ORIGINAL ARTICLE

UDC: 615.464::616.31
DOI: https://doi.org/10.2298/VSP161208034Z

Survival rate of ceramic inlay and onlay restorations in posterior teeth with one-surface or multi-surface after a 10-year follow-up: A systematic review and meta-analysis

Stopa trajanja keramičkih inlej i onlej restaurativnih nadoknada sa jednom ili više površina u bočnim zubima posle 10-godišnjeg praćenja: sistematski pregled i meta analiza

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Abstract

Background/Aim. A large number of studies have been conducted on the survival rate of ceramic single tooth restorations, but few studies have discussed the influence of the number of restoration surfaces on their survival rate. This study aimed to evaluate the survival rate of ceramic inlay and onlay restorations in posterior teeth with one-surface or multi-surface after a 10-year follow-up. **Methods**. PubMed, Web of Science, Cochrane Library, Embase, and Wanfang databases were searched for articles published by July 31, 2016. Randomized controlled trials and non-randomized trials were collected and patients with posterior teeth defect were included. Publication bias and sensitivity analysis were also assessed. **Results**. Five studies comprising 6,720 cases were included in this meta-analysis. The results indicated that the survival rate of ceramic inlay and onlay restorations with two-surface was significantly higher than that of one-surface restorations (within 10 years) [*hazard ratio* (HR) = 2.11; 95% *confidence interval* (CI) = 1.33–3.36, $p = 0.002$], and the survival rate of three-surface restorations was higher than that of two-surface ones (HR = 2.50; 95% CI = 1.36–4.59, $p = 0.003$). **Conclusion.** The current meta-analysis shows that the increase in the ceramic inlay and onlay restoration surfaces increases their survival rate within a 10-year period.

Key words:
denture, partial, fixed; meta- analysis as topic; survival rate

Apstrakt

Uvod/Cilj. Velik broj studija bavio se ispitivanjem veka trajanja keramačkih restaurativnih nadoknada na pojedinačnim zubima, dok je manji broj njih proučavao uticaj broja površina tih nadoknada na njihov vek trajanja. Cilj ove studije bio je da proceni stopu trajanja keramičkih inlej i onlej restaurativnih nadoknada sa jednom ili više površina u bočnim zubima posle 10-godišnjeg praćenja. **Metode.** Pretražene su baze PubMed, Web of Science, Cochrane Library, Embase i Wanfang radi pronalaženja radova objavljenih do 31. jula 2016. godine. Prikupljeni su radovi o randomizovanim kontrolisanim kliničkim ispitivanjima i nerandomizovanim kliničkim ispitivanjima, u koja su bili uključeni pacijenti sa oštećenjem bočnih zuba. Takođe, bila je procenjena pristrasnost i izvršena analiza osetljivosti u ovim publikacijama. **Rezultati.** U ovu meta-analizu bilo je uključeno pet studija sa 6 720 pacijenata. Rezultati su pokazali da je tokom desetogodišnjeg praćenja vek trajanja inlej i onlej keramičkih restaurativnih nadoknada sa dvostrukom površinom bio znatno duži od onih sa jednom površinom [*hazard ratio* (HR) = 2,11; 95% *confidence interval* (CI): 1,33–3,36, $p = 0,002$], kao i da je vek trajanja nadoknada sa tri površine bio duži od onih sa dve površine (HR = 2,50, 95% CI: 1,36–4,59, $p = 0,003$). **Zaključak.** Ova meta-analiza pokazuje da povećanje površina keramičkih inlej i onlej restaurativnih nadoknada produžava njihov vek trajanja tokom perioda od 10 godina.

Ključne reči:
zub, trajne nadoknade; meta analiza; preživljavanje, stepen

Introduction

As a result of patients' increasing demand for highly esthetic restorations, issues concerning the use of composite resins for large restorations in posterior teeth, and discussions regarding possible side effects of dental amalgam have increased indications for tooth-color partial-coverage restorations to restore posterior teeth [1–7]. As an

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alternative to direct partial restorations, indirect restorations were more widely used because they could provide more control over shape and function, particularly in larger defects in posterior teeth. Numerous materials are currently available for making indirect partial restorations [8–9], but the mechanical strength must be taken into account in posterior applications. With the development of adhesive technologies and escalation in aesthetic demands, it is likely that most indirect restorations are currently made from ceramic materials.

