

## Review Article

# Evaluation of all-ceramic and metal-ceramic fixed dental prostheses: a meta-analysis of randomized controlled trials

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**Abstract:** To systematically review the randomized controlled trials (RCTs) and compare the survival rates and complications of all-ceramic fixed dental prostheses (FDPs) with those of metal-ceramic FDPs. Eligible studies were retrieved in relevant electronic databases from their inception to June 8<sup>th</sup>, 2016. Then, quality of the included studies was assessed using Cochrane Collaboration's tool. Heterogeneity across the studies was determined based on Cochrane Q and I<sup>2</sup> statistic. Risk ratios (RR) and its 95% confidence intervals (CIs) were used as a measure of effect size to pool outcomes. A total of 7 RCTs with 350 participants (178 applied all-ceramic FDPs and 172 applied metal-ceramic FDPs) were included in this study. The low risk bias of all included studies suggested high qualities. As a result, all-ceramic FDPs showed a comparable survival rate and copings fracture frequency with those of metal-ceramic FDPs. Although without significance ( $P > 0.05$ ), all-ceramic FDPs had higher occurrences of crowns replacement (RR = 3.20, 95% CI, 0.54 to 18.97), veneering ceramic chipping (RR = 1.87, 95% CI, 0.94 to 3.72) and rough surface (RR = 3.33, 95% CI, 0.98 to 11.35) than metal-ceramic FDPs. It is suggested that all-ceramic FDPs have similar high survival rate and low copings fracture frequency as metal-ceramic FDPs. However, occurrences of other complications, ceramic veneer chipping fractures, crown replacement and rough surface, might be higher in all-ceramic FDPs than metal-ceramic. The alternative use of all-ceramic FDPs should be cautious. More RCTs with large samples are needed to confirm these findings.

**Keywords:** Fixed dental prostheses, all-ceramic, metal-ceramic, survival, complication, meta-analysis

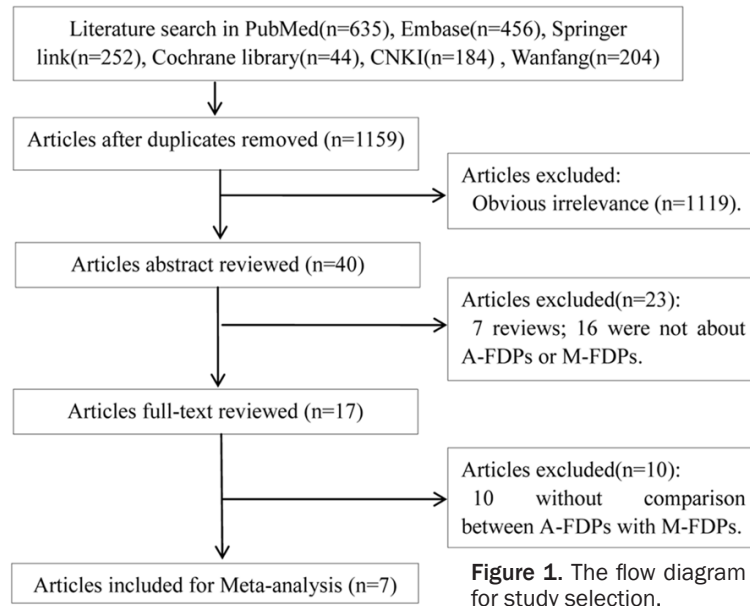
## Introduction

All-ceramic fixed dental prostheses (FDPs) have become popular in recent years because of the increasing demand of esthetics and metal-free materials. In addition, the good biocompatibility makes all-ceramic crowns successfully used in the anterior and posterior segments [1-4]. Although all-ceramic systems have poor mechanical properties compared with metal-ceramic FDPs, several all-ceramic FDPs such as zirconia-based FDP belong to the high-strength ceramic materials. Reportedly, all-ceramic FDPs have the same long-lasting restorations like metal-ceramics [5-7]. Moreover, zirconia-based FDPs have relatively high survival rate (more than 90%, even 100%) after the follow-up time of more than three years [8-11]. Therefore, all-ceramic FDPs have been proposed as alternatives for metal-ceramic

FDPs. However, other studies hold the opposite opinion that all-ceramic FDPs have the limitations. For instance, when applying zirconia-based FDPs, frequency of veneering porcelain chipping might be high and zirconia might be degraded under moist oral environment, which might cause decreased effects [12, 13].

