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Effect of Preparation Designs on the Prognosis of Porcelain Laminate Veneers: A Systematic Review and Meta-Analysis

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Clinical Relevance

Window-type preparations are recommended for porcelain laminate veneers with a butt-joint considered when incisal coverage is needed.

SUMMARY

Objective: To investigate the association between preparation designs and prognosis of porcelain laminate veneers (PLVs).

Methods: Electronic and manual literature searches were performed in Medline, Embase, CENTRAL, and Scopus databases for randomized controlled trials and retrospective and prospective cohort studies comparing any two of three preparation designs. The quality of the included studies was assessed using the Newcastle-Ottawa scale. Pooled hazard ratios and risk ratios were used to evaluate the difference between two preparation designs. Subgroup analyses, sensitivity analysis, and evaluation of publication bias were performed if possible.

Results: Of 415 screened articles, 10 studies with moderate to high quality were included in the meta-analysis. Comparison of preparations with incisal coverage to preparations without coverage revealed a significant result based on time-to-event data (hazard ratio=1.81, 95% confidence interval [CI]=1.18-2.78, I^2=12.5%), but the result was insignificant based on dichotomous data (risk ratio=1.04, 95% CI=0.59-1.83, I^2=42.3%). The other comparisons

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between any two of overlap, butt-joint, and window types revealed no statistically significant difference. Subgroup analyses regarding the porcelain materials, location of prosthesis, and tooth vitality could account for only part of the heterogeneity. No evidence of publication bias was observed.

Conclusions: Within the limitation of the present study, it can be concluded that preparation design with incisal coverage for PLVs exhibits an increased failure risk compared to those without incisal coverage. The failure risk of the overlap type may be higher than the butt-joint type but must be validated in further studies.

INTRODUCTION

Porcelain laminate veneers (PLVs) have been introduced as a conservative solution to esthetic prosthodontics for anterior teeth since the 1980s[1,2] and are widely indicated for those with discoloration, malformation, misalignment, or any other dental defect. With the progress of materials and bonding systems, the long-term success of PLVs has greatly increased. However, no clinical consensus is available regarding the type of design preferred for PLVs.

There are various classification systems to distinguish the different preparation designs for PLVs, of which the traditional three-type classification is frequently used, namely, window, butt-joint, and overlap type.[3] The window type refers to those preparations that do not reduce the incisal edge, which is indicated for teeth with satisfactory incisal length. The latter two preparations are indicated for those who need modification of incisal length or translucency. As to whether a palatal chamfer is prepared, the types are further grouped into butt-joint type and overlap type.

In vitro studies have investigated the stress distribution and fracture strength of PLVs with different preparation designs. Two- and three-dimensional finite element analyses revealed that the butt-joint type tolerates stress better, whereas the overlap type distributes stress more uniformly. In contrast, the window type concentrates stress in the incisal area.[4-7] However, controversy exists regarding dynamic loading tests.[7-12] A meta-analysis focusing on these *in vitro* studies yielded synthetic outcomes suggesting that the fracture strength of the butt-joint type is similar to nonprepared teeth and that overlap type is more prone to fracture compared to the window type.[3]

To date, limited studies have focused on the effect of preparation designs on the prognosis of PLVs. Concerning preparations with or without incisal coverage, the survival rates showed no significant difference in a two-and-a-half-year follow-up study,[13] whereas another study reported that the four-year survival rate of porcelain veneers with incisal coverage was significantly increased compared to that without coverage.[14] Still other studies reported opposite results.[15-17] The survival or success rates of veneers with window, butt-joint, and overlap types are also under discussion. In general, there seemed to be no difference among these three preparation designs;[13,18] nevertheless, some observational studies noted that the survival of the overlap type was superior to the butt-joint type.[19-21] Therefore, the relationship of preparation designs to PLV survival remains unclear.

A recent systematic review investigating the survival rates with or without incisal coverage showed that either type was successful and that incisal coverage tended to be associated with an increased but statistically insignificant failure risk.[22] The single survival rates from original studies were extracted to synthesize an overall value with or without incisal coverage separately by the authors, whereas only three directly comparative studies were identified for the overall odds ratio estimate. However, the failure risk among window, butt-joint, and overlap types remains unknown. The purpose of this article is to comprehensively determine if PLVs with different preparation designs differ in their prognostic survival/success. A secondary purpose is to disclose potential confounding factors influencing the result of meta-analysis for future clinical trials.

METHODS

Protocol and Registration

This review was registered at the PROSPERO (CRD42016040166) and conformed to the proposed MOOSE (Meta-Analysis of Observational Studies in Epidemiology) guidelines.[23]

Search Strategies

The MeSH terms, free key words in the search strategy, were defined based on the PICOS question:

1) Population (P): patients who received PLV restorations.
2) Intervention/comparison (I/C): any two kinds of overlap, butt-joint, and window types.

Table 1: *Search Strategy Used in Electronic Databases*

Database	Search Strategy/Terms
Medline via PubMed	#1 "dental veneers"[mesh]
	#2 porcelain laminate veneer*[tw] OR porcelain veneer*[tw] OR ceramic laminate veneer*[tw] OR ceramic veneer*[tw]
	#3 "Tooth Preparation, Prosthodontic"[mesh]
	#4 tooth preparation[tw] OR dental preparation[tw] OR preparation design*[tw] OR preparation type*[tw] OR incisal preparation*[tw] OR incisal edge preparation*[tw] OR incisal edge reduction[tw] OR incisal porcelain coverage[tw] OR window preparation[tw] OR feather preparation[tw] OR feathered incisal edge[tw] OR butt joint[tw] OR bevel preparation[tw] OR modified overlap[tw] OR full veneer*[tw] OR palatal chamfer[tw] OR palatal extension[tw] OR incisal overlap[tw] OR without preparation[tw] OR nonprepared[tw] OR non-prepared[tw]
	#5 survival[tw] OR success[tw] OR failure[tw] OR longevity[tw]
	#6 #1 OR #2
	#7 #3 OR #4
	#8 #5 AND #6 AND #7
Embase via embase.com	#1 "dental veneer"/exp
	#2 (porcelain OR ceramic) NEXT/2 veneer*
	#3 "tooth preparation" OR "dental preparation" OR "preparation design*" OR "preparation type*" OR (incisal NEXT/2 (preparation* OR coverage*)) OR "incisal edge reduction" OR "window preparation" OR "feather preparation" OR "feathered incisal edge" OR "butt joint" OR "bevel preparation" OR "modified overlap" OR "full veneer*" OR "palatal chamfer" OR "palatal extension" OR "incisal overlap" OR "without preparation" OR "nonprepared" OR "non-prepared"
	#4 "survival" OR "success" OR "failure" OR "longevity"
	#5 #1 OR #2
	#6 #3 AND #4 AND #5
CENTRAL via Cochrane Library	#1 MeSH descriptor: [Dental Veneers] explode all trees
	#2 (porcelain laminate veneer*) OR (ceramic laminate veneer*) OR (porcelain veneer*) OR (ceramic veneer*) OR (dental veneer*) OR (dental laminate*) OR (Veneer*, Dental) OR (Laminate*, Dental)
	#3 #1 OR #2
	#4 MeSH descriptor: [Tooth Preparation, Prosthodontic] explode all trees
	#5 (tooth preparation) OR (dental preparation) OR (preparation design*) OR (preparation type*) OR (incisal preparation*) OR (incisal edge preparation*) OR (incisal edge reduction) OR (incisal porcelain coverage) OR (window preparation) OR (feather preparation) OR (feathered incisal edge) OR (butt joint) OR (bevel preparation) OR (modified overlap) OR (full veneer*) OR (palatal chamfer) OR (palatal extension) OR (incisal overlap) OR (without preparation) OR (nonprepared) OR (non-prepared)
	#6 #4 OR #5
	#7 (survival) OR (success) OR (failure) OR (longevity)
	#8 #3 AND #6 AND #7
SCOPUS	(TITLE-ABS-KEY(porcelain laminate veneers) OR TITLE-ABS-KEY(ceramic laminate veneers) OR TITLE-ABS-KEY(porcelain veneers) OR TITLE-ABS-KEY(ceramic veneers)) AND (ALL("preparation designs") OR ALL("preparation types") OR ALL("incisal coverage") OR ALL("incisal overlap")) AND (ALL("survival") OR ALL("success") OR ALL("failure"))

