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FACULDADE DE MEDICINA DENTÁRIA
VISEU

COMPARING THE RESULTS AMONG ZIRCONIA, TITANIUM-ZIRCONIUM, AND TITANIUM DENTAL IMPLANTS: A SYSTEMATIC REVIEW OF RANDOMIZED CONTROLLED TRIALS

Dissertação apresentada à Universidade Católica Portuguesa para obtenção do grau de Mestre em Medicina Dentária

Por:

Paulo Rafael Esteves Fernandes

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Orientador: Professor Doutor Gustavo V. O. Fernandes

Coorientador: Professor Doutor George Romanos

Viseu, 2021

“E acrescentou: “Seja forte e corajoso! Mãos ao trabalho! Não tenha medo nem desanime, pois Deus, o Senhor, o meu Deus, está contigo. Ele não o deixará nem o abandonará até que se termine toda a construção do templo do Senhor””

-Bíblia, Crónicas, 28:20

DEDICATÓRIA

À minha mãe, irmãos, avós e namorada pelo vosso apoio e pela vossa ajuda nestes tantos anos de luta. Somente com o vosso auxílio foi possível ultrapassar estes anos.

AGRADECIMENTOS

Foram muitas horas e muitos obstáculos vencidos e sem as seguintes pessoas nada disto seria possível.

Professor Doutor Gustavo Fernandes, pelo seu tempo e esforço, pelos conselhos e pelas orientações que tanto ajudaram a que este trabalho fosse possível, sem você nada seria possível.

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À minha mãe, por tudo o que faz por mim e sem ela nada disto seria possível, pela paciência e carinho e por todo o amor.

Aos meus irmãos, que tanto me dão dor de cabeça, mas sem eles os dias longos seriam ainda mais longos.

Aos meus avós, que sempre me apoiaram e mostraram todo o carinho que têm por mim.

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ABSTRACT

Objectives: The objective of this systematic review was to compare within the literature if titanium and titanium-zirconium implants show differences, when evaluated soft and hard tissue, compared to zirconia implants.

Material and methods: The searches were electronically performed (PubMed and Web of Science) and by hand, in October 2020, to identify randomized controlled trials comparing either zirconia implants with titanium or titanium-zirconia implants. The focused question was determined according to PICOT strategy.

Results: A total of 7 studies were included from a total of 202 articles initially found, which 4 of them were duplicates and 198 titles were screened and 191 of them excluded. The follow-up periods ranged from 12 months to 80 months and the mean age from 43.3 to 65.8. The survival rate for titanium implants ranged from 92.6% to 100% and for titanium-zirconium implants from 95.8% to 100%, whereas zirconia implants ranged from 87.5% to 91.25%. The mean marginal bone loss for titanium implants ranged from -1.17mm to -0.125mm, for titanium-zirconium implants from -0.6mm to -0.32mm, and for zirconia implants from -0.25mm to -1.38mm. Regarding mucositis and peri-implantitis, the studies showed little incidence. For bleeding on probing, it was evaluated for zirconia implants a 16.43%, while for titanium implants ranged between 10% and 20% and for titanium-zirconium implants 10% to 13.8%. Probing-in-depth for titanium implants ranged from 1.6mm to 3.05mm, for zirconia implants ranged from 2.21mm to 2.6mm and for titanium-zirconium evaluated probing in depth recording 3.12mm. Regarding the diameters of implants, all types were used (narrow, regular, and wide).

Conclusion: All three types of implants showed similar soft and hard tissue response and behavior, except for the survival rate involving the zirconia implants, which had the lowest value.

Keywords: Implants, Zirconia, Titanium, Titanium-zirconium, Survival rate, Biological complications.