Therefore, several systematic reviews and meta-analyses have been carried out to obtain more reliable results. In a systematic review assessing the efficacy of zirconia-based FDP, the short-term (3 years) data indicate that zirconia-based FDP has low complications but high survival rate, suggesting it could be used as a replacement of metal-ceramic FDP [14]. However, only one of the 12 included studies is randomized clinical study, while others are cohort prospective studies. Thus the evidence might be insufficient and unreliable. A previous meta-

## Meta-analysis of all- and metal-ceramic FDPs



analysis showed that all-ceramic FDPs had a significantly lower 5-year survival rate, but higher frequencies of material fractures than metal-ceramic FDPs. Meanwhile, other technical complications such as loss of retention and biological complications were comparable between the two restorations [15]. Though this meta-analysis applied strict inclusions and assessed multiple outcomes, the included 9 studies were non-randomized controlled trials (RCTs). Additionally, the average follow-up time in the two different methods were quite different (all-ceramic FDP: 3.8 year; metal-ceramic FDP: 8 year), and the authors assumed that annual event rate was constant throughout the follow up time. This might cause bias of the results. Moreover, it was published newly ten years ago, and data needs to be updated. More recently, a meta-analysis includes 40 studies published from 2007 to 2013 to evaluate the 5-year survival rate and incidence of biological, technical and esthetic complications of all-ceramic tooth-supported FDPs, compared with meta-ceramic FDPs [16]. However, like Sailer's study, one major limitation is the assumption of the constant annual event rate for all-ceramic FDPs. In addition, only four of the included studies were RCTs and the remaining were prospective and retrospective cohort studies or case series. Moreover, outcomes of copings fracture, crowns replacement rate and rough surface were not assessed.

Therefore, we performed this meta-analysis, and more importantly, included only RCTs, to comprehensively evaluate the survival rate, copings fracture, chipping of the veneering ceramic, crowns replacement rate and rough surface of all-ceramic FDPs, by the comparison with meta-ceramic FDPs.

### Methods

#### Search strategy

Literature retrieval was conducted in PubMed, Embase, The Cochrane library, Springer link and several Chinese databases such as Wanfang (<http://www.wanfangdata.com.cn/>) and Chinese National Knowledge

Infrastructure (CNKI, <http://www.cnki.net/>) up to June 8<sup>th</sup>, 2016, without language restriction. The search terms were “ceramics” or “ceramic” and “fixed partial dentures” or “fixed dental prostheses” and “test” or “comparison” or “compare”. In order to obtain more relevant studies, manual search was carried out for articles in paper edition, and the bibliographies of relevant studies were also scanned.

#### Inclusion and exclusion criteria

The following studies were included: (1) they were RCTs; (2) the study objects were patients who received FDPs; (3) the study compared outcomes between all-ceramic FDPs and metal-ceramic FDPs; (4) the study involved outcomes as survival rate, rough surface, copings fractured, chipping of the veneering ceramic and crowns replacement rate.

The following studies were excluded: (1) non-RCTs; (2) the study provided incomplete data or unanalyzable outcomes; (3) the studies were reviews, letters and reports.

