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Survival and Complication Rates of Zirconia Ceramic Single Crowns: A Systematic Review

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Abstract

Zirconia-based implants have become well-documented during the last few years, and their outcomes have been reported to be equal to the ones of metal abutments. However, to date, there is no high-level evidence suggesting its superiority over the classic metal-ceramic restorations. Therefore, we conducted the current investigation to systematically review all of the available literature regarding the use of zirconia-based, implant-supported single crowns in edentulous patients with at least 1 year of observation. Finally, we included 15 studies in this systematic review. Following 5 years of observation and follow-up, this review summarized that the 5-year survival rate of zirconia-based bilayers reached 92.0%, ranging from 67.4% to 100%. Moreover, a total of 26 implant failures were encountered, with incidences ranging from zero to 8 failures in the whole cohort. We noted that only a minimal number of zirconia single crowns (SCs) had biological complications over the follow-up period. In terms of technical complications, we noted that the majority of included studies in our review reported technical complications related to zirconia SCs over the observation period. The overall occurrence of technical complications ranged from a single occurrence (out of 19 zirconia SCs) to 17 (out of 148 zirconia SCs). In our study, three studies reported the occurrence of chipping of the veneering ceramic in 5.9%, 3.3%, and 45.5% of examined zirconia SCs, respectively. In one study, the prevalence rate of occlusal roughness was 3.1%, while in the other study it reached as high as 87.5%. In conclusion, Zirconia-based implant-supported single crowns offer a very good alternative to current treatment protocols, with very high 5-year survival rates.

Keywords: *Zirconia; Single Crown; Survival; Complications*

Introduction

The management of single-tooth gaps through the use of implant-supported restorations has become widely-established during the past few years as the most preferred management approach. The major advantage of this approach lies in the conservation of healthy ad-

jacent tooth structure. To date, the standard protocol in this regard involves the use of metal-ceramic crowns. In clinical practice, crowns are both screw-retained or cement-retained [1-3].

All-ceramic crowns have gained a significant amount of attention in recent years due to their high biocompatibility in addition to their potential aesthetic advantages. Clinically, tooth-supported, all-ceramic crowns have shown impressive results in this regard. In a previous review of 34 studies, Pjetursson., *et al*. [4] reported very high, but material-dependent 5-year survival rates of all-ceramic crowns ranging from 87.5% (simple glass-ceramic) to as high as 96.4% (densely sintered aluminum oxide ceramic. However, higher masticatory forces, which occasionally occur with implant-supported restoration [5] limited the use of such materials in implant prosthetics. The material technology properties of fracture toughness, as well as fracture resistance, are not adequate, especially when it is used in the posterior region. The introduction of zirconia as a framework material would help overcome this problem. Zirconia characteristics that are of great interest are its high flexural strength and its high fracture strength, which are unprecedented for a brittle ceramic [6].

Despite the fact that available data, based on basic clinical research, on zirconia revealed promising mechanical properties of this material with a safe application [7,8], it is still not certain whether or not zirconia-based ceramic restorations are a valid alternative to the classic metal-ceramic. In recent years, two systematic reviews have been conducted to investigate the outcomes of implant-supported single crowns (SCs) and fixed dental prostheses (FDPs), without focusing on the variations between all-ceramic and metal-ceramics, but rather on outcomes of great significance such as the survival rate and the frequency of encountered complications [9,10]. The review of Jung., *et al*. [9] reported a 5-year survival rate of 96.3% for implant-supported SCs. Meanwhile, the 5-year rate of various technical complications was noted to be 8.8% for screw loosening, 4.1% for loss of retention, and 3.5% for 'chipping of the veneering ceramic', with a 5-year complication rate of 7.1% for aesthetic complications. More recently, a meta-analysis of zirconia-based SCs reported a relatively higher 5-year survival rate of 97.6%, which was higher in restorations in the posterior region (98.6%). In the same context, the previous review reported an overall 5-year complication rate of 16.2%: 9.6% for biological complications, 6.2% for technical complications, and 0% aesthetic complications [11].