3) Outcome (O): mechanical failure of a PLV, including fracture and debonding.
4) Study design (S): clinical follow-up studies, including controlled clinical trials and cohort studies.

Literature searches were conducted up to June 2016 using the following databases: PubMed/Medline, Embase, and the Cochrane Library (Table 1). There were no restrictions on language or year of publication. References cited in the excluded reviews and included articles were also accessed to identify other potentially relevant studies.

Selection Criteria

After the identification of articles in the databases, the articles were imported into Endnote X7 software (Thompson Reuters, Philadelphia, PA, USA) to remove duplicates. Two independent reviewers initially screened the titles and abstracts of all documents, after which full copies of all potentially relevant studies were obtained for further identifi-

cation. Any disagreement regarding the eligibility of included studies was resolved through discussion and consensus or by a third reviewer.

Studies were considered eligible and were included according to the following criteria: 1) PLVs were restored for anteriors or premolars, regardless of the porcelain materials; 2) at least two types of preparation designs were mentioned or compared; 3) the respective number of survival/failure could be acquired or inferred from articles, or hazard ratios (HRs)/risk ratios (RRs) with 95% confidence intervals (CIs) were provided; and 4) both clinical trials and prospective or retrospective cohort studies were allowed, excluding *in vitro* studies.

Data Extraction

Data were extracted by two reviewers independently and tabulated into separate databases using a standard collection form. Completed forms were then compared and discussed to achieve a consensus. The extracted information included the name of first author, year of publication, country, study design, duration of recruitment and follow-up, number of patients and veneers, composition of gender and age, the porcelain materials and adhesives, and investigated preparation designs and their corresponding number/proportion of events. Moreover, potential confounding factors influencing the survival of PLVs were particularly identified, such as the location of prostheses, tooth vitality, restorative cause, and consistency of operators. Once any missing information was noted, the authors of the included articles were contacted via e-mail to retrieve details.

Quality Assessment

The bias risk and quality of included studies were assessed using the Newcastle-Ottawa Scale (NOS)[24] because the pilot experiment indicated that retrospective or prospective cohort studies were most common. The NOS contains eight scoring items categorized into three fields: Selection, Comparability, and Outcome. Each field could be scored a maximum of one star with the exception of the item of comparability, which could be given a maximum of two stars. Therefore, studies were graded with zero to nine stars based on their matching with the eight items in NOS, where zero to four stars represented low quality, five to six moderate quality, and seven to nine high quality.

Items in need of specific definitions were defined prior to the formal scoring procedure. PLVs restored in worn-out teeth or patients with bruxism were considered with compromised representativeness in the field of Selection. Regarding the field of Comparability, two stars can be given once the PLV restorations were made both in the same porcelain and by the same operator. If only either one was matched but the *post hoc* analysis had considered an adjustment (eg, adjusted HR estimate), the study would still receive two stars. When the duration of follow-up was less than two years or the dropout rate was greater than 20%, the corresponding item regarding follow-up failed to receive a star.

Statistical Analysis

To illustrate the strength of association between preparation designs and survival of PLVs, time-to-event data are considered best in prognostic studies, which often present these data as HRs, Kaplan-Meier curves, or lifetime tables.[25] In this review, both HR and RR were used as measures of the association between preparation designs and failure given the possibility that limited studies may focus on time-to-event data reports. Compared with RR calculated from the event number in different groups, HR appears to be more difficult to acquire. When HR and 95% CI were not specified in the articles, Kaplan-Meier curves were read by the digitizer tool in OriginPro 2016 (OriginLab Corp, Northampton, MA, USA), and then data were utilized to summarize the HR and standard error of ln(HR) by performing survival analyses.[26] Authors were contacted via e-mail for original data if HR or survival curves were not reported. Then HR was calculated using SPSS 22.0 (IBM Corp, Chicago, IL, USA). In the worst case, RR served as an alternative when time-to-event data were not available using all the above methods.

HRs and RRs with their variance of natural logarithm were pooled by a random-effects model using STATA 12.0 (Stata Corp, College Station, TX, USA). An HR or RR >1 indicated a worse prognosis in PLV survival. Statistical heterogeneity was tested using the I^2 statistic (significance level at $I^2 \geq 50\%$). If determinant factors such as porcelain materials, location of prosthesis, and tooth vitality were identified, subgroup analyses was performed using a random-effects model. Given that confounding factors were not consistent among studies, a sensitivity analysis, eliminating one study in each calculation, was performed to explore possible explanations for heterogeneity. Potential publication bias was assessed by visual inspection of the Begg's funnel plots and Begg's test. A two-sided $p \leq 0.05$ was considered statistically significant except where otherwise specified.