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INTRODUCTION

1. INTRODUCTION

The main application of the dental implants is integrated within the oral rehabilitation, supporting prosthetic treatments. (1) Over the past 50 years, implants have been applied in experimental treatments as a modality widely used to replace missing tooth/teeth, presenting a great predictability. (2) They can also be used widely in various treatment options such as fixed prosthetics, removable prosthetics or as support for single crowns or bridges. Dental implants were also integrated in oral rehabilitation with the aim of improving the aesthetics, the act of chewing (mechanical) and to improve speech. The titanium alloy is the gold standard material to produce implants.(1,3) Experienced for many years replacing tooth lost, titanium implants had a high success rate in long-term (2,4), with studies showing survival rates over 95% after 10 years.(2) Therefore, the first implants were made with pure titanium, obtaining a good anchorage in the bone, biological mechanism named osseointegration.(1,5) In the 80's, there was a shift on the market and the commercial pure titanium was considered the main material for this purpose.(6)

Owing many questions emerged pursing to improve the results previously obtained, in 90's, some researchers suggested to modify the implant's surfaces, (7) and they concluded that the best surface had a sandblasting treatment with large grid and acid-etching technique. This type of implants have moderate rough and microrough and, currently, it has received more attention.(8) Even though the titanium implants are biocompatible and have high survival and success rate, they may show esthetic problems, such as discoloration of the peri-implant soft tissue in thin phenotype, and hypersensitivity due to the corrosion of the implant surface.(9) To try solving those problems, the zirconium dioxide (zirconia) implants were introduced as an alternative, presenting a favorable color combined with the good biocompatibility and reduced affinity to bacterial plaque, make this type of implants a feasible choice to the downsides of the titanium implants.(10)

The current form used in zirconia dental implants is the tetragonal, however this form can be changed in the presence of water, transforming the tetragonal shape into the monoclinic, resulting in a progressive deterioration of

the material.(11,12) Moreover, there are two types of zirconia implants, once-piece and two-pieces implants, most commonly used are one-piece implants.(13,14,15) Therefore, they have some limitations related to prosthodontic requirements, according to 3D position and cementation. Zirconia implants can also be a viable option due to a high bending strength, fracture toughness and a good resistance to corrosion and wear. (16) *In vivo* study showed the bone-to-implant contact (BIC) ranged between 66% and 81% for zirconia implants, having different loading design. (17) Rocchietta et al. applied zirconia implants, with surface-modified chemically, and tested in rabbits to confirm if existed benefit in the osseointegration. However, they did not show any benefits compared with the control group. (16)

Thereby, titanium alloys suffer dissolution related to the implant corrosion and could alter the natural oral microbiome, and controversially, zirconia shows a reduced affinity to bacterial plaque.(17) Although zirconia implants do not have an enough background like titanium, the results of the survival rates are very promising. As aforementioned, titanium implants have a high success rate after 10 years compared with innumerous studies analyzed recently for zirconia implants, which showed a survival rate ranging between 87% and 100%, with follow-up from one to eight years.(18)

Zirconia implants have been considered mainly to substitute titanium implants in the anterior region, due to the aesthetic problems mentioned earlier. Some studies have shown a high survival rate of zirconium implants that can be related to titanium implants (10), this means that the results are very promising and that zirconia implants can be a good option to substitute the downsides of titanium implants.

In addition to these two options, another type of implants was developed in order to combine properties of the titanium and of the zirconium, forming the titanium-zirconium implants. These mixed implants did not solve the esthetic problem of the titanium implants. Therefore, they are considered to have a higher tensile strength when compared to titanium, preventing the possible failure of the implants by fracture (19), this means that narrow implants of titanium-zirconium can be used, to substitute either zirconia or titanium implants, on more complicated situations when we have less bone available. (20) By not having the

need of a higher diameter of bone for the implant to succeed, bone regeneration techniques are no longer needed facilitating the implant placement. But there is a downside of using narrow diameter titanium-zirconium implants that is the possible strength fatigue that can lead to implant failure, this means that this type of implant could not be recommended to teeth that have high occlusal forces. (20) By not having good results in teeth with high occlusal forces this type of implant show the same problem as the titanium ones, the color, but in spaces with less bone this type of implant is considered over zirconia implants that need more bone toosseointegrate.

The survival rate of the titanium-zirconium implants does look promising with studies showing a survival rate of above 97% after one and three years of functional loading (21,22).

Thereby, the purpose of this study was to evaluate systematically the literature to assess results in direct comparison between titanium, zirconium and titanium-zirconium implants.

MATERIALS AND METHODS

2. MATERIALS AND METHODS

This systematic review was conducted following the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA) guidelines (Moher, Liberati, Tetzlaff, Altman, 2009) with the focused question being determined according to the Population, Intervention, Comparison and Outcome, Follow-up (PICOT) strategy (Schardt, Adams, Owens, Keitz, Fontelo, 2007). The protocol for this systematic review was registered on PROSPERO (registration number CRD42021236781 provided by the Centre for Reviews and Dissemination/CRD – University of York).