Zirconia-based implants have become well-documented during the last few years, and their outcomes have been reported to be equal to the ones of metal abutments [12]. However, to date, there is no high-level evidence suggesting its superiority over the classic metal-ceramic restorations. Therefore, we conducted the current investigation to systematically review all of the available literature regarding the use of zirconia-based, implant-supported single crowns in edentulous patients with at least 1 year of observation. We aimed to determine the outcomes of zirconia SCs in terms of survival rate and complication rates.

Methods

Search strategy and study selection

The study process was conducted following the accepted methodology recommendations of the PRISMA checklist for systematic review [13]. A systematic electronic database search was conducted for relevant studies published from inception till 2nd July 2020 in seven databases including Google Scholar, Scopus, Web of Science (ISI), PubMed, Cochrane Central Register of Controlled Trials (CENTRAL), Embase and CINAHL using keywords, medical subject (MeSH) terms. In databases not supporting MeSH terms, combinations of all possible terms were used. Moreover, We conducted a manual search of references from the included articles by searching the primary studies that had cited our included papers and scanning references of the relevant papers in PubMed and Google Scholar to avoid missing any relevant publications [14].

We included all original relevant studies which are discussing survival and complication rates of zirconia ceramic single crowns. Papers were excluded if there was one of the following exclusion criteria: pilot studies, duplicate records, data could not be reliably extracted or incomplete reports, abstract only articles, thesis, books, conference papers. Title and abstract screening were done independently by

four reviewers. Then, three independent reviewers performed a full-text screening to ensure the inclusion of relevant papers in our systematic review. Any disagreement was resolved by discussion and referring to the senior author when necessary.

Data extraction

Two authors developed the data extraction sheet using the Microsoft Excel software. Data extraction was performed by three independent reviewers using the excel sheet. The fourth independent reviewer performed data checking to ensure the extracted data accuracy. All the disagreements and discrepancies were resolved by discussion and consultation with the senior author when necessary.

Risk of bias

Three independent reviewers evaluated the risk of bias in included studies. For non-randomized trials, the risk of bias in non-randomized studies - of interventions (ROBINS-I) was used to assess the quality of each included study [15]. For randomized controlled trails, Cochrane's revised quality assessment tool (RoB 2) was used to determine the quality of the included studies [16]. Any discrepancy between the reviewers was solved by discussion.

Results and Discussion

Search results

We identified 634 relative records after excluding of 113 duplicates using the Endnote software version X9. Title and abstract screening resulted in 37 records for further full-text screening. No papers were added after performing manual search trials. Finally, we included 15 studies in this systematic review (Figure 1).

