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Splinted or nonsplinted short dental implants in posterior mandible: a systematic review and meta-analysis

Implantes dentários curtos esplintados ou não esplintados em mandíbula posterior: uma revisão sistemática e metanálise

Implantes dentales cortos ferulizados o no ferulizados en la parte posterior de la mandíbula: una revisión sistemática y un metanálisis

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Abstract
Objective: To evaluate the survival rate (SR), the success rate (SSR), the bone level after loading and also to assess the prosthesis complications of splinted short implants (SSI) compared to non-splinted/unsplinted short implants (NSI) in posterior mandible. Materials and methods: An electronic search of PubMed and Embase databases was conducted. The primary outcome analyzed was SR. Secondary outcomes evaluated were SSR, bone level around implants (BLI), implant failure (IF) and prosthetic failure (PF). Results: A total of 562 articles from PubMed and 367 from Embase were screened by titles/abstracts, 102 articles were selected for full text analysis. Only 10 articles were suitable to be

selected, but only 4 met the inclusion criteria. Meta-analysis showed a mean SR of 99% for splinted and 97% for non-splinted group, which were statistically significant for SSI group (*p*<0.038). NSI presented better BLI, however, the statistical analysis showed no significant difference between SSI and NSI (*p*= 0.170). Conclusion: According to the present study, despite both splinted and unsplinted prosthesis had presented high SR, the splinted prosthesis showed better outcomes for SR and for prosthesis complications. There is no correct or incorrect guideline when it comes to implants rehabilitation, each case has to be studied in an overall view, having patient-centered outcomes. More studies should be conducted in order to fill this lack in the literature about the need of splinting or not short implants.
Keywords: Short dental implant**;** Splinted crown; Single tooth; Partially edentulous; Survival rate.

Resumo
Objetivo: Avaliar a taxa de sobrevivência (SR), a taxa de sucesso (SSR), o nível ósseo após o carregamento protético e também avaliar as complicações protéticas de implantes curtos esplintados (SSI) em comparação com implantes curtos não esplintados (NSI) em mandíbula posterior. Materiais e métodos: Foi realizada uma busca eletrônica nas bases de dados PubMed e Embase. O desfecho primário analisado foi SR. Os desfechos secundários avaliados foram SSR, nível ósseo ao redor dos implantes (BLI), falha do implante (IF) e falha protética (PF). Resultados: Um total de 562 artigos do PubMed e 367 do Embase foram selecionados por títulos/resumos, 102 artigos foram selecionados para análise de texto completo. Apenas 10 artigos estavam aptos a serem selecionados, mas apenas 4 atenderam aos critérios de inclusão. A metanálise mostrou média de 99% de SR para o grupo SSI e 97% para o grupo NSI, sendo estatisticamente significantes para o grupo SSI (p<0,038). NSI apresentou melhor BLI, porém, a análise estatística não mostrou diferença significativa entre SSI e NSI (p= 0,170). Conclusão: De acordo com o presente estudo, apesar das próteses esplintadas e não esplintadas terem apresentado alta SR, os implantes esplintados apresentaram melhores resultados para SR e para complicações protéticas. Não existe uma diretriz correta ou incorreta quando se trata de reabilitação com implantes, cada caso deve ser estudado de forma global, com resultados centrados no paciente. Mais estudos devem ser realizados a fim de suprir essa lacuna na literatura sobre a necessidade de esplintagem ou não de implantes curtos.
Palavras-chave: Implante curto; Coroa esplintada; Dente unitário; Parcialmente desdentado; Taxa de sobrevivência.

Resumen
Objetivo: Evaluar la tasa de supervivencia (SR), la tasa de éxito (SSR), el nivel óseo después de la carga y también evaluar las complicaciones protésicas de los implantes cortos ferulizados (SSI) en comparación con los implantes cortos no ferulizados/no ferulizados (NSI) en mandíbula posterior. Materiales y métodos: Se realizó una búsqueda electrónica en las bases de datos PubMed y Embase. El desenlace primario analizado fue la RS. Los resultados secundarios evaluados fueron SSR, implantes a nivel óseo (BLI), falla del implante (IF) y falla protésica (PF). Resultados: Un total de 562 artículos de PubMed y 367 de Embase fueron examinados por títulos/resúmenes, 102 artículos fueron seleccionados para análisis de texto completo. Solo 10 artículos fueron aptos para ser seleccionados, pero solo 4 cumplieron con los criterios de inclusión. El metanálisis mostró una SR media del 99 % para el grupo SSI y del 97 % NSI, que fueron estadísticamente significativas para el grupo con SSI (p<0,038). NSI presentó mejor BLI, sin embargo, el análisis estadístico no mostró diferencia significativa entre SSI y NSI (p=0,170). Conclusión: De acuerdo con la presente estudie, a pesar de que tanto la prótesis entablillada como la no entablillada presentaron alto SR, la prótesis entablillada mostró mejores resultados para la SR y para las complicaciones de la prótesis. No existe una guía correcta o incorrecta cuando se trata de rehabilitación con implantes, cada caso debe estudiarse en una visión general, teniendo resultados centrados en el paciente. Se deben realizar más estudios para llenar este vacío en la literatura sobre la necesidad de ferulización o implantes no cortos.
Palabras clave: Implante dental corto; Corona entablillada; Diente único; Parcialmente desdentado; Tasa de supervivencia.

1. Introduction

In the 1980s, implant therapy was successfully used in fully edentulous patients (Jemt, 1991). Later, surgeons implemented implant techniques to treat also partially edentulous patients. A large number of studies demonstrated that rehabilitation of a partially edentulous patient with osseointegrated implants is a predictable treatment (Van Steenberghe et al, 1989, Van Steenberghe et al, 1990, Saadoun & LeGall, 1992, Jemt & Lekholm, 1993). However, an atrophic alveolar bone may represent a clinical challenge for the success of implants. This bone atrophy mainly occurs after tooth loss and posterior region are the most commonly affected area (Papapanou et al., 1998). Therefore, this condition implies in a higher risk of damage to important anatomical structures, such as inferior alveolar nerve and maxillary sinus during implant surgery (Renouard & Nisand., 2005).