2.1. Focused Question

The focused question for the present review was as follows: “In clinical studies with partially and fully edentulous patients (P), do the oral rehabilitations with zirconia (I), when compared with titanium implants or titanium-zirconium (C), exhibit differences in clinical outcomes, such as survival rate, success rate, marginal bone loss, osseointegration level, BIC/BAFO (O), during at least 6 months (T).

2.2. Information sources and search strategy

An extensive electronic search was conducted through MEDLINE (PubMed) and Web of Science with a platform-specific search strategy combining controlled terms (MeSH for PubMed) and text words (Supplementary Table 1). An additional manual search was performed on the references of included articles to identify relevant publications. Only articles published in the English-language dental literature from January 2010 until and including December 2020 were included. Two reviewers (P.R.E.F. and G.V.O.F.) independently performed the electronic and manual search.

The publications obtained from the search through all mentioned databases were imported into a reference management software (EndNote X9/Thomson Reuters, Philadelphia, USA) and subsequently screened.

2.3. Inclusion criteria

This systematic review was based on clinical studies. The additional inclusion criteria for study selection were:

- Human studies published in English-language dental literature from January 2010 until December 2020 with at least 10 patients treated.
- Partially or fully edentulous patients rehabilitated with titanium and zirconia dental implants or zirconia-titanium implants.
- A follow-up of at least 6 months after functional loading.
- Detailed information on the implant used.
- Reported details regarding survival and/or failure rates.
- Only the publication with the longest follow-up was included in case of multiple studies involving the same patient cohort (population).

2.4. Exclusion criteria

Clinical studies that did not meet the entire inclusion criteria were excluded, animal studies and laboratorial analysis. Reports based on questionnaires, interviews and case reports/series were also rejected as well as systematic/critical/narrative reviews, publications investigating individually designed zirconia implants or involving patients with significant health problem (ASA Physical Status 3 and above).

2.5. Selection of studies

Duplicates were excluded, and the remaining articles screened by tittle and abstract for eligibility. Further examination regarding inclusion and exclusion was subsequently made by full-text analysis. The full text of any title or abstract that did not provide sufficient information regarding the inclusion criteria was also obtained. Any disagreement between the reviewers was discussed with a third author (G.R.). Cohen's kappa test was adopted to evaluate reviewers' agreement on both title and abstract selection.

2.6. Risk of bias and Quality assessment

The assessment of risk of bias and study quality of the included investigations was performed independently by two reviewers (P.R.E.F. and G.V.O.F.), where randomization process, groups similar at baseline, blinded group allocation, random housing, blinded interventions, random and blinded outcome assessment, reporting of dropouts and other biases (funding) domains were addressed.

2.7. Data extraction and method of analysis

The reviewers extracted the data independently from the selected articles for further analysis using data extraction tables, which included the following parameters:

- Author(s), year of publication and study design (RCT/PS/RS)
- Mean observation period
- Number of patients and implants at the initial stage of the research, mean age of patients and gender.
- Number of patients and implant dropouts, number of early and late implant failure.
- Cumulative implant survival rate (%), biological complications and peri-implant MBL (mm).
- Configuration of the implants and diameter
- Bleeding on probing (BOP) and probing in depth (PD)

RESULTS

3. RESULTS

3.1. Study Selection

After the research we ended up with 202 articles, 55 from PubMed and 147 from Web of Science, that were screened firstly for title and abstract, and then from a full-text read. After the first analysis we had 2 studies that were the same cohort and 4 duplicates that were removed. After scanned by tittle and abstract and then fully read the articles that remain, we ended up with 7 studies.