#### Data extraction and quality assessment

After the eligible studies were selected, two investigators independently extracted the required data using a predefined standard form. The following information was extracted: first author name, publication year, gender, sample sizes in each group (all-ceramic FDPs and

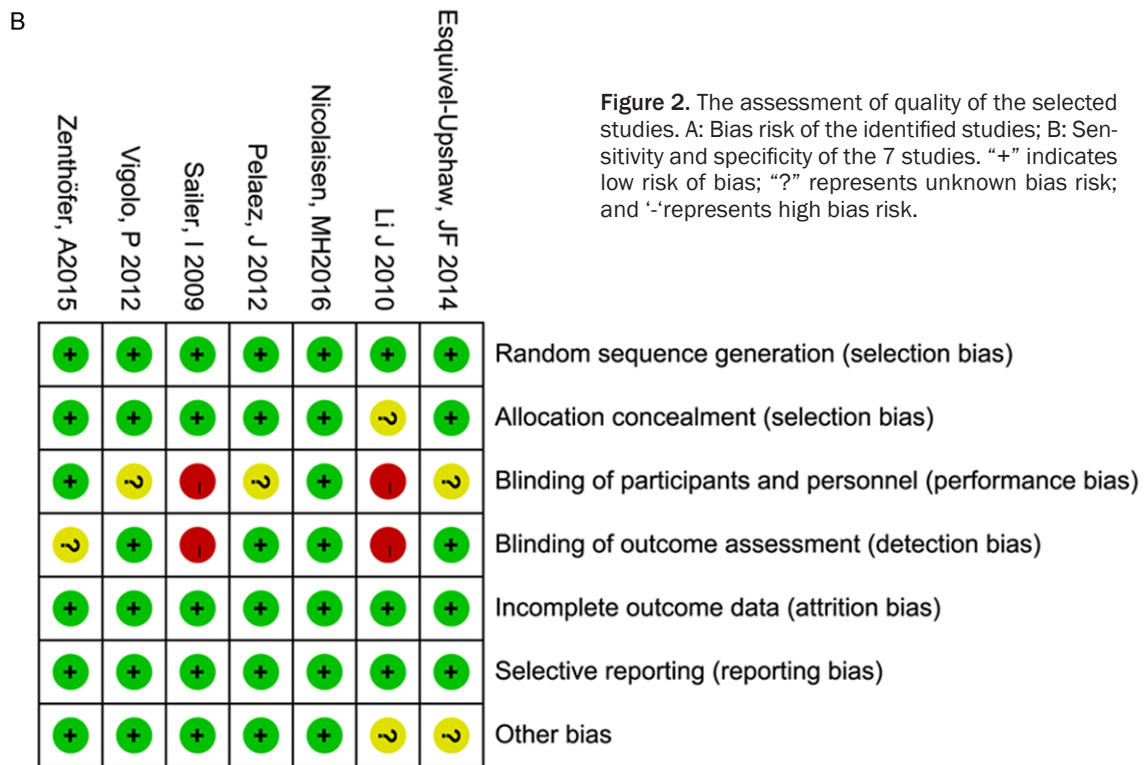
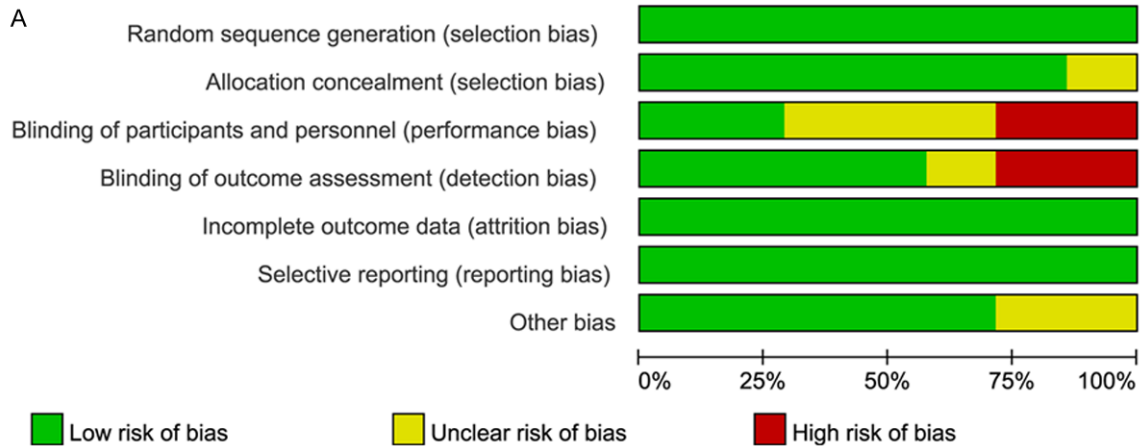
## Meta-analysis of all- and metal-ceramic FDPs