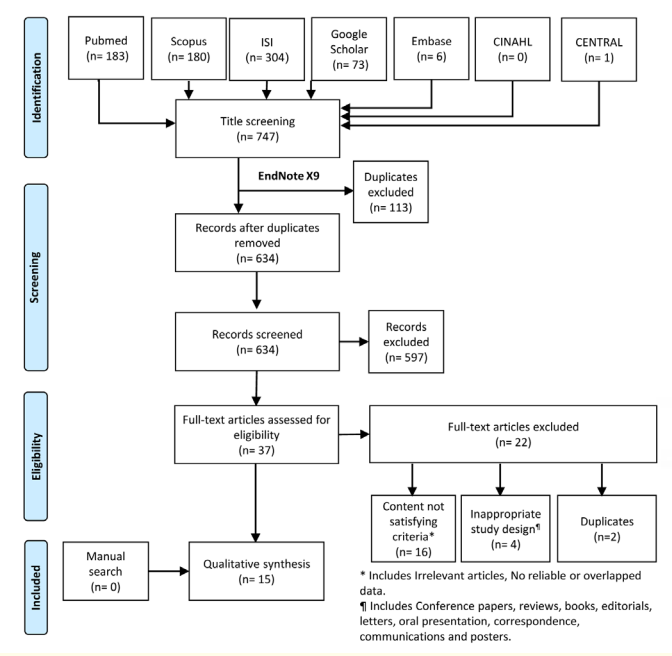

Figure 1: *PRISMA flow diagram showing the process of the review.*

Study characteristics and risk of bias

Nearly all of the included studies (14/15) were observational studies; seven were of prospective study design [17-23] and the other seven were of retrospective one [24-27]. Only one study was designed as a randomized controlled trial. The sample size of all studies was 1944 patients; ranging from 24 to 1159 patients, among different studies. Moreover, the average male percentage was 45%, ranging from 29.6% to 56.25%. The mean ages were also variables across different study populations, ranging from 20.5 years and up to 65.6 years. Furthermore, the last follow up point of the included patients ranged from 3 years and up to 8 years (Table 1).

Author, year	Country	Design	Sample size	Male %	Age mean (SD)	Follow-up (years)	Aim	Conclusion
Balmar, 2020 [17]	Germany and Switzerland	Prospective	60	50	48.1 (±13)	5	To evaluate the clinical and radiological outcomes of one-piece zirconia implants restored with single crowns (SCs) or fixed dental prostheses (FDPs) over an observation period of 5 years in function.	The investigated one-piece zirconia implant showed a high survival rate, very stable marginal bone and mucosal margin levels after 5 years in function. Therefore, it can be considered safe and reliable for the reconstruction of implant-supported SCs or FDPs over a mid-term period
Branzen, 2015 [24]	Sweden	Retrospective	36	47.2	20.5 (±6.2)	Range: 4 to 9	To evaluate the 5-year survival of implants and implant-supported crowns (ISCs) and to assess the functional and aesthetic outcomes from the professional and patient perspectives	One-third of the patients wished for the replacement of their ISCs. Soft tissue adaptation seems to be an important factor for overall satisfaction
Chen, 2019 [25]	Taiwan	Retrospective	32	56.25	Median age 36.2 years with a range 20 to 58 years	6	To assess the six year clinical performance of zirconia abutments supporting all-ceramic crowns in anterior and premolar regions	Zirconia abutments supporting all-ceramic crowns demonstrated high survival rate, good biological and esthetic results. While some technical complications were frequently observed, the complication-free rates were 96.8% for abutments and 81.2% for crowns in the medium-term observation period

De Angelis, 2019 [26]	Italy	Retrospective	38	44.7	65.6 (±7.3)	3	To compare the clinical outcomes of 2 types of implant-supported crown used to replace a single missing posterior tooth in a completely digital workflow: transocclusal screw-retained monolithic lithium disilicate crowns versus transocclusal screw-retained monolithic zirconia crowns.	
Guncu, 2016 [18]	Turkey	Prospective	24	41.7	44.1 (± 11.4)	4	To evaluate the 4-year clinical performance of tooth versus implant-supported single-unit zirconia crowns (LAVA™) placed on posterior region.	Single-unit implant or tooth-supported zirconia crowns may be considered acceptable treatment modalities for restoration of either missing or compromised posterior teeth
Hosseini, 2013 [19]	Denmark	Prospective	59	40.7	27.9 (±9.3)	3	To describe outcome variables of all-ceramic and metal-ceramic implant-supported, single-tooth restorations	The biological outcomes at the zirconia and metal abutments were comparable. Allceramic crowns demonstrated better colour match, but higher frequency of marginal discrepancy compared to metal-ceramic crowns. Generally, the patients noticed no difference in aesthetic outcome of all-ceramic and metal-ceramic restorations
Kolgeci, 2014 [20]	Switzerland	Prospective	127	40.2	62.5 (±13.4)	Up to 7	To evaluate technical complications and failures of zirconia-based fixed prostheses supported by implants	Zirconia-based prostheses screwed directly to implants are clinically successful in the short and medium term