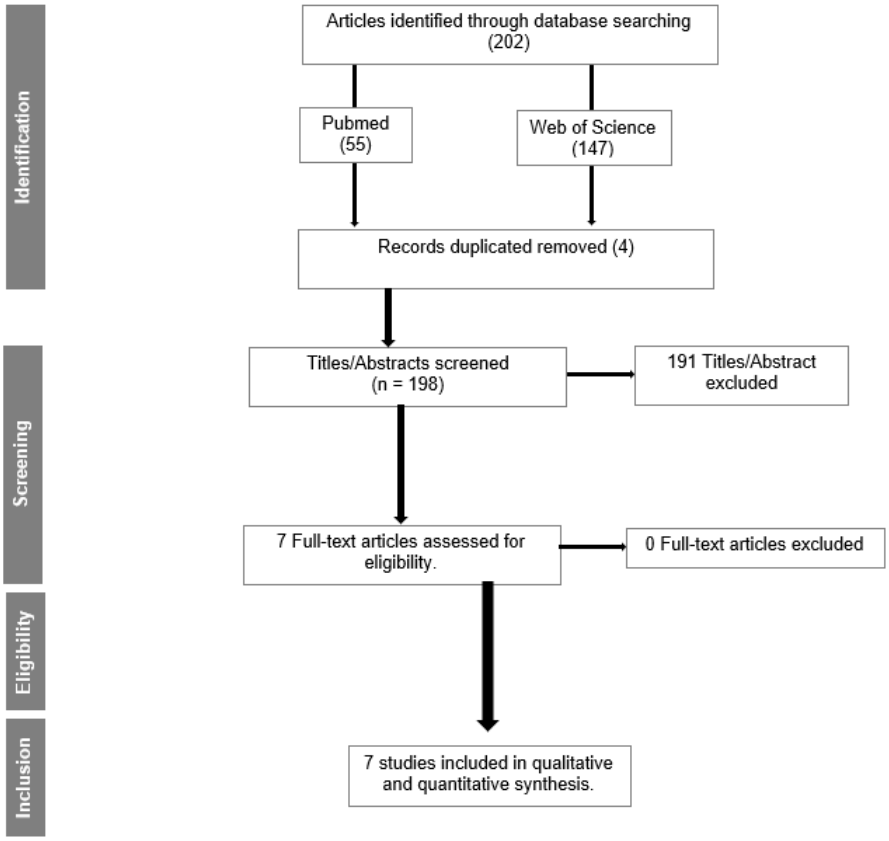

Fig 1 Flow diagram for the search strategy and selection process for included studies.

3.2. Risk of bias

Figure 2 shows the risk of bias for the RCTs included in this systematic review.

Fig 2 Risk of bias for included RCTs. Low risk (green), unclear risk (yellow) and high risk (red) of bias according to the systematic review

3.3. Study characteristics

In these 7 studies, a total of 256 patients were analyzed in the studies and there were at least 24 dropouts, because 2 studies (23,24) did not mention the dropouts. Again, not all the studies (23,24) mentioned how many males and females were included, in the rest of the studies we found 71 males and 48 females included. Regarding the number of implants evaluated, Müller et al. (25) and Al-Nawas (24) did not mention how many implants were analyzed; therefore, there were 169 zirconia implants evaluated alongside 77 titanium-zirconium implants and 166 titanium implants.

A few implants were lost during follow-up. Koller et al. (26) registered 3 implants lost (1 titanium and 2 zirconium) from a total of 31 implants placed (16 zirconium implants and 15 titanium implants). Müller et al. (25) registered 2 implants lost from an unknown total (1 titanium-zirconium and 1 titanium). Ioannidis et al. (23) did not register a single implant lost from a total of 40 implants placed (20 of each titanium-zirconium and titanium), the same was observed from Tolentino et al. (27) in a study that had 10 implants placed (5 of each titanium-zirconium and titanium). The study from Al-Nawas et al. (24) did not mention the exact number of implants that were lost, only refer that some were lost from a non-reported total. Osman et al. (15) registered a total of 31 implants lost (10 titanium and 21 zirconium) from a total of 129 implants placed (73 zirconium implants and 56 titanium implants), whereas Siddiqi et al. (28) registered 31

implants lost (10 titanium and 21 zirconium) out of 150 implants placed (80 zirconium implants and 70 titanium implants).