**Table 1.** Characteristics of 7 included studies

Study	Year	Area	Type of FDPs	Follow-up	N (M/F), age	No. of FDPs	Outcomes*				
							Survival	Copings fracture	Rough surface	Veneer chipping	Replacement
Pelaez, J	2012	Spain	3-unit P-FDPs	2.4 years	37 (15/22), 23-65	40, 20/20*	19/20	1/0	5/2	2/0	1/0
Vigolo, P	2012	Italy	Single-unit P-FDPs	5 years	60 (NA), 19-55	60, 39/19	32/18	0/0	NA	NA	3/0
Sailer, I	2009	Switzerland	3-5-unit P-FDPs	2.8 years	53 (28/25), 54.4 (12.7)	67, 36/31	36/31	0/0	NA	12/6	0/0
Esquivel-Upshaw	2014	USA	3-unit P-FDPs	2 years	55 (21/34), 52-75	72, 36/36	35/36	0/3	5/1	NA	1/0
Li, J	2010	China	3-unit P-FDPs	3-3.5 years	60 (37/23), 25-61	60, 20/40	17/33	1/6	NA	NA	NA
Nicolaisen M	2016	Nicolaisen M	3-unit P-FDPs	3 year	34 (13/21) 36-66	34, 17/17	10/9	4/1	NA	NA	5/3
Zenthöfer A	2015	Germany	3-unit P-FDPs	3 year	21 (9/12) 56 (26-74)	21, 11/10	17/17	2/1	NA	NA	NA

P-FDPs: posterior fixed dental prostheses; RCT: Randomized controlled trial; RCS: Retrospective Clinical Study; M: male; F: female; \*: All-ceramic restoration/metal-ceramic restoration.

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**Figure 2.** The assessment of quality of the selected studies. A: Bias risk of the identified studies; B: Sensitivity and specificity of the 7 studies. "+" indicates low risk of bias; "?" represents unknown bias risk; and "-" represents high bias risk.

metal-ceramic FDPs), follow-up time and outcomes. Discrepancies were resolved by discussing with the third investigator.