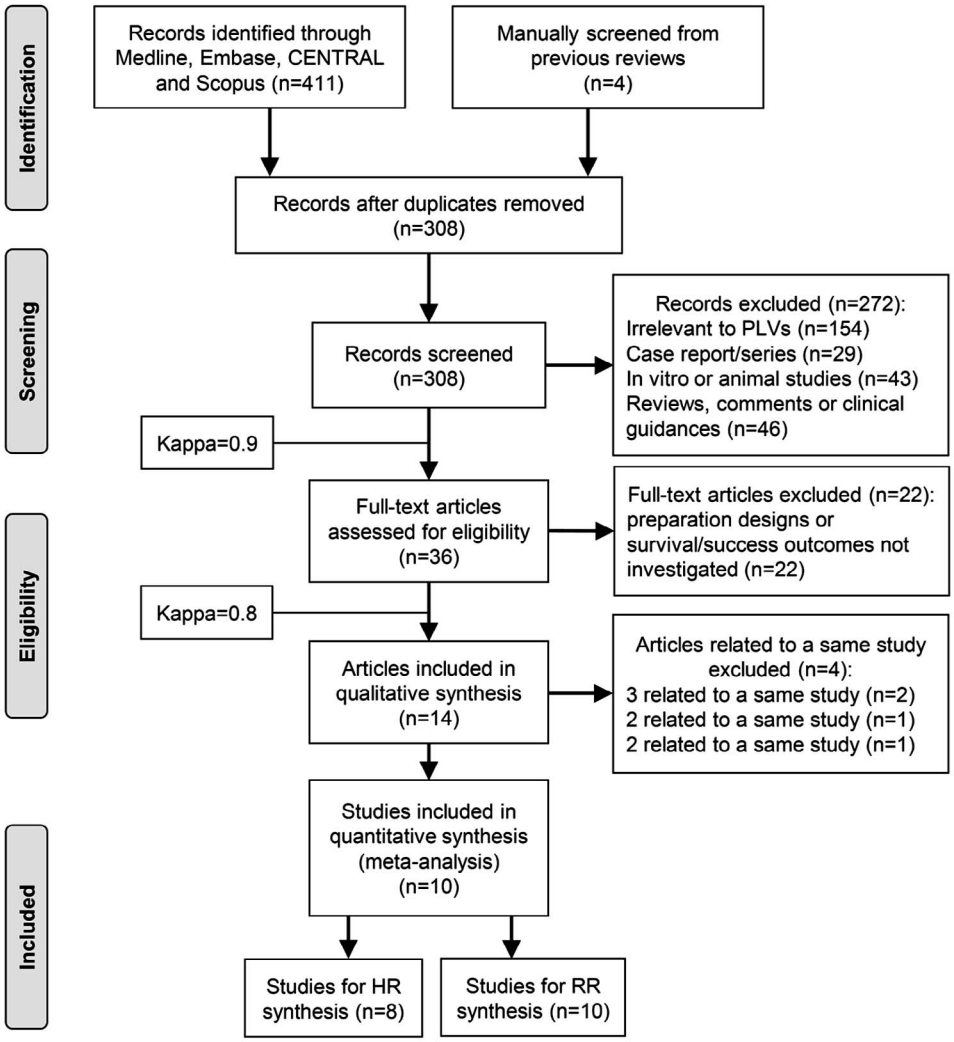

Figure 1. *Flowchart summarizing the study selection.*

Fig 1

RESULTS

Study Selection and Characteristics

With the defined criteria, electronic database searches via Medline, Embase, CENTRAL, and Scopus retrieved 199, 50, 21, and 141 articles, respectively. A total of 411 articles were identified. In addition, four articles were identified after manually screening the references of previous reviews. After the process of duplicate removal, initial screening, and full-text review, 10 studies with 14 articles were included in the meta-analysis (Figure 1). Of the 10 studies, only one reported HR and its 95% CI,[15,17] one provided a simplified lifetime table,[16] five provided Kaplan-Meier curves,[14,19-21,27,28] and one from China provided original data to calculate the HR value on author contact.[29] We did not receive replies from the authors of the remaining two studies.[18,30,31] Thus, eight studies were eligible for the overall HR estimate, and 10 were available for overall RR estimates.

The characteristics of the 10 studies are presented as follows (Table 2). These studies were published between 1998 and 2014, including one from the Netherlands,[18] two from Austria,[16,30,31] one from Australia,[14] three from Turkey,[15,17,21,28] one from China,[29] one from Spain,[27] and one from Germany.[19,20] More than 463 patients with a total of 2429 porcelain veneers were involved in the 10 studies. The designs of most studies were retrospective or prospective cohort studies, except one interim analysis of a randomized controlled trial.[18] However, the trial was incomplete, and its report resembled a cohort study.

Table 2: *Characteristics of the 10 Included Studies*

First Author	Country, Recruitment Period	Study Design; Duration (yrs)	No. of Patients and Veneers	Investigated Comparisons	Corresponding Number of Events/Total	HR Estimate with sSe[ln(HR)]
Meijering (1998)	Netherlands, 1994	Interim of RCT; 2.5	NA; 56	Butt-joint vs window	2/24; 1/32	NA
Dumfahrt (1999, 2000)	Austria, 1987–1996	RCS; 1–10 (mean: 4.5)	72; 191	With vs without incisal coverage	3/137; 4/54[a]	NA
Smales (2004)	Australia, 1989–1993	RCS; 1–7	50; 110	With vs without incisal coverage	1/46; 7/64	0.01 (408.25)[a]
Cortert (2009)	Turkey, 1999–2005	PCS; NA (median: 1.5)	40; 400	Overlap vs butt-joint	8/376; 4/24[a]	0.12 (0.72)[a]
Du (2009)	China, 1999–2007	RCS; 1–8	49; 308	With vs without incisal coverage	22/253; 4/55[c]	0.897 (0.546)[c]
Granell-Ruiz (2010)	Spain, 1995–2003	RCS; 3–11	70; 323	Overlap vs window	25/199; 17/124	1.39 (0.33)[a]
Beier (2012)	Austria, 1987–2009	RCS; 1–21 (mean: 10)	74; 292	Overlap vs window	20/245; 0/47	3.65 (0.54)[b]
Gurel (2012, 2013)	Turkey, 1997–2009	RCS; NA-12	66; 580	With vs without incisal coverage	24/261; 18/319	2.31 (0.3184)
Guess (2008, 2014)	Germany, 2000–2003	PCS; 1–7	14; 44	Overlap vs butt-joint	2/12; 10/32[a]	1.95 (1.61)[a]
Ozturk (2014)	Turkey, 2008–2011	PCS; 0.5–2	28; 125	Overlap vs butt-joint	6/42; 5/83[a]	3.95 (0.68)[a]

Abbreviations: F, female; HR, hazard ratio; M, male; NA, not available; PCS, prospective cohort study; RCS, retrospective cohort study; RCT, randomized controlled trial; RR, risk ratio; USPHS, US Public Health Service.
[a] *Not directly provided in papers but calculated from percentages or estimated from Kaplan-Meier curves.*
[b] *Estimated from Kaplan-Meier curves and lifetime table.*
[c] *calculated from the original data provided by the author.*

Of the 10 studies, descriptions of preparation designs varied, although they were referred to as the same type. The window type was sometimes described as the nonoverlap design or the design with uncovered incisal edge. The butt-joint type was also called the incisal bevel type or modified overlap design, while the overlap type was also called the functional type, full-veneer type, or even overlap type with palatal chamfer. The heterogeneity of names was then unitized and recoded into the same definition according to the respective reporting preparation methods. Regarding the comparisons, four reported with vs without incisal coverage,[14,15,17,29-31] three reported overlap type vs butt-joint type,[19-21,28] one reported butt-joint type vs window type,[18] and two reported overlap type vs window type.[16,27] Of these comparisons, the latter three could be categorized into "with vs without incisal coverage" simultaneously. As a result, four different meta-analyses for HR or RR estimates were performed based on the study comparisons.