Lops, 2013 [21]	Italy	Prospective	85	44.7	54	5	To verify, in a medium-term follow-up, whether or not zirconia (Zr) abutments show similar survival outcomes as titanium (Ti) abutments in posterior areas.	The medium-term survival of Zr abutments in posterior regions was comparable with that of Ti abutments. Long-term evaluations are needed to confirm this finding.
Miura, 2017 [27]	Japan	Retrospective	62	NA	51.4 (range 18-84)	12	To investigate the incidence of clinical complications with tooth-supported zirconia-based all-ceramic single crowns and identify pertinent risk parameters.	Treatment with zirconia-based all-ceramic crowns for molar teeth with metal antagonist occlusion should be undertaken with caution.
Monaco, 2017 [31]	Italy	Randomized controlled trial	72	45.8	18-70	5	To compare the longevity and clinical behavior of single posterior crowns made with pressable ceramic on zirconia and on metal frameworks, and if failures occur, to delineate the contributing factors.	The present randomized controlled trial shows that the survival of zirconia-based and metal-based single crowns is similar over a follow-up period of 5 years. No significant differences in esthetic, functional and biological outcomes were demonstrated between the two groups. The main failure mode was the chipping fracture of the veneering ceramic in both materials
Nothdurft, 2014 [22]	Germany	Prospective	24	NA	NA	3	To assess the clinical performance of a prefabricated zirconium dioxide implant abutment for single-tooth replacement in the posterior region.	The use of zirconia abutments in this study lead to mainly healthy peri-implant hard and soft tissue conditions but, considering the observed failures after 3 years in function, clinical long-term results should be awaited before recommending full zirconia implant abutments in a posterior indication.

Spies, 2019 [23]	Germany and Switzerland	Prospective	44	43.2	46.6 (± 13.1)	5	To assess survival/success rates and patient-reported outcome of zirconia- based posterior single crowns (SCs) supported by zirconia implants in a prospective two-center study after five years of observation	Veneered zirconia-based SCs supported by zirconia implants showed high survival rates and highly satisfied patients' needs. However, significant incidence of technical complications is compromising the clinical long-term outcome for this indication.
Tanner, 2014 [28]	Finland	Retrospective	27	29.6	64.6	Up to 8	To evaluate the survival and the occurrence of technical and biological complications of zirconia crowns and fixed dental prostheses made in the student clinic of Turku University, Finland, between April 2009 and September 2017.	Zirconia crowns and FDPs survived well in this retrospective follow-up study. Chipping of veneering ceramic and bleeding on probing were the most common complications. Thick connector areas made according to material demands resulted in insufficient embrasure spaces and inflammation of marginal gingiva.
Vigolo, 2016 [30]	Italy	Retrospective	1,159	41.9	49.6 (±13.0)	5	To evaluate the 5-year clinical results for a large number of single implants restored by certified prosthodontists in an attempt to establish whether different clinical outcomes could be detected for external- or internal-connection implants.	Within the limitations of this study, it can be suggested that there is no difference in clinical outcomes of single restorations joined to internal- or external-connection implants
Worni, 2015 [29]	Switzerland	Retrospective	95	54.74	59.1 (±11.7)	5	To evaluate technical problems and failures of implant-supported zirconia-based prostheses with exclusive screw retention.	This study shows that zirconia-based implant-supported fixed prostheses exhibit satisfactory treatment outcomes and that screw-retention directly at the implant level is feasible.

Table 1: *Characteristics of the included studies.*
SD: Standard Deviation.

For the 14 included observational studies, none of them did show a critical risk of bias, four studies showed a low risk of bias [17,23,26,27], five studies showed a moderate risk of bias [20,21,24,28,29], and five studies showed a serious risk of bias [18,19,22,25,30]. The highest risk of bias was related to deviations from intended intervention, missing data, and cofounding, mostly due to their study design (Figure 2). For the one randomized controlled trial [31], it showed an overall low risk of bias, with only some concerns regarding the selection of the reported results.