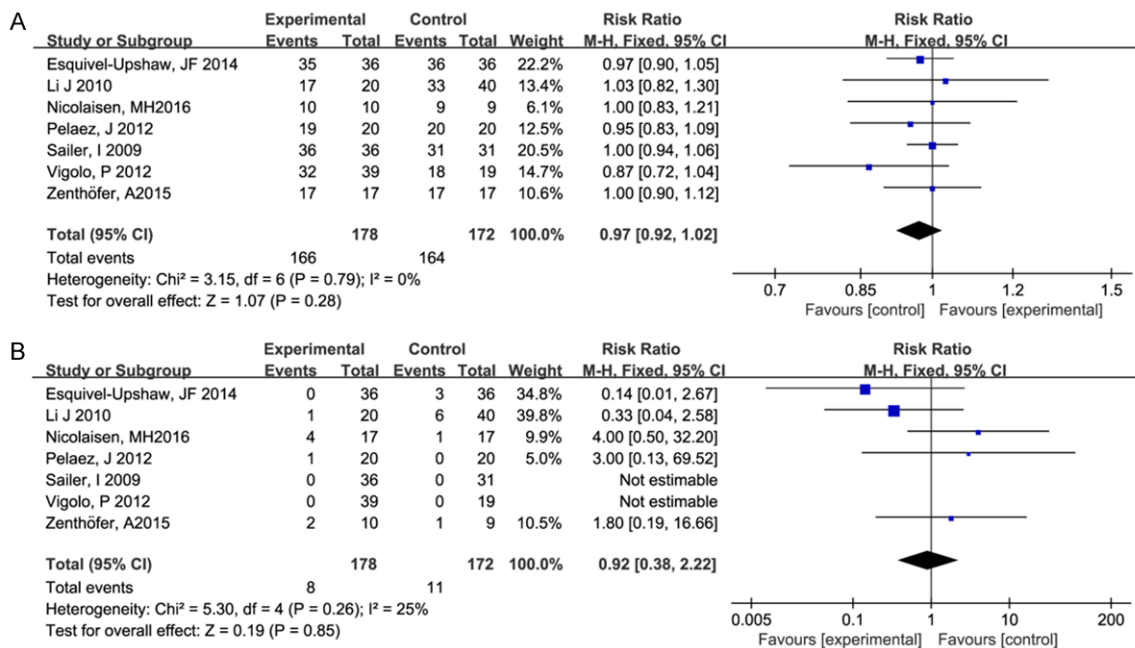
Quality of the included studies was assessed using Cochrane Collaboration's tool [17], which contains 7 items to assess the quality: Random sequence generation, Allocation concealment, Blinding of participants and personnel, Blinding of outcome assessment, incomplete outcome data, Selective reporting and other bias.

### Statistical analysis

Risk ratios (RR) and its 95% confidence interval (CI) were used as a measure of effect size.

Heterogeneity across the included studies was evaluated by Cochrane Q-statistic and  $I^2$  statistic (18).  $P < 0.05$  and/or  $I^2 > 50\%$  indicated a significant heterogeneity, and thus a random-effects model was used to pool the effect size. In contrast, a fixed-effects model was applied if there lacked significant heterogeneity ( $P \geq 0.05$  and/or  $I^2 \leq 50\%$ ). Publication bias was detected via funnel plots. Sensitive analysis was conducted by omitting one study at one time, to observe whether a reverse RR would be generated. If a reverse result was observed, it indicated that the result was unstable. All statistical analyses were performed using the RevMan 5.3 software.

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**Figure 3.** Forest plot of survival rate and copings fracture occurrence in the comparison of all-ceramic fixed dental prostheses (FDPs) and with metal-ceramic FDP. A: Survival rate; B: Copings fracture occurrence.

## Results

### Eligible studies

The flow diagram of study selection was shown in **Figure 1**. As a result, a total of 1,775 articles were obtained after preliminary screening (PubMed: 635, Embase: 456, Springer link: 252, Cochrane library: 44, CNKI: 184, Wanfang: 204). The duplications (616) were eliminated, and 1,119 irrelevant studies were excluded by browsing the title and abstract. In the remaining 40 studies, 23 were removed after abstract reading, and 10 were further eliminated after full-text reading. As no additional studies were screened out by manual search, finally, 7 RCTs [19-25] were included in this meta-analysis.

### Characteristics of the included studies

As summarized in **Table 1**, the 7 RCTs were consisted of 350 participants (178 applied all-ceramic FDPs and 172 applied metal-ceramic FDPs). These studies were published from 2009 to 2016, and their follow-up times were all above two years, with the longest follow-up time of 50 months (4.2 years). Two studies [20, 25] focused the single-unit posterior FDPs, while the remaining five mainly involved 3-unit posterior FDPs.

The result of quality assessment was shown in **Figure 2**. Risk of each bias item was relatively

low, except for performance bias and detection bias. This suggested that quality of the included studies were relatively high.

