serious	not serious	not serious	strong association; all plausible residual confounding would suggest spurious effect, while no effect was observed.	⊕⊕⊕◯ MODERATE	458/527 (86.9%)	458/470 (97.4%)	RR 1.01 (0.99 to 1.03)	87 per 100	1 higher per 100 (1 fewer to 3 higher)
Prostheses Success											
330 (4 N-RCT)	serious[a]	not serious	not serious	not serious	strong association; all plausible residual confounding would suggest spurious effect, while no effect was observed.	⊕⊕⊕◯ MODERATE	152/153 (99.3%)	175/177 (98.9%)	RR 0.99 (0.97 to 1.02)	99 per 100	1 fewer per 100 (3 fewer to 2 higher)

(CI) Confidence interval

(RR) Risk Ratio

(a) All included studies presented some kind of risk of bias.

DISCUSSION

This systematic review focused on clarifying whether the WD influences the clinical and biological behavior of SDIs and/or ESDIs used to rehabilitate posterior regions. The meta-analyses showed that WD implants have similar implant survival and prostheses success rate to RD implants. Thus, it is possible to affirm that the diameter did not influence the prognosis of SDIs and ESDIs .

The meta-analysis of implant survival showed no difference between groups, being similar to the qualitative synthesis, where this rate reached 100% in both groups in six studies (Clelland et al., 2016; Kim et al., 2018; Koo et al., 2010; Rossi et al., 2015, 2010; Sohn et al., 2010). The same was shown at the overall implant failure rate, being 4.62% in WD and 4.84% in RD, corroborating with the findings of a recent retrospective study, where the implant failure rate was also similar for both regular (2.24%) and wide diameter (2.99%) (Lombardo, Signoriello, et al., 2020). So, independently of the diameter, the rehabilitation with reduced length implants is clinically applicable in the long-term, enabling a treatment plan for posterior regions with poor bone availability.

Regarding implant success rate, only three studies (Kim et al., 2018; Mangano et al., 2014; Mendonça et al., 2014) described it. Because of the limited number of studies and designs, this outcome was only analyzed in the qualitative synthesis, showing a lack of literature evidence in this regard. However, the results observed in this study fulfilled the success criterion established in 1986 by Albrektsson (Albrektsson, Zarb, Worthington, & Eriksson, 1986), having a high success rate being 92.75% (WD) and 93.79% (RD). Furthermore, since success criteria were based on peri-implant health (Papaspyridakos, Chen, Singh, Weber, & Gallucci, 2012), it should emphasize that the studies included in the present review showed low rates of peri-implant complications in both groups, 0.84% (WD) and 0.70% (RD), being the excessive bone loss (more than 1.5mm) the most common. A systematic review that investigated implants with reduced length showed a low biologic complications rate, being peri-implant mucositis and peri-implantitis the most common ones (Ravidà, Barootchi, et al., 2019). The present systematic review showed that WD behaves similarly to RD in the soft and hard tissue.

Besides that, this review also reported for both groups, qualitatively, similarly low rate of prosthetic complications as previous systematic reviews (Mezzomo

et al., 2014; Ravidà, Barootchi, et al., 2019), 0.29% (WD) and 0.12% (RD), being crown shipping/fracture and abutment loosening the most commons. The prosthesis success meta-analysis also showed that the WD did not improve the prosthesis performance. Even though a high C:I ratio is unfavorable biomechanically, the incidence of complications, which was also found at the peri-implant evaluation, is favorable, indicating this rehabilitation set as a safe alternative.

From the included studies in this review, it can be inferred that WD did not bring a clinical, biological, or mechanical benefit. Besides, since WD requires greater wear, it may reflect negatively on the peri-implant bone remodeling, because it is almost totally anchored in the cortical bone, which is less vascularized than the cancellous bone, and can directly affecting the bone remodeling (Pilliar, Deporter, Watson & Valiquette, 1991). Also, due to the need for more bone milling, usually the insertion torque and the primary stability of WD implants are higher, which might damage the osseointegration process due to the bone compression (Berglundh, Abrahamsson, Lang, & Lindhe, 2003). It leads to bone resorption concomitantly to the bone neoformation, retarding the secondary implant stability (Berglundh et al., 2003; Javed, Ahmed, Crespi, & Romanos, 2013; Duyck et al., 2015; Bielemann et al., 2019).