Study Quality

The quality of included studies was evaluated with a global score consisting of three fields: Selection, Comparison, and Outcome (Table 3). In total, nine (90%) studies were of high quality, and only one (10%) was of moderate quality. Two studies included patients with worn-out teeth or bruxism, so they could not be scored for the item of representativeness. Similarly, an additional three studies did not meet the requirement of comparability, duration of follow-up, and adequacy of follow-up, respectively.

Failure Risk of Preparation With vs Without Incisal Coverage

Seven studies involving 1860 PLVs were included in this comparison, two of which were excluded because limited information was provided to estimate the HR value. The pooled HR using a random-effects model revealed that PLVs with incisal coverage had a worse prognosis compared to those

Table 2: *Characteristics of the 10 Included Studies (ext.)*

First Author	Potential Confounding Factors					
	Porcelain Materials	Location of Prostheses	Tooth Vitality	Adhesive Systems	Bruxism Excluded	Same Operator
Meijering (1998)	Feldspathic: Flexo-ceram	Maxillary anteriors	Vital+non-vital	Flexo-ceram	NA	No
Dumfahrt (1999, 2000)	Feldspathic: Optec	Maxillary and mandibular anteriors and premolars	Vital+non-vital	Multiple: Variolink; Optec; etc.	No	No
Smales (2004)	Feldspathic: Mirage	Maxillary and mandibular anteriors	NA	Multiple: Mirage; Ultra-Bond	Yes	No
Cortert (2009)	Nonfeldspathic: IPS Empress	Maxillary and mandibular anteriors	Vital+non-vital	Variolink II	Yes	Yes
Du (2009)	Nonfeldspathic: Vintag; Ceramco	Maxillary and mandibular anteriors and premolars	Vital only	3M ESPE	No	Yes
Granell-Ruiz (2010)	Nonfeldspathic: IPS Empress	Maxillary and mandibular anteriors and premolars	Vital only	Syntace	NA	No
Beier (2012)	Feldspathic and non-feldspathic (NA)	Maxillary anteriors	Vital only	Multiple: Optibond FL; Syntac Classic; etc.	NA	NA
Gurel (2012, 2013)	Feldspathic and nonfeldspathic: IPS Empress I/II/ Esthetic; Creation	Maxillary and mandibular anteriors and premolars	Vital+non-vital	Multiple: Variolink II; 3M ESPE; Variolink Veneer; etc.	No	Yes
Guess (2008, 2014)	Nonfeldspathic: IPS Empress	Maxillary and mandibular anteriors	Vital only	Variolink II	NA	No
Ozturk (2014)	Nonfeldspathic: IPS Emax	Maxillary anteriors	Vital+non-vital	Variolink Veneer	Yes	Yes

Table 3: *Study Quality Assessment According to the Newcastle-Ottawa Scale*

Study	Selection				Comparability	Outcome			Global Score
	Representativeness of Exposed Cohort	Selection of Nonexposed cohort	Ascertainment of Exposure	Outcome Not Present at Start		Assessment of Outcome	Follow-Up Long Enough	Adequacy of Follow-Up	
Meijering (1998)	*	*	*	*	*	*	*		7
Dumfahrt (1999, 2000)		*	*	*			*	*	5
Smales (2004)	*	*	*	*	*	*	*	*	8
Cortert (2009)	*	*	*	*	**	*		*	8
Du (2009)		*	*	*	**	*	*	*	8
Granell-Ruiz (2010)	*	*	*	*	*	*	*	*	8
Beier (2012)	*	*	*	*	*	*	*	*	8
Gurel (2012, 2013)		*	*	*	**	*	*	*	8
Guess (2008,2014)	*	*	*	*	*	*	*	*	8
Ozturk (2014)	*	*	*	*	**	*		*	8