Several reconstructive techniques are used to increase bone height in order to insert standard implants (Summers, 1994, Garg & Morales, 1998, Felice et al, 2009). Procedures as distraction osteogenesis, vertical ridge augmentation and inferior alveolar nerve lateralization present consistent literature evidence (Tolman, 1995, Kahnberg & Ridell, 1987, Rosenquist, 1992). However, these complex surgeries procedures could result in major morbidity and higher risk of complications (Esposito et al., 2011). Despite poor bone quality of posterior maxilla, the most predictable technique is sinus floor elevation (Pjetursson et al., 2008). In these cases, there is a sufficient blood supply with maintenance and stabilization of graft materials by the sinus membrane (Summers, 1994, Pjetursson et al, 2008). Nevertheless, inferior predictability is described for the mandible posterior area (Esposito et al, 2011, Rocchietta et al, 2008). Other difficulties related to grafting surgeries are postoperative morbidity, financial cost, increased surgical and treatment time (Felice et al, 2009, Esposito et al, 2011, Rocchietta et al, 2008). For these reasons, studies were conducted to develop different treatment options to avoid complex surgeries, especially for posterior mandible, such as the use of short implants (Renouard & Nisand., 2005). There is no consensus in literature about short implant sizes. Different types of nomenclatures are described such as intra-bony length (Renouard & Nisand., 2006), extra short implant (Deporter et al., 2012) and ultrashort implant (Urdaneta et al., 2012). Authors use different nomenclature according to their own experience when implants present less than 10mm. The use of 4mm short implant length is increasing and so far, is the shortest implant described in the literature (Felice et al., 2016).

Earlier studies showed low survival rate (SR) for short implants, discouraging their use by professionals (Friberg et al, 1991, Berglundh et al, 2002). However, the majority of these studies evaluated implants with machined surface that is recognized by inferior SR (Ten Bruggenkate et al., 1998). Innovative surface treatments of these implants confirmed an improvement on their rationally use. The microtopography of the implant surfaces can induce earlier bone formation and increase the bone implant contact area, which allow the use of a shorter implant size (Van Steenberghe, 1997, Hagi et al, 2004). In spite of the increase on short implants SR, some authors recommend splinting crowns on these implants (Esposito et al., 2011). Likewise, the short implant splinting recommendation it is also encourage by some implant systems. However, there is no evidence for such recommendation and non-splinted short dental implants also demonstrated reliable SR (Telleman et al., 2011). The aim of this systematic review and meta-analysis was to evaluate if short implants in posterior mandible presents higher SR when splinted. The following focused question was addressed: Short dental implants in posterior mandible should be splinted or not?

2. Methodology

The present systematic review was conducted according to PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (Moher et al., 2009) and Cochrane Collaboration Tools (Higgins & Green, 2008), PROSPERO registration number -CRD42017065753.

2.1 Search strategy

Electronic searches were conducted through the PubMed-Medline, Embase databases and Open gray literature, with papers published until October 2022, without any language restriction. The manual search were conducted by the following journals: *Implant Dentistry (2004–2012), International Journal of Periodontics and Restorative Dentistry (2003–2012), Journal of Clinical Periodontology (2004–2012), Journal of Periodontology (2004–2012), Clinical Oral Implants Research (2001, 2003–2012), International Journal of Oral and Maxillofacial Implants (2004–2012), Journal of Prosthetic Dentistry (1999–2012), International Journal of Prosthodontics (2001–2012), European Journal of Oral Implantology (2008–2012) and the Journal of Oral Implantology (2001–2012).* The key-words were selected with an assistance of an experienced librarian from University of São Paulo, which also separated MESH terms from Key-words and distributed as PICO scheme (Table 1).

Table 1. Electronic search according to the PICO scheme, with both Key-words and MESH terms.

P (Population) AND*	**I** (intervention) AND	**C** (Comparison) AND	**O** (Outcome)
Key-words *Reduced alveolar high* **OR** *Posterior atrophic jaws*	**Key-words** *Short dental implant* **OR** *Ultrashort implant* **OR** *Extra-short implants*	**Key-words** *Non-splinted implant* **OR** *Unsplinted implant* **OR** *Single crown* **OR** *Implant splint* **OR** *Splinted crown*	**Key-words** *Successful rate*
MESH terms *Partially edentulous* **OR** *Alveolar bone loss* **OR** *Alveolar resorption*	**MESH terms** *Dental implant* **OR** *Implant supported* **OR** *Dental prosthesis design*	**MESH terms** *Periodontal splints* **OR** *Single tooth*	**MESH terms** *Survival rate* **OR** *Complications* **OR** *Stress mechanical* **OR** *Dental restoration failure*

* On this search strategy “AND” was utilized between groups of PICO, and “OR” was utilized between words of MESH terms and key-words. Source: Authors (2022).

Table 2 presents the final strategy electronic search. All articles from Embase database were screened and revised with the articles from PubMed, excluding every duplicate. Since articles from PubMed were the majority, only the PubMed screening strategy were illustrated in the present systematic review.

2.2 Inclusion criteria

- Randomized clinical trials
- Prospective or retrospective studies
- Implants length < 10 mm
- Partially edentulous posterior mandible
- Patients restored with splinted and non-splinted fixed restorations
- Short implants controlled for at least 3 years after loading
- Cleary data concerning about splinted and non-splinted short implants in the same study.

2.3 Exclusion criteria

- Literature reviews, case report or series
- Studies without information about implant placement area or those without description of the type of prosthesis loading (splinted or not)
- Implants placed in augmented area
- Systemic unhealthy patients

Table 2. Electronic search strategy according to the PICO scheme.

P	((reduce OR reduced OR reduction OR reducing) alveolar (high OR height) OR ((posterior atrophic jaws) OR (posterior atrophic maxilla) OR (posterior atrophic maxillary) OR (posterior atrophic mandibles) OR (posterior atrophic mandibular)) OR ((jaw, edentulous, partially) OR (jaws edentulous partially) OR (mandibles edentulous partially) OR (mandibular edentulous partially) OR (maxilla edentulous partially) OR (maxillary edentulous partially)) OR (alveolar bone loss) OR (alveolar resorption))
I	(short dental implant OR ultrashort dental implant OR ultra short dental implant OR extrashort dental implant OR extra short dental implant OR ((Dental Prosthesis, Implant-Supported) OR (“dental” AND (prosthesis OR prostheses OR denture OR dentures) AND implant AND supported)) OR (dental prosthesis design) OR (dental prostheses design) OR (“dental“ denture design) OR (“dental” dentures design))
C	(((no OR non) AND (splint OR splinted OR splinting) AND (implant OR implants)) OR (“single crown” OR “single crowns”) OR (“single tooth” OR “single teeth”) OR ((splint OR splinted OR splinting) AND (implant OR implants)) OR ((splint OR splinted OR splinting) AND crown) OR ((Dental Implants, Single-Tooth) OR dental implant AND (“single tooth” OR “single teeth”)) OR periodontal splint* OR “single” dental implant))
O	("successful rate" OR "successful rates" OR "success rate" OR "success rates" OR ((crown OR crowns) AND (implant OR implants) AND (ratio OR ratios)) OR survival rates OR complication OR complications OR mechanical stress OR ("dental" "restoration" (failure OR failures)) OR ((crown OR crowns) AND (implant OR implants) AND (failure OR failures)))

These four strategies (P.I.C.O) were linked with “AND” between them and copied at the selected database. Source: Authors (2022).