Regarding the study's quality, none of the studies present a low risk of bias. The major problems were unclear information about the randomization process, cofounders, and appropriate statistical analysis. Since some studies did not present and worked through the data according to confounding factors, it is unclear how it would affect results. An example is smoking, and persistent periodontal disease can be negatively related to the implant survival rate and peri-implant health (Mangano et al., 2014; Mezzomo et al., 2014). In addition, the GRADE approach showed that the certainty of the evidence of the meta-analyses parameters was moderate, indicating that future studies may change the confidence in the estimated effect and may even modify the estimate found in this review (Ryan & Hill, 2016). For improvement of risk of bias and certain of evidence, in future studies, appropriate statistical analysis and exact sample randomization should be performed. So, the confounding factors will be distributed proportionally in the sample.

This review's limitations include a large number of studies presenting outcomes with combined data. Also, an impossibility to perform marginal bone level meta-analysis would clarify the possible effects on peri-implant tissues, especially in a long-term follow-up. Despite these, this systematic review with meta-analysis verified

that WD does not influence the clinical and biological performance of SDI and ESDIs. Therefore, demonstrating that it does not compensate for the significant wear of the bone. Thus, there is needed to performed long-term RCTs with the cofounders described and adjusted in the statistical analysis to evaluate this strategy in a more robust methodological clinical trial.

CONCLUSION

When associated with SDI and ESDI, WD behaves similarly to RD regarding clinical and biological performance in maxillary posterior region rehabilitations, since both present high survival rates and prostheses success rate and low incidence of complications.

DISCLOSURE STATEMENT

The authors declare no potential conflict of interest concerning the authorship and/or publication of this article.

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3 DISCUSSÃO

O presente estudo foi realizado para avaliar o comportamento biomecânico, clínico e biológico que envolve a reabilitação com implantes dentários curtos e extracurtos de diâmetro largo. Para tanto, foram delineados dois estudos que se complementam e que buscaram fornecer evidências que contribuam para a prática da clínica diária. Deste modo, foi possível observar que apesar dos implantes dentários extracurtos com diâmetro largo apresentarem melhor distribuição de tensões no implante, houve um acúmulo de tensão no osso cortical, sugerindo maior risco de reabsorção óssea ao longo do tempo. Entretanto, clinicamente, observou-se que a utilização do diâmetro largo, não influencia o prognóstico do tratamento apresentando taxa de sobrevivência do implante, de sucesso da prótese e de complicações semelhantes aos implantes curtos e extracurtos de diâmetro regular.

Por meio da análise de elementos finitos, no capítulo 2.1, foi possível observar a distribuição de tensões em região posterior de mandibula atrófica reabilitada com coroa unitária (proporção coroa/implante 3:1) suportada por implante extracurto, variando o diâmetro do implante e a direção da carga aplicada para verificar se esse conjunto seria biomecanicamente viável. Assim, foi possível analisar o comportamento do diâmetro largo em comparação com o regular, bem como o comportamento de ambos quando submetidos às cargas axial e oblíqua. Dentre os resultados desse estudo, observou-se que o diâmetro largo gera aumento de tensão no osso cortical de até 99,8%, e quando submetido à carga oblíqua eleva em no mínimo 311,5% a tensão encontrada. O que resulta em valores que ultrapassam os limites críticos de compressão e tração do osso nos grupos de diâmetro largo e no regular sob carga oblíqua, induzindo a reabsorção óssea peri-implantar (Pattin et al., 1996; Sigiura et al., 2000). Além disso, a carga oblíqua aumentou as tensões em todos os componentes estudados em mais de 200%, o que alerta para a necessidade do profissional avaliar cuidadosamente o padrão oclusal do paciente, uma vez que esses valores exarcebados podem comprometer o prognóstico da reabilitação.

Tendo em vista essa alta tensão crítica encontrada no osso cortical, surgiu o questionamento do quanto isso poderia influenciar o comportamento clínico desses implantes com diâmetro largo. Para tanto, dados de sobrevivência do implante, sucesso do implante, sucesso da prótese, complicações peri-implantares e protéticas foram extraídos de estudos clínicos que avaliaram implantes curtos e extracurtos de

diâmetro largo e regular, e organizados em uma revisão sistemática com meta-ánalise no capítulo 2.2, esclarecendo assim qualitativamente e quantitativamente a previsibilidade desses implantes.

Desta forma, foi observado que não há diferença entre o diâmetro largo e regular para a sobrevivência do implante ao longo do tempo. O mesmo foi demonstrado na incidência de falha do implante que fora calculada a partir dos dados dos implantes perdidos versus os instalados, sendo 4,62% no diâmetro largo e 4,84% no regular, o que corrobora com os achados de um estudo retrospectivo recente, onde a taxa de falha do implante também foi semelhante para ambos os diâmetros (Lombardo et al., 2020). Apesar de demonstrarem comportamento semelhante, é preciso frisar que a maioria dos estudos não deixou claro os seus fatores de confundimento, e os que fizeram não realizaram análises estatísticas específicas, não deixando claro a influência que poderiam ter no resultado. Isto pode ser crítico para análise dos resultados, uma vez que, fatores de risco como fumo e doença periodontal persistente podem afetar de forma negativa a taxa de sobrevivência dos implantes (Mangano et al., 2014; Mezzomo et al., 2014).