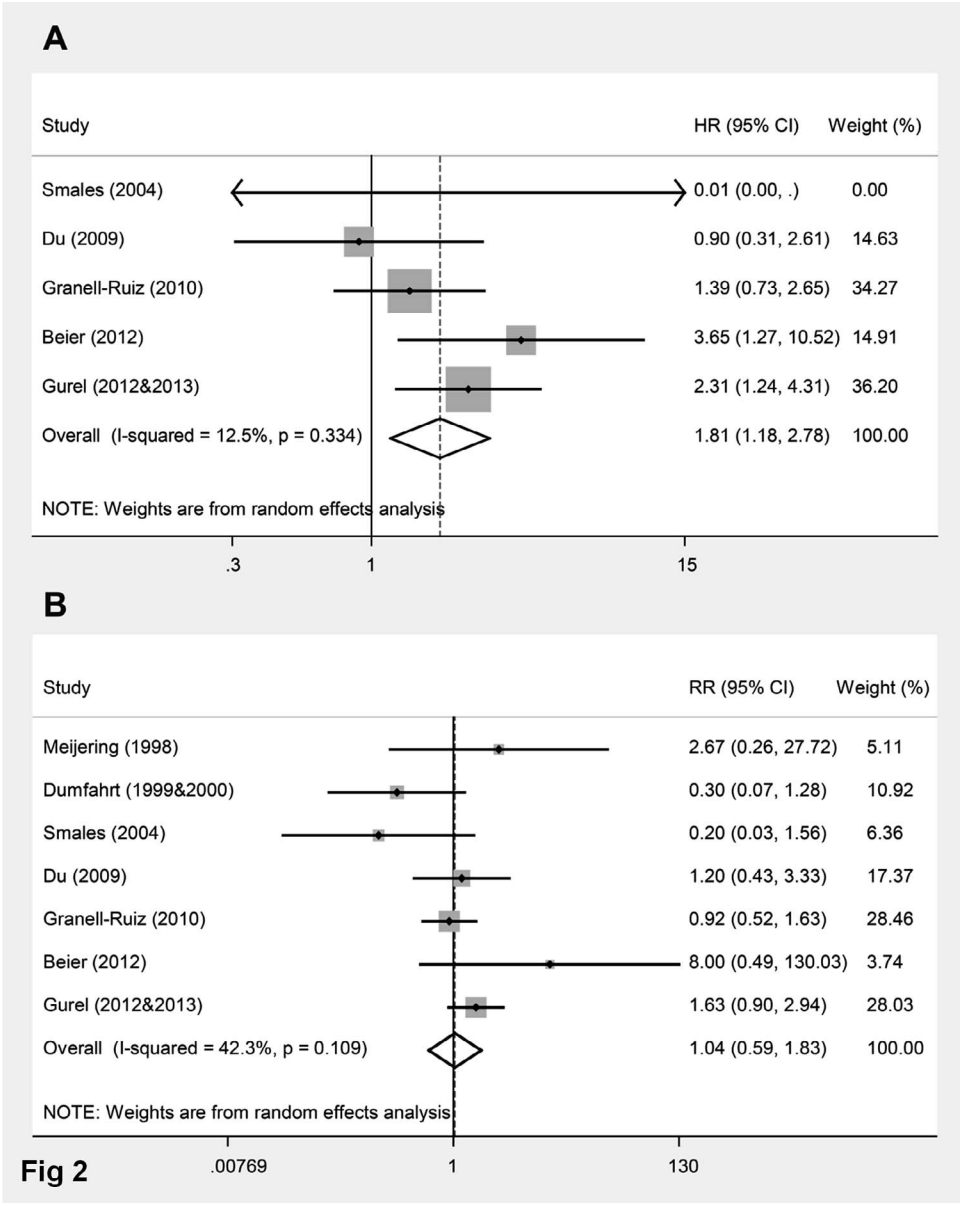

Figure 2. *Meta-analysis of pooled hazard ratios (HRs) (A) and risk ratios (RRs) (B) comparing preparations with and without incisal coverage.*

without incisal coverage (HR=1.81, 95% CI=1.18-2.78) (Figure 2A). Test of inconsistency (I^2=12.5%, p=0.334) excluded significant heterogeneity. However, subgroup analyses were still performed to investigate differences in the results with respect to the porcelain materials, location of prosthesis, and tooth vitality. In the subgroup analysis concerning the porcelain materials, we identified two studies involving both feldspathic and nonfeldspathic PLVs indicating a statistically significant association between failure risk and preparation type with incisal coverage (HR=2.60, 95% CI=1.52-2.65) (Figure 3A). Similarly, when divided based on location of prosthesis, the study involving maxillary anteriors revealed that a significantly increased failure risk was related to PLVs with incisal coverage compared to those without coverage (HR=3.65, 95% CI=1.27-10.52) (Figure 3C). Moreover, studies with PLVs restored on both vital and nonvital teeth indicated that an increased risk was linked to preparations with incisal coverage (HR=2.31, 95% CI=1.24-4.31) (Figure 3E).

Nevertheless, the pooled RR of all studies showed that the failure risk was not related to the preparation type with incisal coverage (RR=1.04, 95% CI=0.59-1.83, I^2=42.3%, p=0.109) (Figure 2B). Then we also divided studies based on the preset perspectives. However, neither of the subgroup analyses regarding the porcelain materials, location of pros-

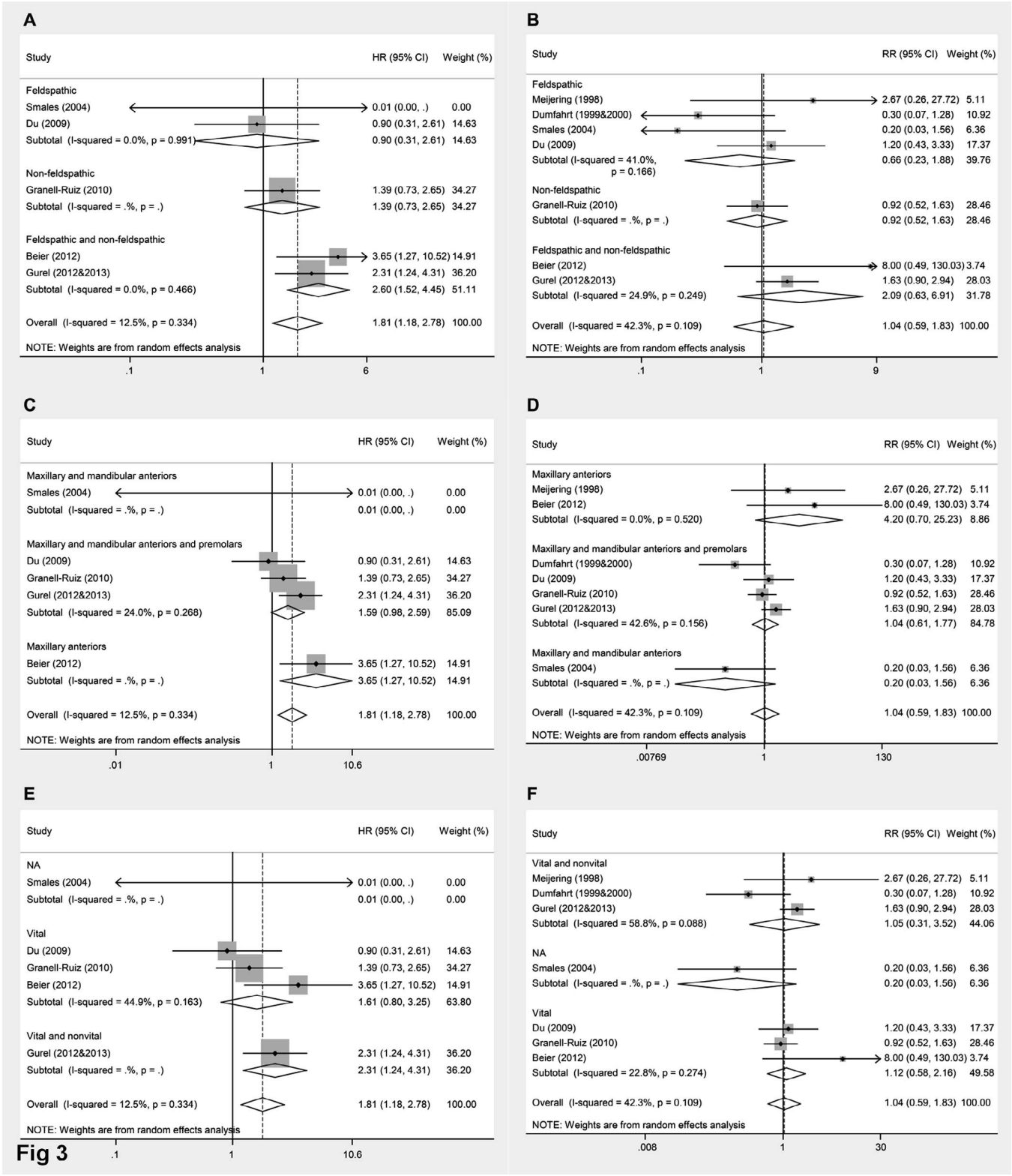

Figure 3. *Subgroup analyses of pooled hazard ratios (HRs) (A,C,E) and risk ratios (RRs) (B,D,F) comparing preparations with and without incisal coverage.*