Indirect ceramic restorations can be made either by a dental technician in the laboratory or by using computer aided design/computer aided manufacturing (CAD/CAM) systems to make chairside restorations in a single session. The procedure of placing indirect inlay restorations includes many steps and a wide variation of ceramic materials and luting cements that can be used. Clinical studies on the success of stress-bearing all-ceramic inlays in permanent posterior teeth have already identified that the longevity of dental restorations is dependent on many different factors, including material-, patient- and dentist-related factors. Amounts of factors related to the materials, such as ceramic properties or characteristics of the adhesive luting technique, have been investigated extensively *in vitro* [5, 10–13]. Clinical studies with limited sample size also have shown the influence of factors related to patients and operators on the clinical outcome of ceramic inlays [13–16]. However, there is a lack of clinical studies analyzing the role of surfaces risk factors on restoration longevity and performance.

This systematic review and meta-analysis aimed to evaluate the difference in longevity of ceramic inlay restorations with one-surface or multi-surface after 10-year follow-up associated with the main clinical outcomes reported in randomized controlled trials (RCTs) and retrospective studies.

Methods

Information sources

We searched the following databases for articles published between 1983 and 2016 that reported on survival of ceramic inlay restorations: PubMed, Web of Science, Cochrane Library, Embase, and Wanfang (by July 31, 2016). References of the included articles were further checked manually. We selected the year 1983 as the starting point because adhesive procedures for ceramics with the use of hydrofluoric acid and silanization were first introduced in that year [17].

Search strategy

PubMed, Web of Science, Cochrane Library, Embase, and Wanfang databases were searched for articles with broad key terms, such as “ceramic,” “Cerec”, “inlay,” “onlay”, “survival,” and “long-term”. The search strategy was carried out using the retrieval type as following: (“ceramic” OR “Cerec”) AND (“survival” OR “long-term”) AND (“inlay” OR “onlay”). In addition, we searched all these databases to avoid missing relevant studies published before July 31, 2014. Only studies published in English and Chinese were included. Manual search of reference lists of retrieved articles was also performed.

Study selection and eligibility criteria

All titles and abstracts of the selected studies were first assessed for the following inclusion criteria: clinical studies related only to all-ceramic inlays in human posterior teeth and those with clinical follow-up (prospective studies, retrospective studies, or RCTs). The full text was evaluated for articles without abstracts or for abstracts with an insufficient description. After evaluating the full text of the articles according to the previously defined exclusion criteria, articles with the following features, without language restrictions, were considered ineligible: 1) articles without a description of the procedure or those in which uncommon preparations had been performed (e.g, bridge abutments, splinting, uncommon bonding procedures, occlusal coverage of posterior teeth without preparation, or implant abutments or restorations including metal); 2) case reports; 3) literature or systematic reviews, protocols, interviews, and *in vitro* studies; 4) studies conducted in isolated groups (bruxism, hypoplasia, others); 5) studies with the same sample (the most recent and/or most complete was considered); 6) studies without a survival analysis or those with incomplete data for the analysis; 7) studies with a dropout rate higher than 30%; and 8) studies with a follow-up shorter than 10 years.

Data extraction

We extracted information from the studies (that had been collected based on the aforementioned criteria), such as author names, publication year, volume and issue; article design; number of cases and placebos, efficacy and safety assessment. Yun Zou and Jing Bai independently checked the data from all the included studies. Subsequently, a third reviewer (Jingzhou Xiang) discussed inconsistent evaluations and thereby helped to reach a final agreement.