3.4. Smoking history

Some studies had different methods when it comes to smokers. Koller et al. (26) was the only study that did not refer any information about smokers or past smokers in the study. Osman et al. (15), Al-Nawas et al. (24) and Tolentino et al. (27) did not include patients that smoke more than 10 cigarettes a day. Ioannidis et al. (23) included patients that smoke less than 20 cigarettes a day. The only two studies that did not include smokers were by Müller et al. (25) and Siddiqi et al. (28), but Müller (25) do refer a total of 31 patients that did not have history of smoking (66%) and 16 patients that were past smokers (34%). Regarding the studies that did compare the parameters between smokers and non-smokers was from Ioannidis et al. (23) that do refer those differences were not found between the two groups.

3.5. Implant features

We classified each implant according to its diameter and configuration, it means, whether it is one-piece or two-piece implant. Some studies did not mention if they were using one or two-piece implants (24,27). Three (23,25,26) out of five other studies presented two-piece implants, whereas the remaining two studies used one-pieced implants (15,28).

Regarding the diameter, only one study (28) used narrow, regular, and wide implants both for zirconium and titanium implants (3.8mm to 5mm). Three studies (24,25,27)used narrow diameter implants (3.3mm), both for titanium and titanium-zirconium implants. The only study (23) that used regular (for titanium implants 4.1mm) and narrow diameter (for titanium-zirconium 3.3mm). Koller et al. (26) used regular diameter implants both for zirconium and titanium (4.1mm) and Osman et al. (15) placed regular and wide diameter implants both for titanium and zirconium (3.8 to 5mm).

3.6. Survival rate (SR)

Regarding the SR, the studies with 1-year follow-up were performed by Tolentino et al. (27), Al-Nawas et al. (24), and Osman et al. (15), had a SR for the titanium implants of 100% (5 implants placed), 97.8% (non-reported total) and 95.8% (56 implants placed) respectively. Therefore, for zirconium implants, only

Osman et al. (15) studied them registering a 90.9% SR (73 implants placed). The other two studies (24,27) placed titanium-zirconium implants obtaining a SR of 100% (5 implants placed) and 98.9% (unknown total), respectively. The study from Siddiqi et al. (28) had a 98.57% titanium survival rate (70 implants placed) and 91.25% zirconium survival rate (80 implants placed) over a follow-up period of 1-year.

For 3-year follow-up, Ioannidis et al. (23) registered a SR for titanium implants of 97.3% (20 implants placed) and for titanium-zirconium of 98.7% (20 implants placed). Already for the longest follow-up period performed (26), the SR obtained was 93.33% for titanium implants (15 implants placed) and 87.5% for zirconium (16 implants placed), over a period of 6 years and 8 months.

3.7. Marginal bone loss (MBL)

On the MBL parameter, all studies had mean values calculated. Koller et al. (26) registered -1.38mm and -1.17mm for zirconium and titanium implants, respectively. Müller et al. (25) shown a -0.60mm for titanium-zirconium implants and -0.61mm for titanium implants. Ioannidis et al. (23) demonstrated a -0.40mm marginal bone loss for titanium-zirconium implants and -0.31mm for titanium. Tolentino et al. (27) revealed -0.32 mm form MBL of titanium-zirconium implants and -0.35mm for titanium implants. A MBL of -0.42mm for zirconium implants and -0.18mm for titanium implants was shown by Osman's et al. (15) study. Al-Nawas et al. (24) registered a -0.34mm for titanium-zirconium implants and -0.31mm for titanium. Finally, the study from Siddiqi et al. (28) revealed a -0.25mm marginal bone loss for zirconium implants and -0.125mm for titanium implants.

3.8. Mucositis/Peri-implantitis, Bleeding on Probing (BOP), and Probing-in-Depth (PD)

Regarding mucositis and peri-implantitis, two studies (15,27) did not observe any of these two parameters. Others (24,25,26) did not mention if mucositis was present or was evaluated. There were only two studies that evaluated or mentioned the presence of mucositis, Ioannidis et al. (23) that had 10 titanium implants and 8 titanium-zirconium implants, and Siddiqi et al. (28) who mentioned that none of the implants placed had mucositis.

Peri-implantitis was evaluated by five studies. Koller et al. (26) mentioned that 1 titanium implant had to be removed due to peri-implantitis; Müller et al. (25) had 1 titanium and 1 titanium-zirconium implant with peri-implantitis; the same result was registered by Al-Nawas et al. (24). Ioannidis et al. (23) had 2 titanium-zirconium implants with peri-implantitis. Siddiqi et al. (28) did not have any implants with peri-implantitis.