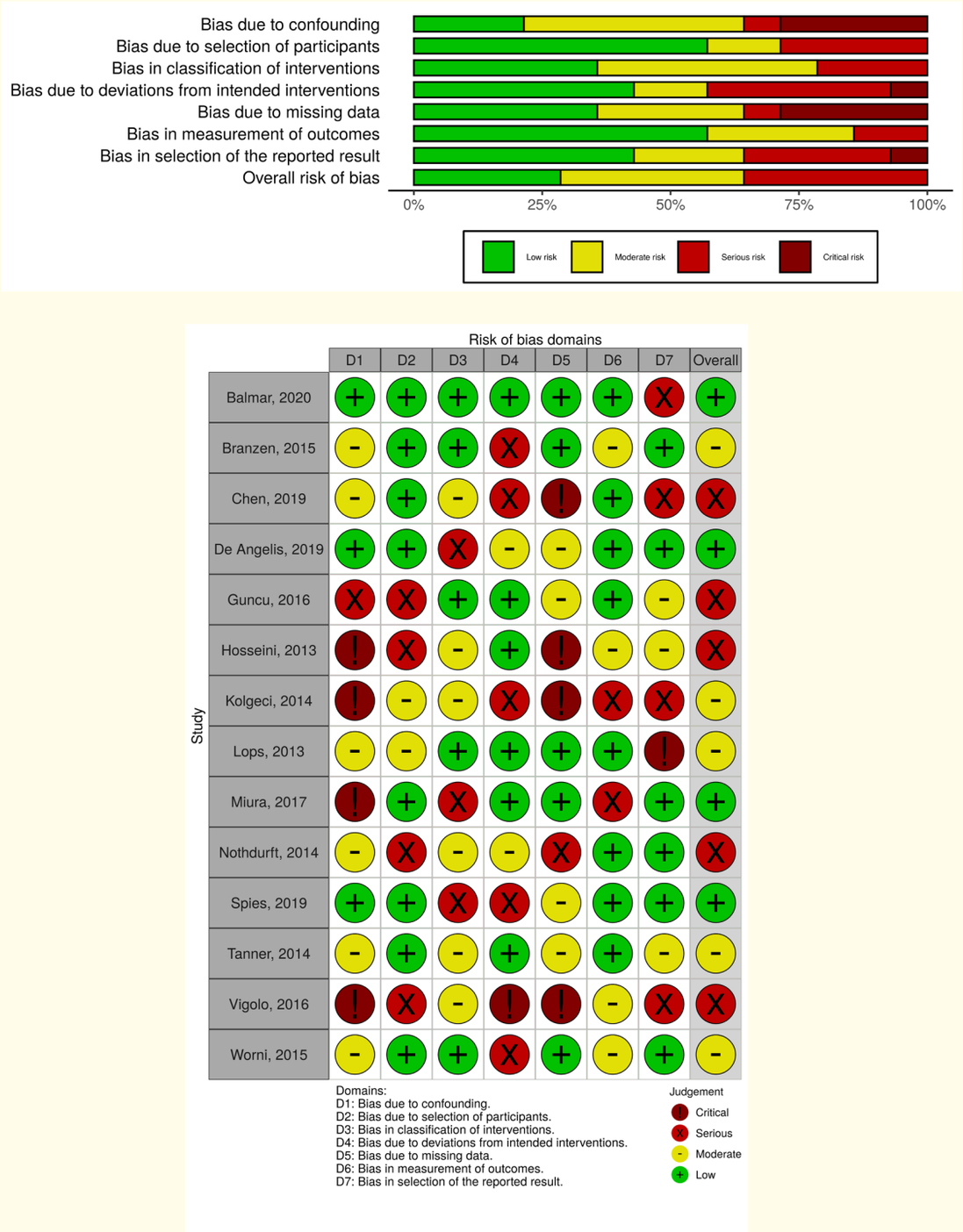

Figure 2: *Quality of the included studies. A: Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies; B: Risk of bias summary: review authors' judgements about each risk of bias item for each included study.*

Survival and complication rates

Despite the fact that many research studies reported the long-term survival rate and complications of zirconia-based FDPs [32-34] however, the number of available reports describing the long-term outcomes of zirconia-based single crowns (SCs) is scarce. Therefore, we conducted the current investigation to systematically review all of the available literature reporting the long-term survival rate and complications of zirconia-based SCs implants in edentulous patients after 1 year of placement. Herein, we will report the estimated 5-year survival rates and complication rates of zirconia-ceramic, implant-supported SCs.