Table 4: *Sensitivity Analysis for the Pooled Hazard Ratios (HR)/Risk Ratios (RRs) by Omitting a Single Study Sequentially*

Study Omitted	HR (95% CI)	RR (95% CI)
With vs without incisal coverage		
Meijering (1998)	—	0.98 (0.53, 1.79)
Dumfahrt (1999, 2000)	—	1.21 (0.72, 2.01)
Smales (2004)	1.81 (1.10, 2.97)*	1.16 (0.69, 1.95)
Du (2009)	2.01 (1.33, 3.04)*	0.99 (0.49, 2.00)
Granell-Ruiz (2010)	2.06 (1.17, 3.65)*	1.05 (0.47, 2.33)
Beier (2012)	1.62 (1.08, 2.46)*	0.97 (0.56, 1.67)
Gurel (2012, 2013)	1.59 (0.88, 2.85)	0.87 (0.43, 1.74)
Overlap type vs butt-joint type		
Cortert (2009)	3.55 (1.04, 12.12)*	1.18 (0.28, 5.09)
Guess (2008, 2014)	0.69 (0.02, 21.30)	0.55 (0.03, 9.64)
Ozturk (2014)	0.33 (0.02, 4.64)	0.25 (0.06, 1.00)

*$p < 0.05$ in significance test of the pooled effect statistic.

thesis, and tooth vitality yielded statistically significant outcomes (Figure 3B,D,F).

To evaluate the stability of our results, we performed a sensitivity analysis by omitting a single study sequentially and recalculating the summarized HR or RR for the remaining studies (Table 4). The result changed only when the study by Gurel and others[15,17] was removed, indicating that our findings were quite robust and reliable. In addition, visual inspection of Begg's funnel plot and Begg's test to evaluate publication bias revealed no evidence of publication bias among studies investigating preparations with or without incisal coverage (HR: p=0.734; RR: p=0.764) (Figure 4).

Failure Risk of Overlap Type vs Butt-Joint Type

A total of three studies were eligible for the comparison of the overlap type and butt-joint type. The global analysis of either the pooled HR or the RR estimates revealed insignificant results (HR=0.91, 95% CI=0.07-12.02; RR=0.54, 95% CI=0.09-3.32) (Figure 5), indicating no distinction between the failure risk of the overlap type compared to the butt-joint type. The test of inconsistency indicated that distinct heterogeneity existed among these three studies (HR: I^2=84.3%; RR: I^2=85.3%). Then the subgroup analyses based on location of prosthesis and tooth vitality (because all were composed of nonfeldspathic PLVs) were performed to work out the cause of heterogeneity (Figure 6). The heterogeneity was reduced only when the studies were divided according to the location of prosthesis. The study by Ozturk and others[28] revealed an increased failure risk along with the preparation of overlap type compared to butt-joint type (HR=3.95, 95% CI=1.04-14.98). This finding favors the butt-joint type when determining the reduction of the incisal edge for preparation of a porcelain veneer. Sensitivity analysis, when excluding the study by Cortert and others,[21] made the pooled HR >1 significant (Table 4). However, given the limited number of studies and incomprehensible heterogeneity, the failure risk of the overlap type compared to the butt-joint type remained unclear.

Failure Risk of Overlap Type vs Window Type

Only two studies were eligible for the comparison of the overlap type and window type, and the pooled HR and RR indicated no differences between their failure risks (HR=2.05, 95% CI=0.81-5.18; RR=1.84, 95% CI=0.22-15.64) (Figure 7). The test of inconsistency revealed obvious heterogeneity between the studies (HR: I^2=57.0%; RR: I^2=61.3%). Although the subgroup analyses were limited due to the limited number of included studies, the study by Beier and others[16] involving "feldspathic and nonfeldspathic" PLVs and location in "maxillary anteriors" yielded a positive outcome (HR=3.65, 95% CI=1.27-10.52), which is similar to the results of subgroup analyses performed in the comparison of with vs without incisal coverage.

Failure Risk of Butt-Joint Type vs Window Type

Only one study, by Meijering and others,[18] was eligible for the comparison of butt-joint type and window type. This study could provide only the failure frequency in each cohort so as to calculate the RR estimate of the butt-joint type vs window type. It investigated feldspathic veneers restored on maxillary anterior vital or nonvital teeth. No difference