Bleeding on probing (BOP) and probing-in-depth were analyze by a few studies that were included in this review. Regarding the BOP, only two out of seven studies did not mention this parameter (15,25). The BOP registered for titanium implants was 12.6% of Koller (26), 20% of Ioannidis (23), 10% of Tolentino (27). Al-Nawas (24) registered a modified BOP that evaluated the percentage of patients that had bleeding on probing and not the percentage of implants, the percentage of patients who had titanium implants and registered blood on probing was 94.5%. The study including zirconium implants that studied BOP registered a 16.43% by Koller (26). Regarding titanium-zirconium implants Ioannidis (23) registered a 13.8% BOP, Tolentino (27) registered 10% BOP. Al-Nawas (24) registered a modified BOP, that evaluated the percentage of patients that had bleeding on probing and not the percentage of implants and registered 97.7% of patients with sulcus bleeding. Already for the Siddiqi's study (28), the authors reported no significant difference for BOP between titanium and zirconia group.

Analyzing the results, only three out of the seven studies included mentioned the parameter probing-in-depth. Ioannidis (23) that registered 2.6mm for zirconium implants and 2.9 mm for titanium, while Tolentino (27) registered 3.11 mm for titanium-zirconium implants and 3.05 mm for titanium implants. Siddiqi (28) recorded 1.6 mm for titanium implants and 2.21 mm for zirconium.

Table 1 Detailed Information on Outcomes of Included Studies. Ti-Titanium/ Zr- Zirconium/ MBL- Marginal Bone Loss

Study	Number of Ti Implants	Number of Zr Implants	Survival Rate Ti	Survival Rate Zr	Mean MBL Ti	Mean MBL Zr
Osman et al. (15)	56	73	95.8%	90.9%	-0.18mm	-0.42mm
Koller et al. (26)	15	16	93.33%	87.5%	-1.17mm	-1.38mm
Siddiqi et al. (28)	70	80	98.57%	91.25%	-0.125mm	-0.25mm

Table 2 Detailed Information on Outcomes of Included Studies. Ti-Titanium/ Ti-Zr- Titanium-Zirconium/ MBL- Marginal Bone Loss

Study	Number of Ti Implants	Number of Ti-Zr Implants	Survival Rate Ti	Survival Rate Ti-Zr	Mean MBL Ti	Mean MBL Ti-Zr
Ioaniddis et al. (23)	20	20	97.3%	98.7%	-0.31mm	-0.40mm
Al-Nawas et al. (24)	NR	NR	97.8%	98.9%	-0.31mm	-0.34mm
Müller et al. (25)	NR	NR	92.6%	95.8%	-0.61mm	-0.60mm
Tolentino et al. (27)	5	5	100%	100%	-0.35mm	-0.32mm

DISCUSSION

4. DISCUSSION

The aim of this systematic review was to compare zirconia implants with the gold standard titanium implants and verify whether the behavior after loading, in order to present the best option for treatments. Moreover, it was considered titanium-zirconium implants once it has a mix of both materials, which permits to do a direct comparison. Thus, various parameters were considered to make this review such as MBL, SR, percentage of implants loss, smoking history, mucositis, peri-implantitis, BOP, and probing-in-depth.

4.1. Smoking history

In the past studies shown that smoking can be a risk factor for implant failure and complications (1), so this is an important factor to evaluate for comparison with patients that do not smoke or do not have a history with tobacco, because smoking can difficult the oral hygiene and consequently lead to complications with the implants. The results of this review do not evaluate the difference between this groups, only Müller et al. (25) do evaluate the two groups and concluded that no differences were found between patients that did not have history with smoking and patients that were past smokers. One study does not evaluate patients that did or did not smoke (26). Only one study included do not include patients that do smoke, but it did not refer if they were past smokers or not, which can alter the results of the research (28). The other studies do include patients that smoke, three of them included patients that smoke less than 10 cigarettes a day (15,24,27) and one included patients that smoke less than 20 cigarettes a day (23), but only this second one do mention that differences were not found between smokers and non-smokers.