Zirconia-based crowns are known as a well-established all-ceramic alternative to metal-ceramic crowns on either implants and teeth in clinical practice nowadays. At either instance, zirconia-based crowns have shown relatively optimum 5-year survival rates [8,35]. Recently, a systematic review and meta-analysis were published in 2018, critiquing the available evidence regarding implant-supported all-ceramic single crowns. This review revealed that veneered zirconia SCs can still be the utmost stakeholder for all-ceramic implant-supported alternative of a single missing tooth [36]. Following 5 years of observation and follow-up, this review summarized that the 5-year survival rate of zirconia-based bilayers reached 92.0%, ranging from 67.4% [37] to 100% [38,39]. This finding indicated that the survival of the current SCs is above average. In the same context, another systematic review and meta-analysis were conducted on eight studies investigating the survival of 912 zirconia-based SCs, with a mean follow-up period of 5.1 years. This meta-analysis reached even a higher 5-year survival rate of 97.6% (95% CI = 94.3 - 99%) and concluded that zirconia is a good all-ceramic restorative option for SCs in anterior and posterior regions. In our review, we included a total of fifteen studies reporting the 5-year survival rate of zirconia-based SCs, and going in line with the aforementioned observations, we noted that the 5-year survival rate of zirconia SCs ranged from 89.9% [18] to 100% [21,24,25]. That being said, the 5-year survival rate could potentially be influenced by the position of the zirconia-based ceramic implant. In the previous review of Pjetursson., *et al*. [11] the authors reported that posteriorly-positioned zirconia-based ceramic implants had superior outcome in terms of 5-year survival rate compared to anteriorly-positioned ones, with a rate of 98.6% vs. 97.7%. However, the difference between both groups is slight and would not affect the overall performance and efficacy of zirconia SCs.

In our study, a total of 26 implant failures were encountered, with incidences ranging from 0 [21,24,25] to 8 failures in the whole cohort [30]. The exact reasons for zirconia SCs failure are not clearly described in the included studies. However, in general, the reasons for failure include technical and biological complications, extensive ceramic veneering fracture, endodontic failure, periodontal lesion, root or tooth fracture, change of prosthetic treatment, and peri-implantitis [40]. In terms of complications, there were three main categories of complications reported in the literature: technical complications, biological complications, and aesthetic complications. Noteworthy, there were no standardized definition criteria of these complication categories. For example, in some studies, technical complications were identified when the zirconia-based SCs had one of the following issues: abutment screw loosening, veneering ceramic chipping, occlusal roughness, and crown loosening [25] while in other studies, both root and abutment fractures were considered as parts of biological complications [27]. Therefore, there should be a clear definition criterion of each complication category in the literature that would help identify which complication goes under which category in order to properly examine the outcomes of zirconia-based SC implants.

In terms of aesthetic complications, in our review, none of the zirconia-based SCs had to be redone secondary to aesthetic complications, with no aesthetic complications in all thirteen included reports. This goes in line with the previous meta-analysis of zirconia-based crowns, which reported no aesthetic complications in the eight analyzed studies [11].

As regards biological complications, zirconia-based implants have been reported to have a low plaque accumulation rate [41,42] with excellent integration of both hard and soft tissue [43]. Consistently, in our study, we noted that only a minimal number of zirconia SCs had biological complications over the follow-up period. In the previously mentioned meta-analysis, the 5-year complication rate of both soft tissue complications and significant marginal bone loss was 5.3% and 4.3%, respectively. In the same context, the rate of biological complications in our study was low, with only 4 cases of biological complications (3 root fractures and 1 abutment fracture [27]. However,

as previously mentioned, abutment and root fractures should be identified as technical complications and not as biological complications, as the authors of this study clarified.