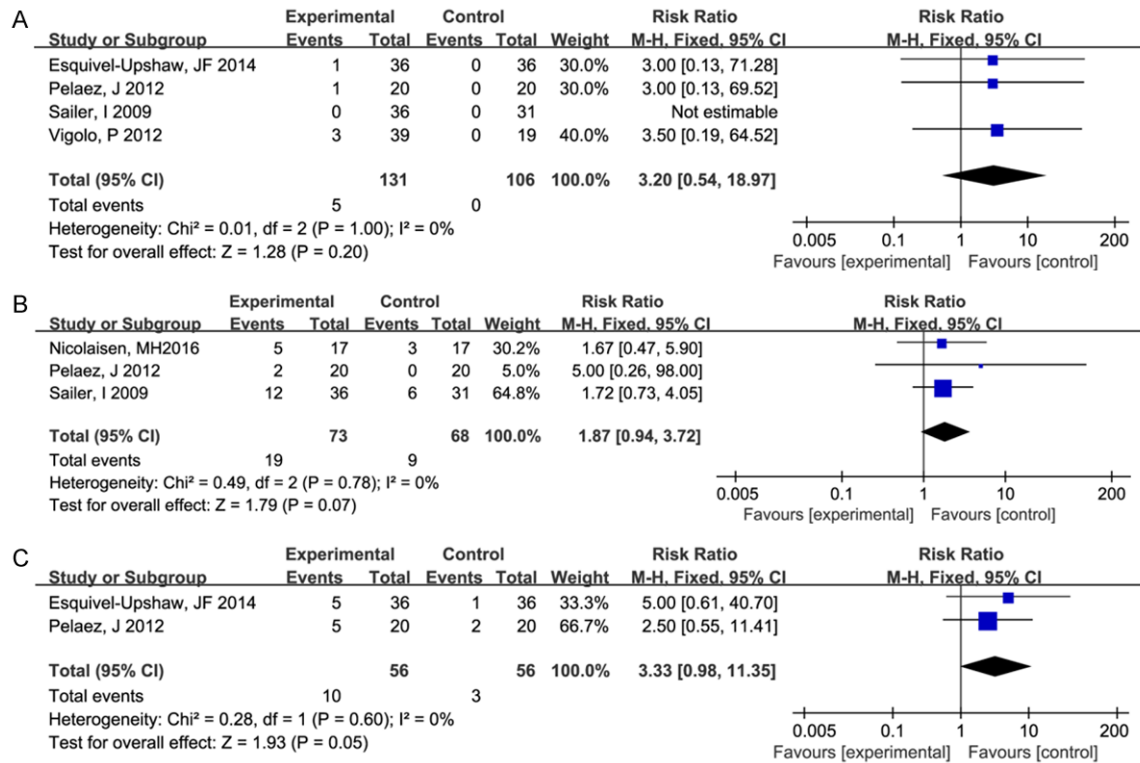
### Outcomes

The seven studies all reported the outcomes of survival rate and copings fracture. The fixed-effects model was used because no significant heterogeneity was detected (survival rate:  $I^2 = 0.0\%$ ,  $P = 0.79$ ; copings fracture:  $I^2 = 25\%$ ,  $P = 0.26$ ). The results showed that no significant differences were observed between all-ceramic and metal-ceramic FDPs on survival rate ( $RR = 0.97$ , 95% CI, 0.91 to 1.02,  $P = 0.28$ , **Figure 3A**) and copings fracture ( $RR = 0.92$ , 95% CI, 0.38 to 2.22,  $P = 0.85$ , **Figure 3B**).