Quality assessment of the included studies

The quality of all the included studies was assessed according to the Newcastle-Ottawa quality Assessment Scale [18] independently by 2 reviewers (Yun Zou, Jing Bai). Disagreements were resolved by another reviewer (JingZhou Xiang). The Newcastle-Ottawa Quality Assessment Scale falls into three categories, including Selection, Comparability, and Outcome. The categories Selection and Outcome have four and three items, respectively. The category Comparability has only one item. When a study is assessed item by item, it is awarded a maximum of one star (★) for each item within the Selection and Outcome categories. A maximum of two stars can be awarded for the

Comparability category. Generally, the study which was awarded more than five stars in total was considered to be included in this meta-analysis.

Statistical analysis

The strength of association between one-surface and multi-surface was estimated by hazard ratio (HR) value and 95% confidence interval (CI). A meta-analysis of surfaces risk factors on restoration longevity and performance, were performed using Review Manager Version 5.3 software (provided by the Cochrane Collaboration) to obtain a HR. *Z*-test determined the significance of the pooled HR and $p < 0.05$ was considered as statistically significant. Heterogeneity of the studies was assessed using the Cochrane Q and I^2 statistic [19], which represents the percentage of total variation among studies that is attributed to heterogeneity rather than chance [20]. Both fixed-effects and random-effects models were used: if the I^2 test < 50% or $p \geq 0.05$ (Q-test), we used the fixed-effects model; if there was significant heterogeneity among the included studies (I^2 test > 50%), the random-effects model was employed.

Egger rank correlation tests were used to assess the extent of publication bias. In addition, sensitivity analysis was also performed. Those two procedures were conducted using STATA 11 (Stata, College Station, TX, USA).

Results

Study selection

The search strategies employed yielded 569 studies (Figure 1). The titles and abstracts were screened and 21 studies were excluded at this step. Then, full-text articles were screened against the inclusion criteria. Thus, 5 studies [15, 21–24] comprising 6,720 ceramic inlay restorations were included in our study. We followed the PRISMA guidelines and illustrated the study selection by the PRISMA flow diagram (Figure 1).