2.4 Outcome measures

The primary outcome evaluated on the present systematic review was the SR. Secondary outcomes evaluated were SSR, bone level around implants (BLI), implant failure (IF) and prosthetic failure (PF). The SR was established by the presence of the short implant during the complete follow up period. The SSR was based on Albrektsson et al (1986) and included the absence of mobility, absence of pain and/or paresthesia, bleeding on probing and an average of radiographic marginal bone loss (MBL) of less than 1.5 mm during the first year of function and less 0.2 mm annually. The BLI was the measure from the crestal bone to the implant abutment, using a probe and compared baseline measurement to the last follow up period. The IF was characterized as the implant failure after the prosthetic loading. The PF was stablished as the prosthesis failure or any complication, with no damage to the implant itself.

2.5 Quality assessment

The risk of bias of included studies was evaluated according to the methodology applied and assessed by two reviewers (CAD and MSRZ). The criteria for judging risk of bias was applied according to the Cochrane Collaboration’s tool for assessing risk of bias (Higgins & Green, 2008). Based in Telleman et al (2011), studies with four or more pluses were considered methodologically acceptable. The present systematic review and meta-analysis evaluated as a high risk of bias studies with less than 5 pluses. As medium risk of bias studies with 5 or 6 pluses. For studies with low risk of bias this review considered more than 6 pluses. Both reviewers independently generated a score for the included articles. No blinding for author, institute or journal was performed.

2.6 Statistics analysis

Kappa score were calculated to assess the degree of agreement between the two reviewers. If there was any disagreement between those two reviewers, a third one (RCM) would choose whether or not the article would be included. All statistical analysis and assessment of heterogeneity among studies were performed using commercially available software (Comprehensive Meta-Analysis; CMA, Biostat, Englewood, NJ, USA). The level of significance was 5% ($p < 0.05$). A different classification of implant length was proposed by authors and meta-analysis was conducted to evaluate the SR based on this new classification (Table 3).

Table 3. Implant length classification.

Implant nomenclature	Standard	Short	Extra / Ultrashort
Implant length	> 9 mm	≤ 9 mm > 6 mm	≤ 6 mm

Source: Authors (2022).

3. Results

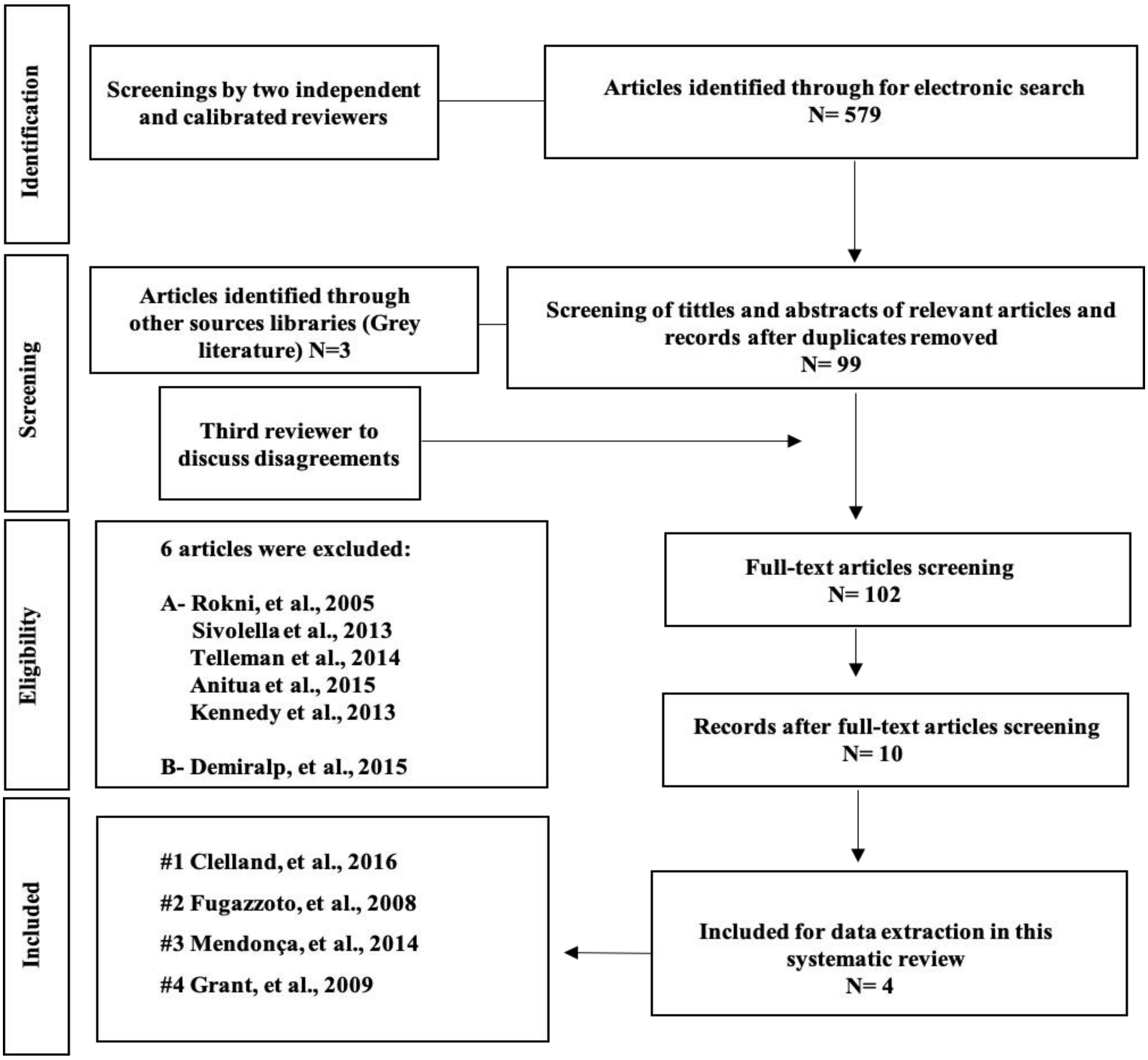
3.1 Selected articles

The electronic search identified 576 articles from PubMed and 329 from Embase. Articles that did not accomplished the inclusion criteria and also all duplicates were excluded. Three articles searched from grey literature were eliminated after screening. A total of 102 articles were selected for full text analysis, but only 10 articles were suitable to be selected. However, six of them needed to be excluded because of lack of information and follow up time (Rokni et al, 2005, Sivolella et al, 2013, Tellman et al, 2014, Anitua et al, 2015, Kennedy et al, 2013, Demiralp et al, 2015) (Fig 1). The agreement between reviewers was calculated and Kappa value was 0.62. A third reviewer decided in a consensus which article would be selected for meta-analysis. Unfortunately, none of the doubtful articles were selected. The disagreement appeared due to the difficulty of identifying the type of prosthetic load, with little information about which and how many implants would have been splinted or not. Consequently, four articles were selected: #1- Clelland et al (2016); #2- Fugazzotto (2008); #3- Mendonça et al (2014); #4- Grant et al (2009).