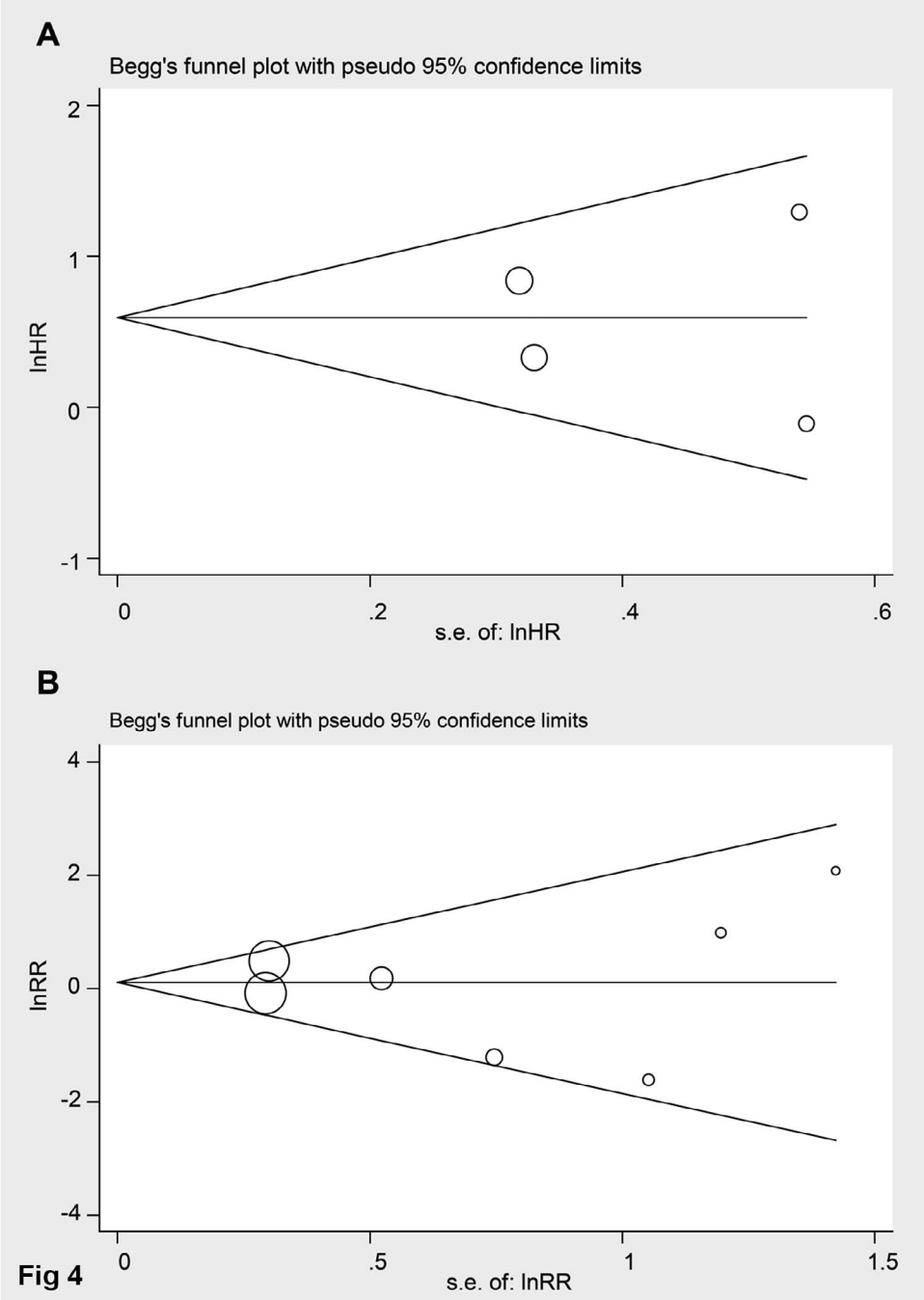

Figure 4. *Begg's funnel plots for included studies for pooled hazard ratios/risk ratios (HRs/RRs) comparing preparations with and without incisal coverage.*

was noted between the failure risks of the butt-joint type compared to the window type (RR=2.67, 95% CI=0.26-27.72).

DISCUSSION

The interest in the association between preparation designs and risk of failure of PLVs is rapidly growing. Various studies have discussed the effect of preparation designs on PLV survival or success since 1998 from the perspective of comparing with and without incisal coverage or comparing any two of the overlap, butt-joint, and window types. Some studies reported no statistically significant survival rates between veneers with and without incisal coverage,[13,14] whereas some studies revealed significantly more failures in veneers with coverage compared to those without coverage.[15-17] Thus, controversy exists in studies investigating any two concrete designs.[13,16,18-21,27-29] To better illustrate the role of preparation types in the prognosis of

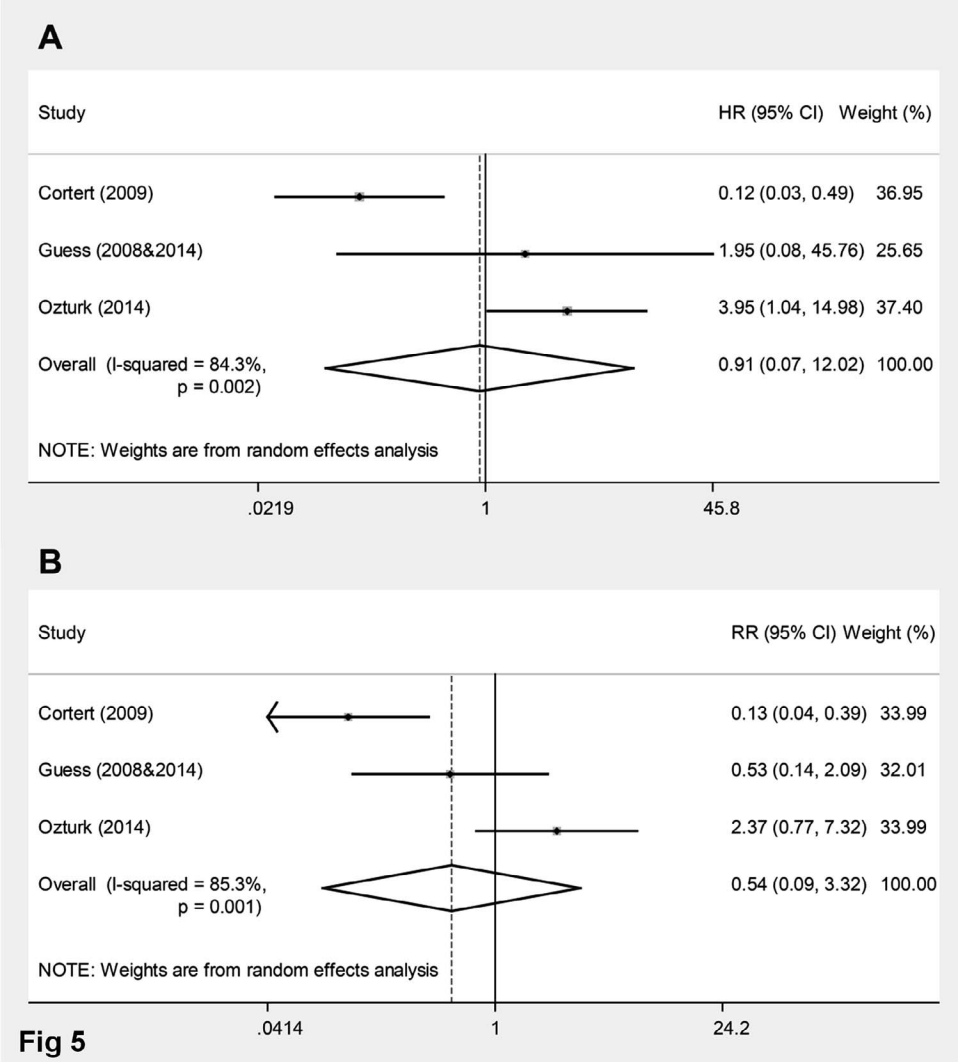

Figure 5. *Meta-analysis of pooled hazard ratios (HRs) (A) and risk ratios (RRs) (B) comparing overlap and butt-joint types.*

PLVs, systematic review and meta-analysis are advantageous to augmenting sample size and statistical power from individual studies. An earlier systematic review focusing on incisal coverage stated that an overall OR of 1.25 pooled from three studies was associated with incisal-edged-covered veneers, but the results were statistically insignificant (95% CI=0.33-4.73).[22] Furthermore, a recommended preparation design among overlap, butt-joint, and window types remains unknown, although a fairly large amount of clinical research has arisen.