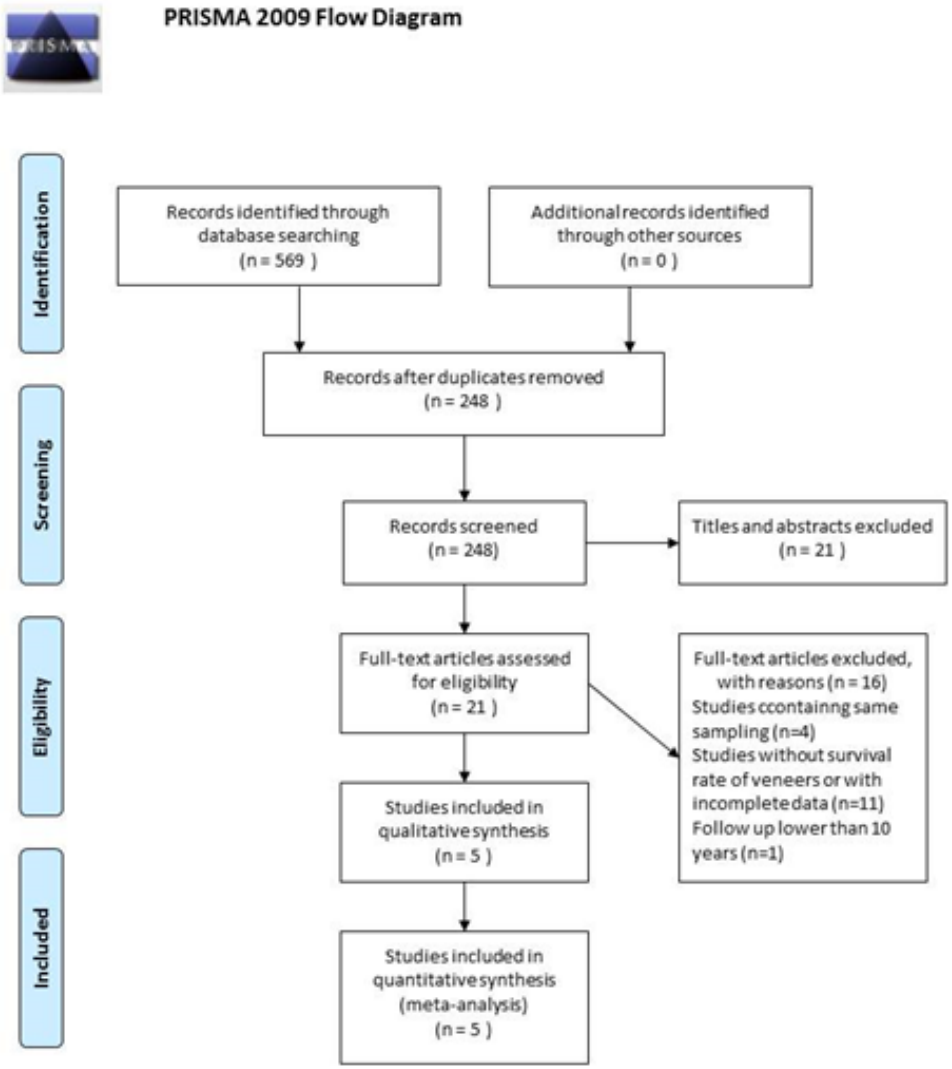

Fig. 1 – PRISMA flow diagram for the study selection process. In this meta-analysis, 5 studies were selected for qualitative analysis.

Table 1

The characteristics of the studies [15, 21–24] included in this meta-analysis

First author	Year of publication	Country	Type of study	Follow-up (years)	Material	Number.of restored surfaces	Evaluation criteria
Reiss [22]	2000	Germany	Retrospective cohort	10	Feldspathic porcelain	32 one-surface 344 two-surface 519 three-surface	USPHS
Otto [24]	2002	Switzerland	Retrospective cohort	10	Feldspathic porcelain	23 one-surface 67 two-surface 85 three-surface	USPHS
Stoll [15]	2007	Germany	Retrospective cohort	10	Glass-ceramic	304 one-surface 754 two-surface 438 three-surface	NS
Beier [21]	2012	Austria	Retrospective cohort	20	Glass-ceramic	38 one-surface 141 two-surface 155 three-surface	CDA
Collares [23]	2016	Brazil	randomized controlled trial	10	Ceramic	205 one-surface 1359 two-surface 2256 three-surface	NS

All studies were published in English.
CDA – California Dental Association; USPHS – United States Public Health Service; NS – not specified.

Table 2

Results of literature [15, 21–24] quality assessment according to the Newcastle-Ottawa quality Assessment Scale

First author, year of publication	Selection	Comparability	Outcome
Reiss, 2000 [22]	★★★★	★★	★★
Otto, 2002 [24]	★★★★	★★	★★
Stoll, 2007 [15]	★★★★	★★	★★
Beier, 2012 [21]	★★★★	★★	★★
Collares, 2016 [23]	★★★	★★	★★★

Study characteristics

The characteristics of the included studies are presented in Table 1. The selected articles were published from 2000 to 2016. The 5 aforementioned studies included 6,720 ceramic inlay restorations characterized by one-surface, two-surface and three-surface. The experiment group included ceramic inlays with one-surface, and the control group included ceramic inlays with multi-surface.

All the included studies were marked by more than five stars on quality assessment (Table 2). These studies all illustrated explicit diagnostic criteria, good comparability between subgroups, and clear results.

Meta-analysis

The substantial heterogeneity was described with an I^2 value of 0%; thus, fixed effects models were used, showing that the survival of one-surface was significantly different from that of two-surface (95%CI:1.33,3.36 $p = 0.002$) (Figure 2). Because the I^2 value was 0% ($I^2 = 0\%$; $p = 0.41$), the data extracted were those obtained by the fixed effects

model showing a significant difference between one-surface and three-surface (95%CI: 1.36, 4.59 $p = 0.003$) (Figure 3).