3.2 Study characteristics

Three included articles (Fugazzotto, 2008, Mendonça et al, 2014, Grant et al, 2009) were retrospective studies and only one (Clelland et al., 2016) was a randomized prospective study. For all articles were required at least two experimental groups: splinted short implant (SSI-control group) or non-splinted short implant (NSI-test group). Study #1(Clelland et al., 2016) was a randomized split-mouth study which evaluated 108 short implants (9 mm and 6 mm), being 54 implants for each side of the mandible. The control group achieved 100% of SR, while the test group had one failure (SR=98.15%). These patients had 3 years of follow up and all implants from the control group were splinted to another short implant or to an 11mm implant. Study #2 (Fugazzotto, 2008) evaluated 229 splinted short implants and 315 single short implants with 6, 7, 8 and 9 mm.

Figure 1. Flow-chart electronic search and screening of the studies.



A- Incomplete data for Meta-analysis / **B**- Short time follow up. The agreement between reviewers was calculated and Kappa value was 0.62. A third reviewer decided in a consensus which article would be selected for meta-analysis. Unfortunately, none of the doubtful articles were selected. The disagreement appeared due to the difficulty of identifying the type of prosthetic load, with little information about which and how many implants would have been splinted or not. Consequently, four articles were selected: #1- Clelland et al (2016); #2- Fugazzotto (2008); #3- Mendonça et al (2014); #4- Grant et al (2009). Source: Authors (2022).

The control group had 4 implants lost (98%) and the test group had 5 implants lost (98.4%). Implants from the control group were splinted to both standard and short implants (3 or 2-unit). Study #3 (Mendonça et al., 2014) evaluated the SR and MBL from 207 splinted short implants and 186 non-splinted short implants. The follow up time was an average of 10 years and implant length were 7 and 8.5 mm. The control group had 5 implants lost (97,6%), while the test group had 14 implants lost (92,5%). The MBL showed no statistically difference between control and test groups. Study #4 (Grant et al., 2009) evaluated SR from 255 implants from the control group and 75 implants from the test group, with implant length of 8 mm for both groups. No implant failure was observed in control group and only one lost was observed from the test group, achieving 100% and 98.7% respectively. In addition, implants were splinted only to short implants (3 or 2-units). Summary and characteristics of selected studies are described on tables 4 and 5.

Table 4. Summary of selected studies.

Study # and author	Patients (n)	Mean age (y)	Total implants (n)	Implants number (n)	Mean follow up time (mo)	Loading protocol*	Augmentation procedures	Mean bone loss (mm)	Prosthesis complications	Early failures** (n)	Failure after loading (n)	Survival rate (%)
#1- Clelland et al.	19	56	108	NSP: 54 SP: 54	36	Conventional	No	NSP: 0.14 SP: 0.52	NSP group showed 5 screw loosening. One broken / chipping prosthesis for SSI. No broken screws for both groups	No	NSP: 1 SP: 0	SP: 100% NSP: 98.1%
#2- Fugazzotto et al.	NC	52	544	NSP: 315 SP: 229	29	Conventional	No	NR	NC	No	NSP: 5 SP: 4	SP: 98.4% NSP: 98 %
#3- Mendonça et al.	NC	63	393	NSP: 186 SP: 207	36.2	Conventional / early	No	NSP: 1.27 SP: 1.22	NC	NR	NSP: 14 SP: 5	SP: 97.6% NSP: 92.5%
#4- Grant et al.	124	56	335	NSP: 75 SP: 255	16	Conventional	No	NR	NC	4	NSP: 1 SP: 0	SP:100% NSP: 98.7%

NC, not clear; NR, not reported; NSP, Nonsplinted group; SP, Splinted group; ***** Immediately, implant placement time / Early, 6-12 weeks / Conventional, after 3 months; ** Implant lost before prosthesis loading. Source: Authors (2022).

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Table 5. Characteristics of selected studies.

Study # and author	Year of publication	Study design	Study setting	Implant system /Connection type	Diameter (mm)	Length (mm)	Type of prosthesis / retention	Implant surface	Augmentation procedures	Smoking status
#1- Clelland et al.	2016	Randomized clinical split mouth	University	OsseoSpeed (Dentsply Sirona) /internal	3.5, 4 and 5	6, 8, 9 and 11	Metal and metal-ceramic/ cement and screw retained	RS: 108 SMS: 0	No	No
#2- Fugazzotto et al.	2008	Restrospective	Private practice	Straumann/ Internal	NC	6, 7, 8 and 9	NR/NR	RS: 544 SMS: 0	No	< 10 per day
#3- Mendonça et al.	2014	Restrospective	Research institute	NR/ Internal and external	4.1 and 5	7, 8.5 and 10	Metal-ceramic/ NR	RS: 157 SMS: 292	No	< 10 per day
#4- Grant et al.	2009	Restrospective	NR	NR/NC	3.5, 4.3, 5 and 6	8	NR/NR	NR	No	NC

NR, not reported; NC, not clear; RS, rough surface; SMS, smooth surface; ***** Immediately, implant placement time / Early, 6-12 weeks / Conventional, after 3 months; ** Implant lost before prosthesis loading. Source: Authors (2022).

3.3 Quality assessment

All included studies were evaluated according to the quality assessment based on Cochrane assessment tools. Studies #2 (Fugazzotto, 2008) and #4 (Grant et al., 2009) presented high risk of bias, study #3 (Mendonça et al.,2014) presented medium risk of bias and study #1(Clelland et al., 2016) received low risk of bias. According to the quality assessment from present systematic review and meta-analysis, all included articles were methodologically acceptable, since all of them received at least four pluses. However, only one study was considered as low risk of bias, mainly because presented baseline homogeneity, blindness from operator, outcome assessor and also from patient. Figure 2 describes the quality assessment from included articles in more details.

Figure 2. Quality assessment of included articles according to Cochrane assessment tools.

	Has a sample size calculation and power been reported?	Has baseline homogeneity been achieved?	Has eligibility criteria been clearly described?	Has the intervention been clearly described?	Are the outcomes clearly described?	Is blinding used to assess the outcome? If not, does this have no effect on the evaluation of the results?	Were the patients blinded for treatment?	Is the outcome assessor different from the operator?	The authors have declared no conflict of interests?	Has the follow-up been completed?	Have the ethical considerations been considered?	TOTAL
Study #1	?	+	+	+	+	?	+	+	+	−	+	8
Study #2	?	−	+	+	+	−	−	?	−	+	−	4
Study #3	?	−	+	−	+	−	−	?	+	+	+	5
Study #4	−	−	?	+	+	+	−	?	−	+	−	4

Source: Authors (2022).