In terms of technical complications, we noted that the majority of included studies in our review reported technical complications related to zirconia SCs over the observation period. The overall occurrence of technical complications ranged from a single occurrence (out of 19 zirconia SCs) [26] to 17 (out of 148 zirconia SCs) [27]. In our study, three studies reported the occurrence of chipping of the veneering ceramic in 2 (5.9%), 3 (3.3%), and 19 (45.5%) of examined zirconia SCs, respectively. Moreover, it was previously reported that the 5-year rate of ceramic fracture or chipping was 2.8% [11]. Meanwhile, chipping of the veneering ceramic, to date, is still a frequently reported complication of zirconia-based ceramic reconstruction in the literature [44]. During the primary applications of zirconia as framework material, the occurring of chipping was due to the fact that prototype veneering ceramics were utilized [45]. Later on, low-fusing veneering ceramics that were particularly-designed and adapted to the biomechanical properties of zirconia were introduced, and then the technical procedure of veneering zirconia was adjusted [46]. The issue of chipping of zirconia-based ceramic SCs still persists as the most commonly encountered technical complication, even in recently-published studies. In addition to material-related factors, a wide range of clinical factors may contribute to the risk of chipping of the veneering ceramic. It was shown that a combination of certain oral conditions such as temperature and pH alterations [47] and material defects as a result of the veneering procedure could increase the risk of chipping [48]. That being said, monolithic reconstruction provides a promising alternative to the bi-layer zirconia SCs [49]. A clearly recognized increase in the application of monolithic zirconia, implant-supported crowns can already be identified. Even though we aimed to analyze the outcomes of monolithic zirconia-based SCs after a minimal observation period of 3 years; however, only one study (out of the 13 included studies) examined monolithic zirconia implants [26]. In this particular study, a total of 19 monolithic zirconia implant-supported SCs were examined, and only one zirconia SC had a technical complication (abutment screw loosening). Nevertheless, more long-term clinical studies are still warranted in this regard before clinical recommendations can be applied.

Some technical complications were not frequently reported in the literature, and therefore, it was not thoroughly analyzed in this review. For example, occlusal roughness was studied in only two cohort studies. In one study, the prevalence rate of occlusal roughness was 3.1% [25] while in the other study it reached as high as 87.5% (35/40 of zirconia SCs) [23]. This highly-noted difference in the occurrence rate could be explained by the incorporation of several reasons for increased roughness, including a crystalline phase over time in the oral cavity such ass tooth-brushing [50] environmental condition [51] abrasions during mastication [52] or attrition secondary to antagonistic wear [53].

We have encountered several limitations upon conducting this systematic review, the most important of which is the clear lack of randomized controlled clinical trials investigating the survival and complications of zirconia-based implant-supported SCs. Among the fifteen included studies, 7 were prospective cohort studies [17-23] 6 were retrospective cohort studies [24-26,28-30] 1 was a retrospective clinical study [27] and 1 was a randomized clinical trial [31]. Secondly, the absence of a control group made it difficult to reach a conclusion about the superiority or inferiority over monolithic treatment protocols in the restoration of zirconia-based implants. Moreover, our results are based on the pooled data presented in included studies of various types of implants that are placed in different positions in the jaw (maxilla vs mandible; anterior vs posterior), and the lack of stratification of these data based on the position made it difficult to determine if the outcomes would have been affected based on their location. Another critical point is the clear lack of a standardized approach to report biological and technical complications in the current literature. This made it difficult to determine the most frequent type of complication encountered in zirconia-based SCs as some studies defined root and abutment fractures as biological and not technical complications [27].

Conclusion

Zirconia-based implant-supported single crowns offer a very good alternative to current treatment protocols, with very high 5-year survival rates. The number of failures associated with zirconia-based SCs is limited. However, 'chipping of the veneering ceramic' is the

predominantly encountered technical complication in bi-layered zirconia-based single crowns. Contemporary types of monolithic zirconia frameworks would be a valuable option in this regard; yet, long-term clinical studies investigating the outcomes of monolithic zirconia-based restorations are still warranted to reach a definitive conclusion.

Funding

None.

Conflicts of Interest

No conflicts related to this work.

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