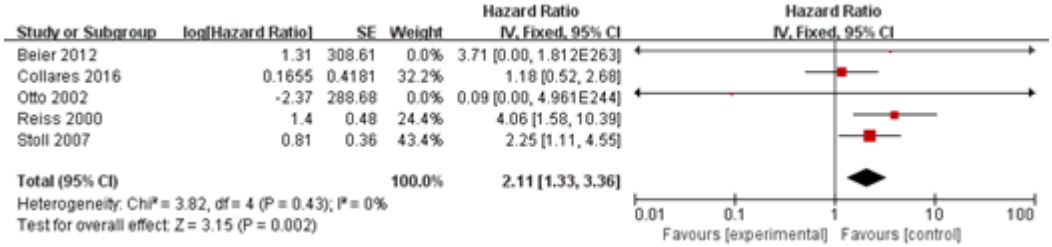

Fig. 2 – Forest plot of inlays, one-surface vs. two-surface.
CI – confidence interval; SE – standard error.

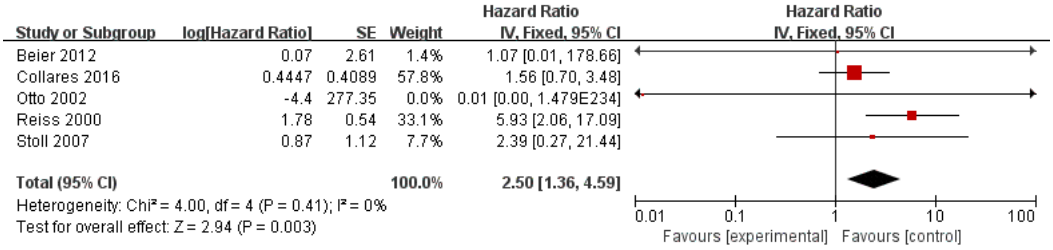

Fig. 3 – Forest plot of inlays, one-surface vs. three-surface.
For abbreviations see under Fig. 2.

Publication

The Egger rank correlation tests showed that there was no publication bias in these two meta-analyses ($p = 0.937$, $p = 0.968$).

Discussion

According to the present systematic review and meta-analysis, and concerning the outcome, the survival rate of ceramic inlays and onlays increases with the increase in the number of inlay and onlay surfaces. This conclusion was different from the conclusions in the studies included. In general, several factors may be associated with the survival rate of ceramic inlays: the design of the inlays, fabrication methods, bonding procedures, use of composite resin cements, vital or non-vital teeth habit of the participants, and the evaluation criterion of the study.

The descriptions of all-ceramic inlays preparation were presented only in one study [21], which emphasizes the shoulder preparation and occlusal reduction of at least 1.5 mm from the deepest pit in the fossae, because this could improve the fracture resistance strength of all-ceramic restoration. The other four studies did not describe the preparation of inlays, and the influence of the surface on the survival of ceramic inlays could therefore not be evaluated.

Three studies [15, 21, 22] divided the restorations into two groups: vital teeth and non-vital teeth. Restorations on vital teeth showed significantly fewer failures compared to restorations on non-vital teeth during the 10-year follow-up in all these studies. However, the samples of vital teeth were obviously much larger than those of non-vital teeth, and items were not subgrouped by surface. The evidence was therefore insufficient to indicate whether vital teeth may or may not be the factors in the survival rate of ceramic inlays with one-surface or multi-surface.

The restorations were polished in one follow-up study [15], while an *in-vitro* study showed that the ceramic polishing with rotating instruments may creating microcracks in the marginal zone. Hence, whether or not to apply polishing is still debatable. Besides, none of the studies involved proved that polishing during the treatment has an effect on the survival rate of the ceramic inlays surface. Each restoration received dual-cured resin composite at the time of treatment. A 10-year prospective study compared the performance of inlays cemented with a chemically cured and dual-cured resin composite. After 10 years of clinical service, the inlays luted with chemically cured resin composite had a higher survival rate (89%) compared to dual-cured resin composite (77%). Three studies [21–23] mentioned using dentin bonding, and one of the studies [21] showed that although more than half of the failures occurred in restorations with no dentin bonding, the differences were not significant. The surface survival rate of multi-surface was lower than that of one-surface. Reiss and Walther [22] suggested that the risk of failure was significantly reduced when a dentin adhesive was applied. It was also confirmed that the survival rate of multi-surface was higher than that of one-surface. Besides, Hass et al. [25] reported that a survival rate of 95% after 7 years means the dentin adhesive used had no significant influence on the results either. In contract, Posselt and Kerschabaum [26] found significantly higher survival probabilities for inlays incorporated with a dentin