3.4.1 Primary outcomes

The present meta-analysis evaluated the primary outcome SR of included articles and of each implant length group (Table 3). The forest plot graph of included studies (Figure 3) showed statistical difference for splinted implants (p=0.038), with higher failure rate for NSI group (Odds Ratio = 2.26).

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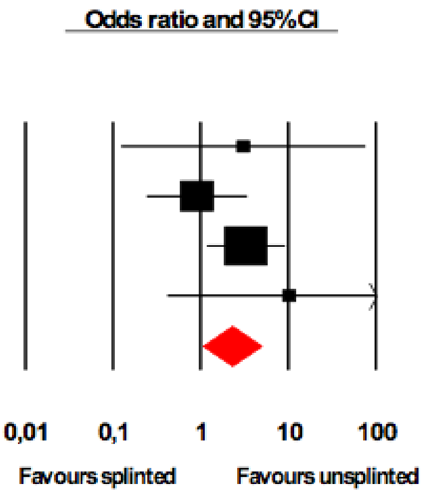
Figure 3. Forest plot graph from meta-analysis comparing SSI and NSI of included articles.

Study	Statistics for each study				
	Odds ratio	Lower limit	Upper limit	Z-Value	p-Value
Study 1	3,056	0,122	76,699	0,679	0,497
Study 2	0,907	0,241	3,416	-0,144	0,886
Study 3	3,288	1,161	9,314	2,241	0,025
Study 4	10,289	0,415	255,196	1,423	0,155
	2,264	1,048	4,892	2,079	0,038



The Nonsplinted/Unsplinted group (NSI) had higher failure rate (Odds Ratio = 2,26) and SSI group was statistically different, with higher SR (p-value < 0,038) in comparison to NSI. Source: Authors (2022).

The second meta-analysis (Figure 4) evaluated SR for SSI and NSI groups based on the present classification of implant length: standard, short and ultrashort implants (Table 3). For each implant length group the corresponding meta-analyses demonstrated higher failure for NSI, however, with no statistical difference between groups (p=0.282).

3.4.2 Secondary outcomes

The secondary outcome BLI was evaluated comparing SSI to NSI. The measurement was conducted using a periodontal probe to measure the bone level of the crestal bone to the implant platform, at the baseline (after prosthetic loading) to the last follow-up period. Only two selected articles (Clelland et al, 2016, Mendonça et al, 2014) presented the adequate data for BLI meta-analyses. The forest plot graph showed no significant difference between SSI and NSI (Fig 5). Conversely, the NSI group of the study #1 presented a bone gain after loading, which is quite the opposite from what usually happens with the bone level after loading. That was the main reason why, in this article, we chose to use the term BLI instead MBL. Related to IF, the SSI group had 9 failures after loading, which represents 1.2% of IF. The NSI group showed 23 failures after loading, which revealed 3.6% of IF. Concerning about PF, only one included article (Clelland et al., 2016) described about prosthesis complications. Regarding screw loosening, SSI did not present any case, however, NSI showed 5 screw loosening. Only one broken/chipping prosthesis could have been observed, only for SSI group. No broken screws were visualized, for both groups. The others 3 included articles did not document any prosthesis complications.

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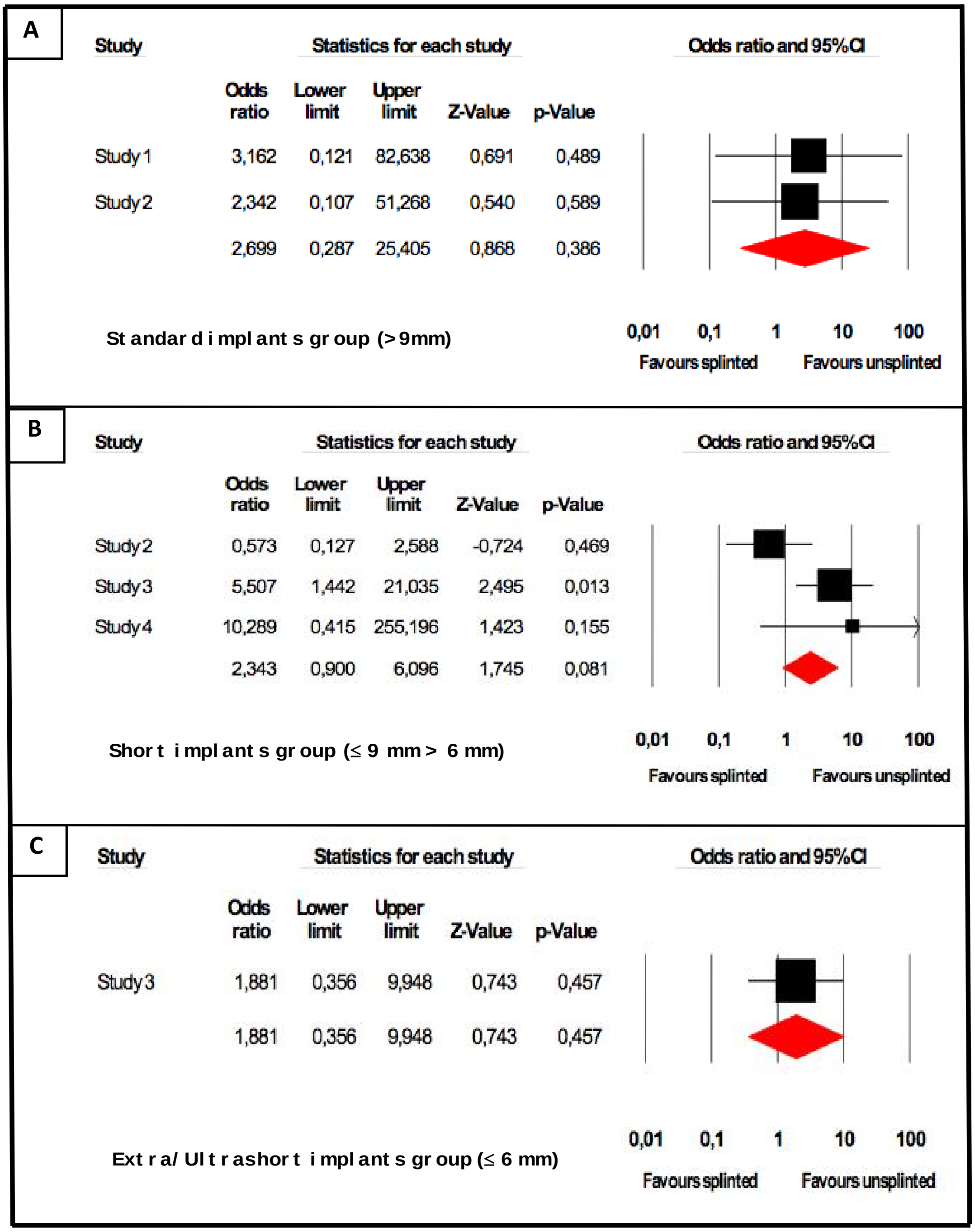
Figure 4. Forest plot graph from meta-analysis related to the implant length classification (Table 3).