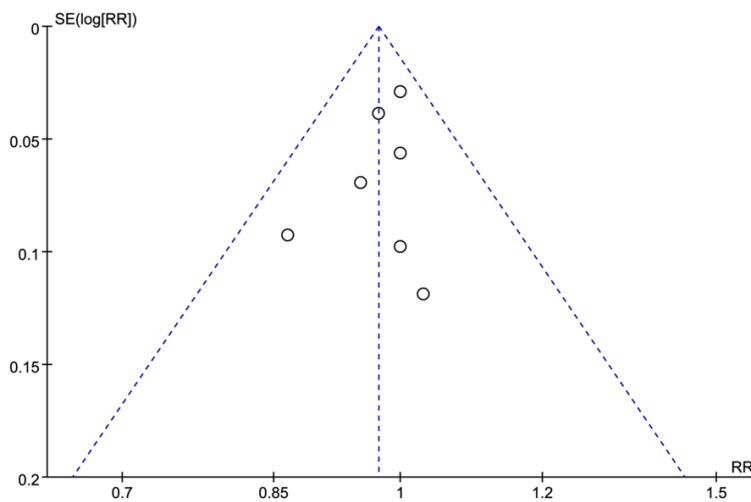
Four studies examined the outcome of crowns replacement rate, and a fixed-effects model was applied (heterogeneity:  $I^2 = 0.0\%$ ,  $P = 1.00$ ). All-ceramic FDPs showed a higher crowns replacement rate than metal-ceramic, however without statistical significance ( $RR = 3.20$ , 95% CI, 0.54 to 18.97,  $P = 0.20$ , **Figure 4A**).

Three studies covered chipping of the veneering ceramic under a fixed-effects model (heterogeneity:  $I^2 = 0.0\%$ ,  $P = 0.78$ ). Although all-ceramic FDPs showed a higher frequency of chipping of the veneering ceramic, the difference was not significant ( $RR = 1.87$ , 95% CI, 0.94 to 3.72,  $P = 0.07$ , **Figure 4B**).

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**Figure 4.** Forest plot of frequencies of ceramic veneer chipping, rough surface and rate of crown replacement in the comparison of all-ceramic fixed dental prostheses (FDPs) and with metal-ceramic FDP. A: Ceramic veneer chipping; B: Rate of crown replacement; C: Rough surface.



**Figure 5.** Funnel plot of the included studies.

Two studies reported the rough surface using a fixed-effects model (heterogeneity:  $I^2 = 0.0\%$ ,  $P = 0.60$ ). All-ceramic FDPs showed a higher rough surface than meta-ceramic, however without significant difference ( $RR = 3.33$ , 95% CI, 0.98 to 11.35,  $P = 0.05$ , **Figure 4C**).

### Publication bias

As reflected in the funnel plot (**Figure 5**), there was not significant publication bias among studies reporting survival rate, suggesting a reliable result. With regard to other outcomes, as number of the included studies was small, publication bias was not examined.

### Sensitive analysis

No reverse result was appeared after the removal of any study, indicating that our results were stable.

### Discussion

In this study, we included 7 RCTs with 178 all-ceramic FDP cases and 172 metal-ceramic FDP cases. As a result, we found that all-ceramic FDPs showed a comparable effect with meta-

ceramic FDPs on outcomes such as survival rate and copings fracture. On the other hand, the rate of crowns replacement, frequencies of veneering ceramic chipping and rough surface were higher when applied all-ceramic FDPs than meta-ceramic FDPs, however without statistical significance.

The definition of survival of FDPs is that FDPs remains in situ with or without modifications during the entire observation period. Zirconia-based FDPs always have a relatively high survival rate due to the property of high-strength ceramic material [26]. In our study, zirconia-ceramic FDPs were the only all-ceramic FDPs material. Therefore, it is understandable that all-ceramic FDPs had a similar survival rate to metal-ceramic FDPs in our present study. In Pjetursson's meta-analysis, different with our finding, they claim that all-ceramic FDPs achieve a lower survival rate than metal-ceramic, although without significance [16]. The reason might be that in their study, different all-ceramic materials were taken into consideration, such as glass ceramic FDPs, glass-infiltrated alumina FDPs and the densely sintered zirconia FDPs, and the former two belong to the low-strength materials. Especially, survival rate of glass-infiltrated alumina FDPs was 86.2%. Importantly, we should note that various studies have shown that the 5-, 10-, 15- and 20-year survival of metal-ceramic FDPs were 95% [27], 90% [28], 85% [5], and 41%-73% [29], respectively. In contrast, all-ceramic FDPs have lower survival rates than metal-ceramic FDPs [15]. Therefore, in order to obtain more precise survival rates, all-ceramic FDPs need to achieve longer follow-up time, similar to metal-ceramic FDPs.