4.2. Survival Rate

Titanium implants had a SR over 95% within 10 years of follow-up (2), which has been reported as a long-term evaluation in the literature. Therefore, 5 out of 7 studies included in this systematic review, surpassed this percentage, nonetheless, with a lower period of follow-up. The studies with 1-year follow-up (15,24,27,28) demonstrated a survival rate raging from 95.8% to 100%. After three years, it was registered (23) an equivalent value (97.3% of SR) for titanium

implants. Nevertheless, other two studies had a lower SR according to the greater period of assessment, such as Müller et al. (25) with a 92.6% for titanium implants after 5-year follow-up and Koller et al. (26) with 93.33% for 6 year and 8 months follow-up.

Compared to the SR for zirconium implants, a systematic review (29) concluded that the implants had 92% of SR after 1 year of function which is considered a low percentage according to the small period of follow-up, when compared with the results presented by Osman et al. (15), Koller et al. (26), and Siddiqi et al. (28) who had similar results, respectively, 90.9% with the same period of follow-up, 87.5% with 6-year and 8 months of follow-up, and a 91.25% over 1 year. This is also corroborated by the meta-analysis (30) who obtained a 91.5% of SR for a total of 1948 zirconium implants, therefore, with a high mean follow-up of 42.37 months.

This study also shown that other studies reported a lower SR for zirconium implants when compared to titanium. When the follow-up is increased, a lower SR is found, getting as low as 77.3% for a 7-year follow-up (31). Although two studies did not conclude a significant difference found between titanium and zirconium implants for implants loss (15,26), one concluded that titanium implants had a superior SR than zirconium (28), and the literature does conclude on the same fact, showing significant difference between them, reporting that zirconium implants have a significant lower SR when compared to titanium (30).

Regarding the SR for titanium-zirconium implants, a meta-analysis shown a mean of 97.7% within 2 years of follow-up (20), similar values found in the results of this systematic review, which present a SR as high as 100% (27) and 98.9% (24) over a year of follow-up, 98.7% over 3 years (23), and 95.8% over 5 years (25). This result showed that the titanium-zirconium implants is close to titanium implants, and has a higher SR than zirconia, which means that titanium implants are still considered with a better SR over the years when compared to both zirconium and titanium-zirconium implants. Long-term studies with higher follow-ups are needed to confirm it, but the data suggest that both titanium-zirconium and zirconium implants, especially zirconia, have a lower SR overtime when compared to the gold standard, titanium implants.

4.3. Marginal Bone Loss

Regarding the MBL on the titanium implants, it was possible to analyze that the results had a little difference between the studies. Koller et al. (26) had the highest MBL, recording -1.17mm (obtained after 6 years and 8 months), followed by Müller et al. (25) with -0.6 mm (after 5 years), and Tolentino et al. (27) with a loss of -0.35mm (after 1 year). Al-Nawas et al. (24) and Ioannidis et al. (23), respectively 1- and 3-year follow-up), both registered a MBL of -0.31 mm. The studies that had the least MBL were Osman et al. (15) and Siddiqi et al. (28), both with 1-year follow-up, respectively with -0.18mm and -0.125mm.

When it comes to the MBL of the zirconium implants, the studies showed a loss ranging from -0.67mm (33) to -0.89 mm (30). Compared with the results that was obtained in this systematic review, the numbers are in the middle range of the three studies analyzed (included zirconium implants). There were register of a MBL of -1.38 mm, -0.42 mm, and -0.25 mm, respectively, by Koller (26), Osman (15), and Siddiqi (28). These results suggest that titanium and zirconium implants did not differ concerning the MBL presented overtime, however we must have in mind that, although it was achieved a good number of titanium and zirconium implants, these studies have small follow-up period, becoming needed to confirm this data a have longer period of evaluation.

The meta-analysis performed by Altuna et al. (20) showed a MBL of -0.41mm after 2 years for titanium-zirconium implants. The results of our review did not differ significantly from those showed by Altuna (20), whereby four studies (23-25,27) showed similar numbers, such as Müller et al. (25), Ioannidis et al. (23), Al-Nawas et al. (24), and Tolentino et al. (27) with MBL of -0.60 mm, -0.40 mm, -0.34 mm and -0.32 mm respectively.

Whereas other studies showed a higher value for MBL, mainly Badran et al. (33) who registered -0.7 mm. These results for titanium-zirconium implants showed similar MBL compared to titanium and zirconium implants, which was also demonstrated by other studies in the literature (31,33). It must highlight there was a few numbers of titanium-zirconium implants evaluated which this is an obstacle that affects the outcome of this systematic studies.