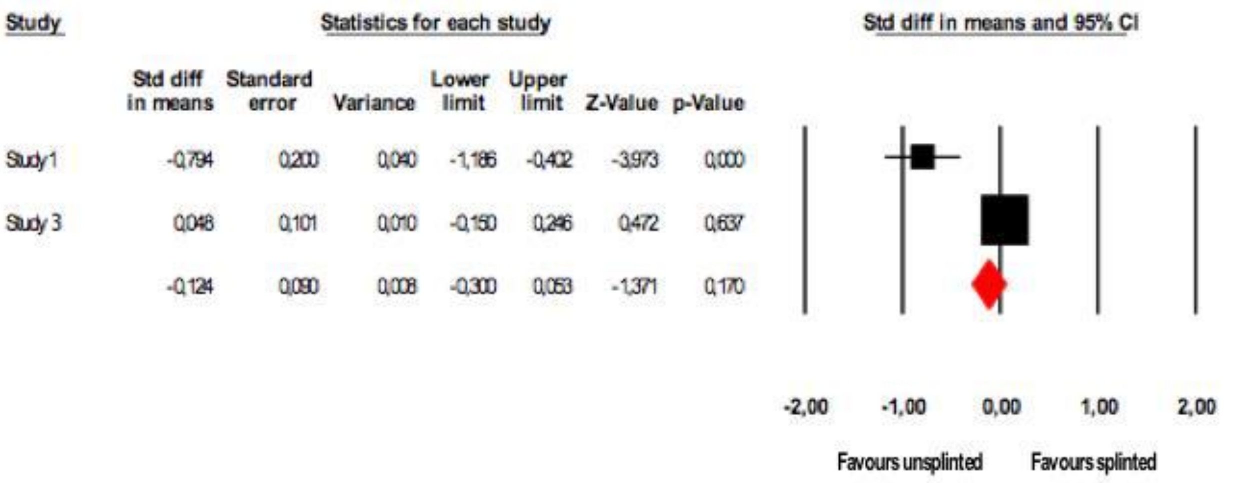


A: Showed no significant difference between SSI and NSI for implants with more than 9mm length (*p*-value< 0,457). **B:** No significant difference between SSI and NSI for implants shorter or equal to 9mm and higher than 6mm (*p*-value< 0,081). **C:** No significant difference between SSI and NSI for implants shorter or equal to 6mm (*p*-value< 0,386). Despite the fact that for all statistical analysis (A, B and C) none had showed significant difference, the failure rate for NSI was major in all 3 evaluation. Source: Authors.

3.4.3 Secondary outcomes

The secondary outcome BLI was evaluated comparing SSI to NSI. The measurement was conducted using a periodontal probe to measure the bone level of the crestal bone to the implant platform, at the baseline (after prosthetic loading) to the last follow-up period. Only two selected articles (Clelland et al, 2016, Mendonça et al, 2014) presented the adequate data for BLI meta-analyses. The forest plot graph showed no significant difference between SSI and NSI (Figure 5). Conversely, the NSI group of the study #1 presented a bone gain after loading, which is quite the opposite from what usually happens with the bone level after loading. That was the main reason why, in this article, we chose to use the term BLI instead MBL. Related to IF, the SSI group had 9 failures after loading, which represents 1.2% of IF. The NSI group showed 23 failures after loading, which revealed 3.6% of IF. Concerning about PF, only one included article (Clelland et al., 2016) described about prosthesis complications. Regarding screw loosening, SSI did not present any case, however, NSI showed 5 screw loosening. Only one broken/chipping prosthesis could have been observed, only for SSI group. No broken screws were visualized, for both groups. The others 3 included articles did not document any prosthesis complications.

Figure 5. Meta-analysis forest plot graph related to bone level around implants (BLI).



Related to the measure of the crestal bone to the implant platform (BLI), no statistical difference was observed between study 1 and 3 (*p*-value< 0,170). However, instead losing bone after loading, study #1 presented gain of bone around implants for the NSI group. Source: Authors.

3.5 Success criteria

After a careful screening data from all included articles, no criteria standardization was observed for the SSR evaluation. Due to the different aspects adopted to evaluate SSR, a quantitative analysis was at least problematic to be conducted, as it would result in a heterogeneity meta-analysis, with high risk of bias. Therefore, a descriptive analysis was performed, in the present systematic review, for the success criteria. Study #1 achieved all those criteria described previously, such as implant stability and less than 0.1mm bone loss after the first year of loading. Bone loss with screw exposure was more frequent on NSP group (5 patients) and 1 for SP group. Only the control group presented damaged prosthesis (two-unit). Concerning the MBL, study #1 had no statistically difference between control and test group. However, an important achievement was the gain of bone on both groups in 3 years of follow up (NSP: 0.37mm / SP: 0,02mm). Success criteria adopted for study #2 was from a study reported previously (Albrektsson et al., 1986). MBL was not evaluated on study #2, but radiographic implant stability assessment was reported. In addition, no prosthetic complications were documented. Concerning the IF, there were 4 for the NSP group and 5 for the SP. Study #3 described another success criteria (Ross et al., 1997), including absence of mobility, painful symptoms, radiolucency during radiographic evaluation and progressive marginal bone loss <1mm during the first year and 0.2 mm per subsequent year. An MBL evaluation was described with no statistically difference between control and test groups and not influenced by implant length (7 and 8.5 mm). Based on their success criteria, control group showed 5 IF, achieving 97.7% of success. The test group had 16 IF which represents 93.2% of success. No PF was documented. The success criteria documented in study #4 was clinical evidence of the osseointegration at stage II surgery and, after restoration, loss of cervical bone (<1mm) for the first year and 0.1mm for each successive year. No prosthetic complications, bleeding or painful symptoms were included on their success criteria. No MBL evaluation was performed. The study showed 99% of SSR.

3.6 Studies missing data

The most common data provided by articles which discuss short implant SR are usually concerning about the implant, as length, surface, location and stage of the surgery. That is the reason why 14 authors were contacted by email and were gentle requested about the prosthetic data (splinted or non-splinted crown) from their studies. Unfortunately, no answer was obtained until the conduction of the statistical analysis.