The tough and strong material properties of zirconia make it have superior fracture resistance, thus coping fractures are infrequent in zirconia-based ceramic FDPs [30]. It is reported that fracture toughness values of zirconia copings are much higher compared with other all-ceramic core materials [31]. In our study, as zirconia-based FDPs were the only all-ceramic FDP material, it is reasonable that all-ceramic FDP obtained a comparable copings fracture with metal-ceramic FDP in our meta-analysis.

As all-ceramic FDPs are latterly developed restorations, more clinical studies focus on asse-

ssment of the failure for veneered zirconia FDPs [2, 32, 33]. Actually, incidence of the ceramic veneer chipping fractures of metal-ceramic FDPs was 6%, based on retrospective data [34]. Aging or low-temperature degradation is the most focused ceramic veneer phenomena that might be associated with ceramic veneer chipping. The degradation of zirconia-based material's mechanical properties is highly related to zirconium dioxide's hydrothermal transformation from tetragonal to monoclinic phase. Zirconia has the property of low thermal conductivity; however the surface treatment of zirconium dioxide by abrasion could make a local temperature rise which will trigger the phase transformation [35]. Another study also indicates that the abrasions exhibited in the affected patients are the clinical reasons for the major chipping of the ceramic veneer, and its frequent occurrence could reduce the success rate of zirconia-based FDPs [11]. This might be the reasonable explanation for the slightly higher frequency of ceramic veneer chipping in all-ceramic FDP than in metal-ceramic one in our study. The lack of significance might be due to that only three RCTs with small sample size were included in the meta-analysis.

It is demonstrated that several technical problems, such as the veneering ceramic fracture, are more frequent in zirconia-based FDPs restoration [20]. Because of this reason, numbers of crowns that need to be replaced are higher than metal-ceramic FDPs. In addition, survival rate of all-ceramic implant-supported single crowns is relatively lower than meta-ceramic ones (92.2% vs. 95.4%) [36]. Consistent with this finding, although without significance, our pooled result suggested that all-ceramic FDP had a higher rate of crown replacement. Likewise, the small number of the included RCTs might be the causative factors for the lack of significance.

The clinical data indicate that chipping fracture of the veneering ceramics of zirconia-based FDPs is highly related to the roughness of veneering ceramic [37]. Therefore, the higher rate of rough surface in all-ceramic FDPs might be the reasons for higher frequency of ceramic veneer chipping, compared with metal-ceramic. However, more RCTs with large amount of samples are needed.

In our meta-analysis, all of the included studies were RCTs with high quality, and the original studies have quite precise design and reliable methodology. Additionally, all-ceramic and metal-ceramic FDPs from each study were operated by the same dentist, which avoid the bias caused by different operation methods. Moreover, there lacked significant heterogeneity across all the included studies regarding to each outcome. Despite these obvious advantages, this meta-analysis also had several limitations. First, the sample size of the included studies was relatively small. Although the quality of all included studies were high, more RCTs with larger samples are needed to verify our results. Second, follow-up time of the included studies was short, and we speculate that differences between all-ceramic and metal-ceramic FDPs might be significant when a longer follow-up time was applied. Third, due to the limited number of the included RCTs, we did not perform a subgroup analysis to evaluate the outcomes of different metal frameworks.

In conclusion, all-ceramic FDPs had a similar survival rate and frequency of coping fracture as metal-ceramic FDPs. However, occurrences of other complications, such as ceramic veneer chipping fractures, crown replacement and rough surface, might be higher in all-ceramic FDPs than metal-ceramic. The alternative use of all-ceramic FDPs should be cautious. Nevertheless, more RCTs with large samples and longer follow-up time period are required to confirm these findings.

### Disclosure of conflict of interest

None.

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