adhesive, but there was no significant evidence to arrive at the conclusion above.

Clelland et al. [27] suggested that application of silanation had a greater effect on improving the strength of the ceramic restoration, particularly if the surface was rough. Two of the studies included in this meta-analysis refer to silanation. In one of the studies [22], all the ceramic inlays were silanized directly after drying before seating, and the outcome indicated that the survival rate of multi-surface was higher than one-surface. In the other studies, 86% of inlays were silanized before placement and the results showed that survival rate of one-surface was higher than multi-surface. However, the current evidence was not sufficient to draw the conclusion on whether silanation has an effect on the survival rate of the surface of inlays. One study [15] showed that the number of surfaces did not influence their longevity.

Restorations in two studies [15, 21] were fabricated at the Department of Operative Dentistry, School of Dental Medicine. All of the patients in the other three studies [22–24] had been recruited from a single private dental office. Trials undertaken in a university hospital environment are normally conducted in accordance with fixed placement and evaluation protocols, in idealized conditions without the restraints of time and available materials. The data obtained in this manner should show the optimum performance of the restorative system. University studies are normally fixed-term studies with a defined placement and evaluation time-scale. The trials undertaken in a dental practice environment tend to be influenced by reduced clinical working-time, variation in the use of luting materials, and usually the inability to adhere to a strict case selection protocol [28]. Therefore, different locations of research could influence the survival rate of the surface of inlays.

Two studies [21, 24] pointed out that the patients who participated in the research were diagnosed with bruxism. Otto and De Nisco [24] confirmed the fact that during the follow-up, two to three patients with multiple failures were diagnosed with bruxism. This may mean that this particular group of patients should be considered a risk group with regard to Cerec restorations. In the clinical study by Beier et al. [21], 33% of all fractured inlays occurred in patients with signs of bruxism, but no significant differences were reported. Therefore, the conclusion regarding whether or not bruxism has an impact on the survival of the surface of inlays could not be drawn.

A large number of studies have been conducted on the survival rate of ceramic single tooth restorations. Different factors were held responsible for the survival of the restorations. Only a few studies discussed whether the number of surfaces has an influence on the survival rate. The meta-analysis consisted of three studies [21, 23, 24] confirmed that the survival rate was decreasing with the surface increased. However, one study [22] showed that the survival rate was increasing with the surface increased. The present study showed that the survival risk was decreasing with the surface increased. The current evidence indicates that the survival rate increased with the increase of the number of inlay surfaces. The clinical dentists should take account of the number of surfaces during treatment.

Several limitations and sources of bias should be considered in this meta-analysis. First, only studies published in English and Chinese were searched in the process of study selection. No evidence of significant publication bias in this study was reflected by the test. Second, few studies reported the survival rate of ceramic inlay surfaces, and the sample used in this meta-analysis is not large enough to perform a subgroup analysis. Therefore, more original studies are needed. Furthermore, the included studies were mostly from Europe. The absence of representative data from other parts of the world may have made the results more prone to potential selection bias.

Conclusion

In conclusion, this meta-analysis indicates that the survival rate increased with the increase in the number of surfaces of inlays and onlays. We suggest the clinical dentists should take into account the influence of the number of surfaces during treatment, and improve the survival rate of the ceramic inlays.

Acknowledgement

This study was approved by the China Medical University Ethical Review Board. We had no source of funding for the study and have no conflicts of interest.

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Received on December 8, 2016.
Accepted on March 26, 2021.
Online First March, 2021.