4. Discussion

The present systematic review and meta-analysis aimed to answer the clinical question: Short dental implants in posterior mandible should be splinted or not? Based on the presented data the answer was positive for splinted prosthesis, whereas the splinted prosthetic loading promoted superior SR. Meta-analysis showed a mean SR of 99% for splinted and 97% for nonsplinted group. These results were statistically significant for splinted implant group in posterior mandible ($p<0.038$). Misch et al (2006) suggested that splinted implants might lead to fewer stress transmitted to each bone–implant interface compared with non-splinted implants. Studies (Rokni et al, 2005, Misch et al, 2006) demonstrated that splinting short implants can improve the uniformity of occlusal load distribution. Ylmaz et al (2011) showed no difference for splinted or non-splinted prosthesis under axial loading. Nevertheless, under oblique forces splinted rehabilitations allowed better uniformity of forces. A finite element study aimed to evaluate the periimplant bone stress distribution comparing splinted to nonsplinted implants. An in vivo loading data was conducted on models with two implants and forces were applied for the finite element evaluation. Regarding the limitations of the study, splinted prosthesis presented better outcomes, with less stress distribution to the periimplant bone (Shigemitsu et al., 2013). These results support the present BLI meta-analysis, which demonstrated no statistical difference on the periimplant bone, without significant bone loss for both groups. Another recent finite element study evaluated the biomechanical performance of splinted and nonsplinted implants in posterior mandible. Two implants length were analyzed, 5mm and 11mm, and were compared regarding the prosthesis type: splinted and nonsplinted prosthesis. The results showed that the splinted crown, on short implants, presented less stress to the surrounding bone. However, related to the standard implant size, the results showed no significant difference between splinted and nonsplinted implants (Toniollo et al., 2017). This study presents a new evidence, which short implant behavior should be considered apart from longer implants in terms of bone strain distribution, when related to the prosthesis type. However, more studies, especially randomized clinical studies, need to be conducted in order to establish such evidence. A photoelastic study (Pellizzer et al., 2014) compared the effects of splinting and not splinting prosthesis in five groups of resins photoelastic models (A: 3.75 x 7 mm and 3.75 x 7 mm, B: 3.75 x 10 mm and 3.75 x 7 mm, C: 3.75 x 13 mm and 3.75 x 7 mm, D: 3.75 x 10 mm and 3.75 x 10 mm and E: 3.75 x 13 and 3.75 x 10 mm). The results showed better stress distribution for splinted implants in comparison to nonsplinted implants. The implant size had significant importance to the periimplant bone stress, which the shorter the implant, the higher the stress applied to the periimplant bone. It was concluded that splinted prosthesis had better biomechanically behavior in comparison to nonsplinted implants. This study also corroborates with Toniollo et al (2017), showing that short implants behavior related to the prosthesis type should be considered apart from standard implants, supporting the objective of the present systematic review. In addition, this study (Toniollo et al., 2017) showed superior results for splinted prosthesis which are also in agreement with the present systematic review, demonstrating better outcomes for SSI in comparison to NSI. However, several studies (Tellman et al, 2011, Rokni et al, 2005, Fugazzotto, 2008, Mezzomo et al, 2014) on the currently literature present high SR for nonsplinted short implants and describe no influence of implant length related to SR. A systematic review (Mezzomo et al., 2014) concluded that single short implants in posterior mandible has high SR and SSR, seeing as a predictable alternative to major surgeries for the posterior mandible rehabilitation. However, still remain the important clinical question related to the best prosthesis type for those short implants in the posterior mandible. The present systematic review answered this question, showing that short splinted implants had better outcomes. Nonetheless, the systematic review was based on a heterogeneity data for the prosthesis type and reduced number of studies for meta-analysis. In accordance, Telleman et al (2011) concluded that the weakness of their systematic review was also related to the lack of information about prosthesis type of short implants. In the present study, a great amount of studies had to be rejected due to the lack of prosthesis information, especially the number, type and localization of splinted units. Another problem is the lack of studies with adequate study design evaluating short implant prosthesis behavior. The present systematic review evaluated the risk of bias of all included articles. Included studies with the strongest evidence strength were studies #2 and #3. However, according to quality assessment, study #3 received high risk of bias and #2 medium risk of bias. The only study with low risk of bias had little evidence strength on meta-analysis (Fig 2). In addition, an important finding in the present study is the implant length influence on the SR, related to the prosthesis type. All implants were classified according to their length and 3 groups were defined: standard, short and extra/ultrashort (Table 3). The type of the prosthesis (splinted or nonsplinted) were compared in relation to each implant length group. No statistical difference was observed between groups indicating that implant length presents no influence on SR of splinted or nonsplinted implant. These results are not in accordance with those finite elements studies previously discussed, in which differences on bone stress distribution could be seeing between splinted and nonsplinted short implants in comparison to long ones. Whereas, long implants presented no difference in terms of splinted or nonsplinted prosthesis, short implants showed better outcomes for the splinted group (Toniollo et al., 2017). These different outcomes between the present systematic review to those finite elements studies (Shigemitsu et al, 2013, Toniollo et al, 2017) are related to the lack of appropriated studies on the literature.

The short implant size nomenclature is not standardized. Initially, an 11mm implant length was considered short implant (Misch et al., 2006), since the former knowledge about implant retention was: “the greater the implant length, the greater its SR”. After that, studies revealed that implant surface treatment was directly related to SR (Tellman et al, 2011, Strietzel & Reichart, 2007, Kotsovilis et al, 2009). With technology innovations, several implants with reduced length were produced, especially to avoid reconstructive surgeries (Esposito et al, 2011, Renouard & Nisand, 2006). Currently, the shortest implant commercially available has 4 mm and there is an expectation that through over the years, the implant length might decrease even more. This might be one of the reasons why short implant length remains without nomenclature standardization. A study (Misch et al., 2006) considered that length of short implants should be equal to or less than 10 mm. Two systematic reviews (Tellman et al, 2011, Mezzomo et al, 2014) considered that implants with length inferior to 10 mm could be categorized as short implants and above this measure, long implants. Rokni et al (2005) considered long implants those with 9 mm or more and 7 to 5 mm as short implants. Another study (Deporter et al., 2008) named 5 mm implants as ultrashort. Another study (Urdaneta et al., 2012) considered implants > 8 mm as long, <8 mm as short and <6 mm as ultrashort. Two other studies (Slotte et al, 2015, Calvo-Guirado et al, 2016) considered the nomenclature of extra short implants with length less then 5 mm. Due to this nomenclature diversity and according to reviewed literature, the present article defined a classification for lengths of reduced size implants (Table 3) and it might facilitate the understanding by surgeons and also be useful for future clinical studies.

An important factor related to implant size is the crown/implant ratio, which majority of the studies agrees that should be ≤1 (Kotsovilis et al., 2009). However, a systematic review (Mezzomo et al., 2014) showed long-term SR for implants with crown/implant proportion >1, indicating that an implant with length less than its crown could be utilized. Nevertheless, the limits of this proportion/ratio and relation with the success of the short implants splinted or not, remain unknown. Further studies are necessary to evaluate mainly crown/implant length ≥2, which can be visualized in extra-short implants cases and to compare the type of prosthesis (splinted or not).