4.4. Mucositis/Peri-implantitis

Regarding the biological complications involving mucositis and peri-implantitis, a few studies mentioned them. Only two studies evaluated the presence of mucositis. Ioannidis et al. (23) recorded 10 titanium implants with mucositis from a total of 20 titanium implants (50%) and 8 titanium-zirconium implants out of 20 placed (40%); Siddiqi et al. (28) did not find any cases of mucositis of 80 zirconium implants and 70 titanium. Those results may be an indicative that zirconium implants have a low prevalence of mucositis because of the lower bacterial affinity (10) when compared to titanium. The studies, which did not mention any evaluation of the presence of mucositis, showed a limitation on the data gathered (15,24,25,26,27).

Regarding peri-implantitis, only two studies included did not evaluate this parameter (15,27). Others recorded very low incidence of peri-implantitis, only having one or two implants affected (23,24,25,26). The only study did not have any incidence of peri-implantitis (28).

4.5. Bleeding on Probing (BOP) and Probing in Depth (PD)

Analyzing the result for BOP and PD, it was possible to observe that only a few studies demonstrate these characteristics. Regarding the BOP, it cannot conclude whether titanium, zirconium, or titanium-zirconium implants have a higher or lower BOP matched, once the sample size was small. Al-Nawas (24) did not analyze the BOP of the implants, conversely, only showed the percentage of patients that had bleeding while probing procedure (94.5% for titanium group and 97.7% for titanium-zirconium group). Siddiqi (28) mentioned a general bleeding index that evaluated maxilla or mandible and not implant bleeding.

Evaluating PD, it cannot conclude which one has had a better result because the sample size was too small to evaluate. However, the PD of titanium, zirconium, and titanium-zirconium implants seem to be similar.

4.6. Study Limitations

This review does present some limitations because of a low number of studies that do compare the implants. Some limitations were faced on the meta-analyzes because of the different periods of follow-up, due to be only included

RCT studies which is the best type of clinical study as initially designed, and the low number of studies comparing zirconia, titanium implants and titanium, titanium-zirconium implants.

CONCLUSION

5. CONCLUSION

Within the limitations of this systematic review, it was possible to conclude that all types of implants analyzed show similar results for all parameters evaluated comparing soft and hard tissue response and behavior, suggesting that all types of implants are viable and a reliable treatment alternative. Therefore, the survival rate of zirconia implants when compared to titanium and titanium-zirconium implants, showed a lower survival rate. Nevertheless, it must notice that, there was a large difference for the follow-up period among the studies which difficult long-term evaluation and efficacy. Moreover, more clinical studies are needed comparing these materials to corroborate all the data analyzed.

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Supplementary Table 1 – Search strategy carried out and filters applied.		
	MEDLINE (PubMed)	Web of Science (WoS)
	P – Fully or partially edentulous patients treated with dental implants	
#1	(("Dental Implants" [MeSH Terms]) OR (Dental Implant† [Supplementary Concept]))	'tooth implantation' OR 'tooth implant' OR 'dental implant' OR 'dental implants'
	I – Rehabilitation with zirconia dental implants	
#2	(("Zirconium" [MeSH Terms]) OR (Zirconium Oxide [Supplementary Concept]) OR (Zirconia [Supplementary Concept]) OR (Yttria Stabilized Tetragonal Zirconia [Supplementary Concept]) OR ("Ceramics" [MeSH Terms]))	'zirconium oxide' OR 'zirconium' OR 'ceramics' OR 'yttria stabilized tetragonal zirconia'
#3	**C – Rehabilitation with titanium dental implants or titanium-zirconia**	
#4	**O – Clinical outcomes (survival rate, success rate, marginal bone loss, and osseointegration level)**	
#5	**T – At least 6 months**	
	(#1 AND #2)	
Search Combination	No combination was done with **#3**, and **#4**, since most of the papers on dental implants are about titanium, and the combination with keywords related to outcome would limit even more the search. Item **#5** was manually evaluated.	
Filters	English, Humans, 10 years	

† is a truncation symbol to retrieve terms with a common root within the database