Outro fator crítico para o desempenho clínico de implantes curtos e extracurtos de diâmetro largo é a avaliação da perda óssea marginal, já que esses implantes ficam, quase na sua totalidade, ancorados no osso cortical gerando alta concentração de tensões nessa área, como visto no capítulo 2.1. Na presente revisão sistemática apenas um estudo relatou a perda óssea marginal de acordo com o diâmetro, tendo encontrado -0,7±0,8 mm no grupo de diâmetro largo e -0,9±0,5 mm no grupo de diâmetro regular (Rossi et al., 2018). O mesmo acontece na avaliação dos dados sobre o sucesso do implante, que foram coletados somente em três estudos com designs diferentes, não permitindo a realização de meta-análise. Ainda assim, mesmo as menores taxas reportadas pelos estudos estão acima do limite de taxa de sucesso exigida para o implante, e as taxas de perda óssea marginal estão dentro dos limites de sucesso estabelecidos na literatura, na qual a perda óssea marginal deve ser inferior a 1,5 mm (Albrektsson et al., 1986; Papaspyridakos et al., 2012). O que é corroborado também pelo baixo indície de complicações peri-implantares encontrados em ambos os grupos. No entanto somente com a síntese qualitativa não se pode inferir o impacto desses dados nos resultados encontrados.

Já em relação ao sucesso da prótese, foi possível coletar dados suficientes para a síntese quantitativa dessa revisão sistemática, que demonstrou também não

haver diferença entre os grupos (RR 0.99 [0.97; 1.02]; p = 0,70; I^2 = 0%). Este resultado vai ao encontro do que foi observado no capítulo 2.1, no qual houve aumento de tensão no abutment de no máximo 12,7% no grupo de diâmetro largo sob carga oblíqua, não sendo clinicamente relevante. No entanto, ao ser avaliado sob carga oblíqua, independente do diâmetro utilizado, foi possível observar que os valores de tensão do abutment e do implante ultrapassam em mais de duas vezes o limite para deformação permanente e de ruptura do titânio grau IV (Breme et al., 2016), o que contraindica o uso de implante extracurtos na presença de carga oblíqua por sugerir alto risco de falha para o implante e abutment nessas condições.

Os valores exacerbados de tensões na avaliação da carga oblíqua na análise de elementos finitos, associados à escassez de estudos na literatura que focassem na avaliação do diâmetro largo em comparação com o diâmetro regular para a realização da síntese quantitativa da revisão sistemática, alertam para a necessidade de realização de mais estudos. Entretanto, é válido frisar que os resultados encontrados pelos estudos presentes nessa dissertação devem ser interpretados com cautela devido as suas limitações. Estudos *in sílico* são análises teóricas numéricas e devem ser validados primeiramente por estudos *in vitro*, além disso, a revisão sistemática com meta-análise não permitiu avaliar quantitativamente dados importantes clinicamente como o sucesso do implante e o nível ósseo marginal, como também apresentou predominância de estudos com alto e pouco claro risco de viés.

A fim de sanar as demais dúvidas sobre essa proposta reabilitadora é necessário primeiramente realizar estudos *in vitro* focados na biomecânica desses implantes em condições adversas, como por exemplo sob carga oblíqua. E em seguida, realizar estudos clínicos randomizados controlados que tenham como objetivo principal avaliar e comparar o comportamento a longo prazo dos implantes curtos e extracurtos de diâmetro largo e regular, para assim obter embasamento científico sólido para indicação desse conjunto reabilitador.

4 CONCLUSÃO

- O uso de implantes com diâmetro largo resulta em uma biomecânica favorável para o implante dentário extracurto, mas tem um risco potencial de sobrecarregar o osso cortical e resultar em perda óssea ao longo do tempo, principalmente sob carga oblíqua.
- O uso de implantes com diâmetro largo evidenciou desempenho semelhante aos implantes de diâmetro regular.

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ANEXOS

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ANEXO 2 - VERFICAÇÃO DE ORIGINALIDADE E PREVENÇÃO DE PLÁGIO

Influência do diâmetro largo de implantes curtos e extracurtos na distribuição de tensão, desempenho clínico e biológico em reabilitação de regiões posteriores.

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