Considering the short implant diameter, a finite element study (Nagasawa et al., 2008) evaluated the periimplant bone strain for wide and narrow implants, in different implant insertion depth and in two types of bone quality. The strain distribution was higher in wide implants in comparison to narrow implants. Related to the insertion depth, strain levels in periimplant bone were reduced as the depth was increased. In addition, a poor bone quality increased the strain levels on periimplant bone. These results could probably indicate some pathway. However, these outcomes are based on a finite element study, therefore still a lack of studies on the literature comparing those variables to splinted and nonsplinted implants, especially for *in vivo* studies.

Another important aspect is related to the number of splinted implants, if there is any difference between splinting to more than 2 or 3, in terms of stress distribution to the bone. A finite element study aimed to assess the stress distribution associated with splinted and nonsplinted implant-supported mandibular fixed complete denture design. One model simulated 1-piece framework, another model simulated 2-piece and the last one was 3-piece frameworks. An axial and oblique load were applied. The 3-piece framework demonstrated less periimplant stress. Despite the fact that full edentulous patients cannot be compared to partially edentulous patient biomechanically speaking, this study showed that splinting implants to more than two units has better outcomes in terms of bone strain distribution (Alvarez-Arenal et al., 2014).

Due to the absence of information in the literature, a more detailed information about of the splinting type could not be performed in the present systematic review. Therefore, more clinical studies should be conducted, precisely to evaluate the number of implants splinted together and associate them with each respective implant size, location, bone quality and implant insertion level.

Related to MBL around splinted and nonsplinted short implants, the present meta-analysis showed no statistical difference between groups. The analysis had to be conducted based only in two of those 4 selected articles. The reason for that is related to the fact that there is no standardization in terms of bone level measurements. Each study adopts its own method to measure the crestal bone to the implant platform. A systematic review of short implants described the same problematic for implant bone level measurements. Mainly, their MBL meta-analysis could not be performed due to the heterogeneity data from selected studies, since some articles considered the baseline as the implant insertion, and others the prosthetic loading (Annibali et al., 2012). In the present systematic review, the bone level measure was referred as BLI instead MBL, since an actual bone loss could not be observed in one of the selected articles. Regardless of this bone gain, the present meta-analysis presented no significant difference between groups (Fig 5).

Clelland et al (2016), identified a bone gain only on the nonsplinted short implant group, which they defined as a negative MBL the increase of bone height after the short implant loading. Furthermore, the only statistical difference was in non-splinted group, which indicated substantial bone gain results. One of the hypothesis for these results could be related to difficult to maintain oral hygiene in splinted prosthesis, and therefore, increasing the possibilities of having bone loss, as a consequence of periimplantites. The MBL around implants could be related to occlusal overload, poor hygiene, poor bone quality and systemic conditions (Grossmann et al., 2005). Even a minor MBL around short implants is a challenge and could cause an early implant loss due to its reduced length.

Several studies demonstrated (Tellman et al, 2011, Mendonça et al, 2014, Grant et al, 2009, Mezzomo et al, 2014) long-term predictability of short implants. However, there is no evidence for patients with parafunctional oral habits. Oblique forces seem to be more uniform on splinted implants (Mezzomo et al., 2014), and this might be one of the indications for splinting short implants in patients with parafunctional oral habits. Concerning about occlusal overload, splinted prosthesis could benefit patients with parafunction habits. Despite of that, parafunctional patient requires better evaluation, which a bite guard should be the first step.

One of the disadvantages of splinting implants would be the difficulty of plaque control that could initiate peri implant mucositis and periimplantitis (Grossmann et al., 2005). In addition, any short implant bone loss is a significant risk factor, due to the short height, increasing the chances of implant failure. Splinted prostheses often dislike patients because of the difficulty to clean interproximal areas (Shigemitsu et al., 2013). However, the present systematic review showed better outcomes for splinted implants. Therefore, despite the difficult on oral hygiene, patients still have a great responsibility related to the maintenance of those implants, including the splinted ones, and professional cleaning should be conducted according to the professional recommendations.

Some authors consider that the fabrication of a passively seating splinted prosthesis of multiple implants could be more challenging to accomplish than individual implant crowns (Shigemitsu et al., 2013). However, the number of occlusal contact points and occlusal adjustment might be easier to manage in splinted prosthesis in comparison with a single crown. Expertise opinions, including authors from the present systematic review, believe that due to the addition of more material quantity added in a splinted prosthesis crown, increases the reinforcement of the restoration, making it last longer than an individual one.

Patient-centered outcomes are currently used in clinical studies and should promote more qualitative data to find the best treatment for the patients. Based on that, Clelland et al (2016) recorded patient preference and the results revealed better outcomes for non-splinted compared to splinted prosthesis. However, biomechanically speaking splinted implants presented better results in the present study, a condition that should be consider at the treatment planning phase.

4.1 Implications for clinical practice

Splinted prosthesis for short implants seems to indicate better SR in posterior mandible compared to unsplinted prosthesis. Despite the fact that few studies in the literature objectively compare splinted and nonsplinted prosthesis, a large amount of finite element studies corroborates with the results of the present systematic review, in which splinted short implants have better SR, with less stress on periimplant bone. In addition, these results might demonstrate a strategy to benefit those patients with parafunctional oral habits, bruxism and malocclusion. For those conditions, the occlusion might be compromised, therefore, splinted prosthesis should be considered the gold standard treatment.

4.2 Implications for research

Several in vitro and finite element studies aim to compare splinted to nonsplinted short implant prosthesis. However, there is a lack of clinical trials evaluating the best short implant prosthesis type. To better understand and to establish this knowledge, more researches should be conducted, evaluating more implant characteristics, such as implant surface, type of platform and abutment, insertion depth, number of splinted implants, bone quality, implant location, and to relate them to the type of prosthesis.

Only one included study on the present systematic review presented low risk of bias (Clelland et al., 2016). This condition strongly indicates that more studies need to be conducted, with an adequate study design, and mainly evaluating the difference between splinted and non-splinted short implants prosthesis. In addition, patient-centered outcomes evaluation is necessary in order to improve the treatment for patients.

5. Conclusion

This systematic review and meta-analysis demonstrated that short implant SR increased with splinted prosthesis loading in posterior mandible. Nevertheless, both unsplinted and splinted prosthesis presented high SR and are suitable to be use with success, which may indicate that there is no formula or correct guidelines to load short implants in posterior mandible. Due to the lack of scientific evidence, the meta-analysis was based on few studies and mainly with high risk of bias. Therefore, more randomized clinical trials comparing splinted and non-splinted short implants need to be conducted.

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