The results in the present review indicated that an increased failure was related to incisal coverage. However, as the design of incisal coverage includes the concept of overlap type and butt-joint type, a thorough analysis becomes necessary to clarify which one declines the survival rate of incisal coverage and whether differences exist between overlap and butt-joint types. The multiple comparisons yielded three, two, and one studies, respectively, as well as substantial between-study heterogeneity. Therefore, the evidence was still insufficient to answer the above questions.

The most recent study by Ozturk and others,[28] who investigated nonfeldspathic PLVs (IPS E.max) restored on maxillary anteriors (vital or nonvital), reported an HR of 3.95 comparing the overlap type to the butt-joint type. This finding is consistent with the sensitivity analysis concerning overlap type vs butt-joint type when omitting the study of Cortert and others.[21] Thus, we speculate that an increased risk was associated with the overlap type compared to the butt-joint type. Moreover, a tentative inference was built that the overlap type may predict a poorer prognosis in the comparison of overlap and window types (Figure 7).

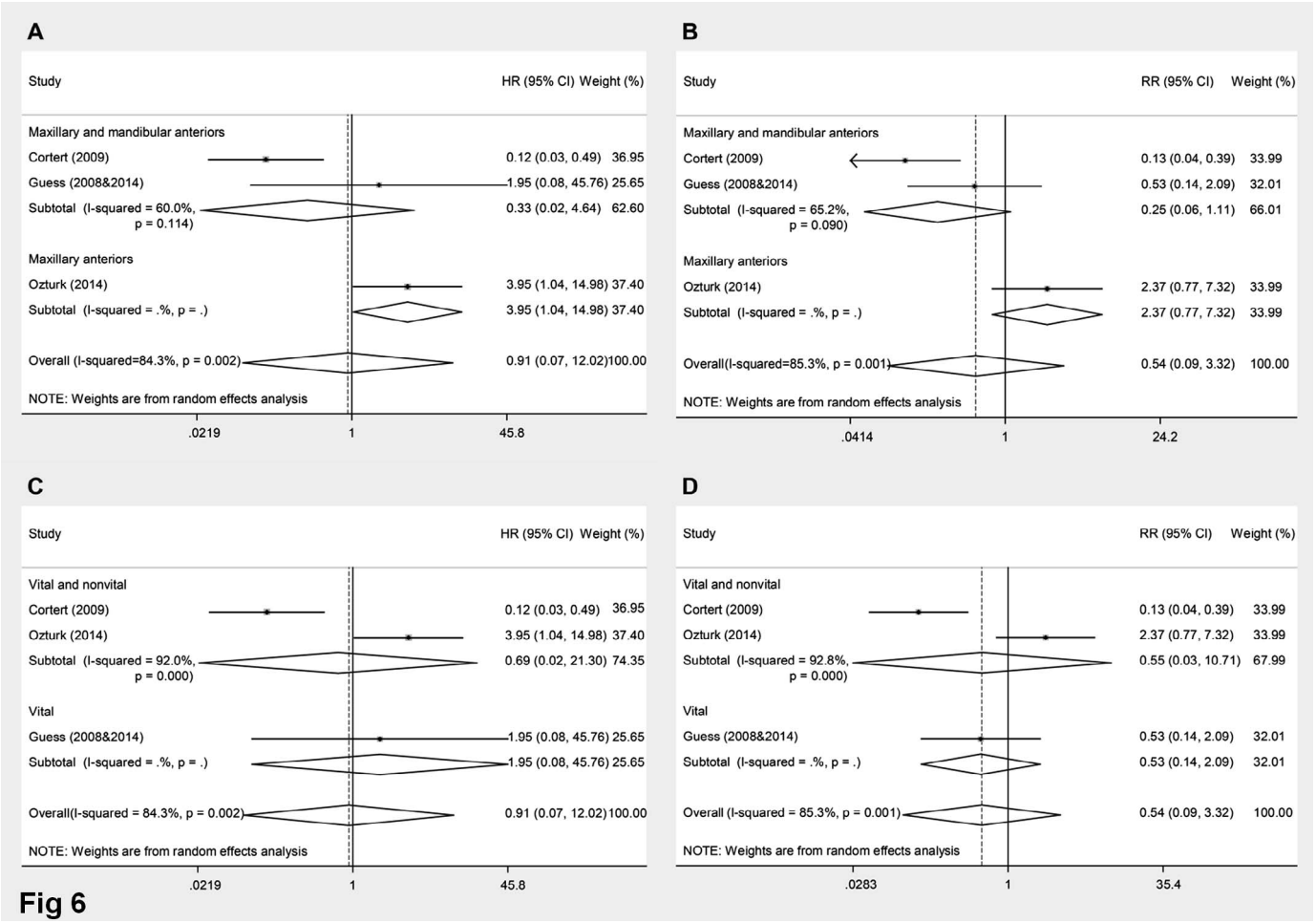

Figure 6. *Subgroup analyses of pooled hazard ratios (HRs) (A,C) and risk ratios (RRs) (B,D) comparing overlap and butt-joint types.*

Finite element analysis (FEA), as corroborative evidence, can help us understand this issue since it is an effective and powerful solution to describe stress distribution with different preparation designs theoretically. The two-dimensional FEA revealed that a butt-joint design suffers less tensile stress but more compressive stress than an overlap design.[5] This is due to the chamfer margin extending to the palatal concavity and consequently an increased stress concentrating at the restoration interface. The characteristic of overlap type was also seen when compared to the window type;[32] however, the overlap type shows a higher principal maximum stress to withstand than the window type.[7] The three-dimensional FEA presented a more uniform stress distribution in the adhesive layer in the overlap design than other designs;[4,6] thus, the overlap type was recommended for PLVs. Nevertheless, Bergoli and others[7] supposed it possible that results of FEA change if fragile materials, such as feldspathic porcelain, are used, which is consistent with the conclusion in the above FEA analysis.[5] In conclusion, we insist that the butt-joint type is recommended when incisal coverage is needed, especially for feldspathic porcelain.

Indeed, the three-type classification for PLVs is not a sufficiently comprehensive method to describe the preparation. Clinicians were often required to deal with the proximal preparation with the consideration of diastema, interproximal caries, and severely discolored teeth. Of the included studies in this systematic review, Cortert and others[21] divided the proximal preparation design into a proximal chamfer and proximal slice, the survival rate of which differed significantly. The reason why the study by Du and others[29] was only classified into preparation with or without incisal coverage was because a Chinese "ILU" classification system was used. The concept of "ILU" arose from the three-dimensional shape of PLVs, with the window type named "I" and the butt-joint or overlap type not

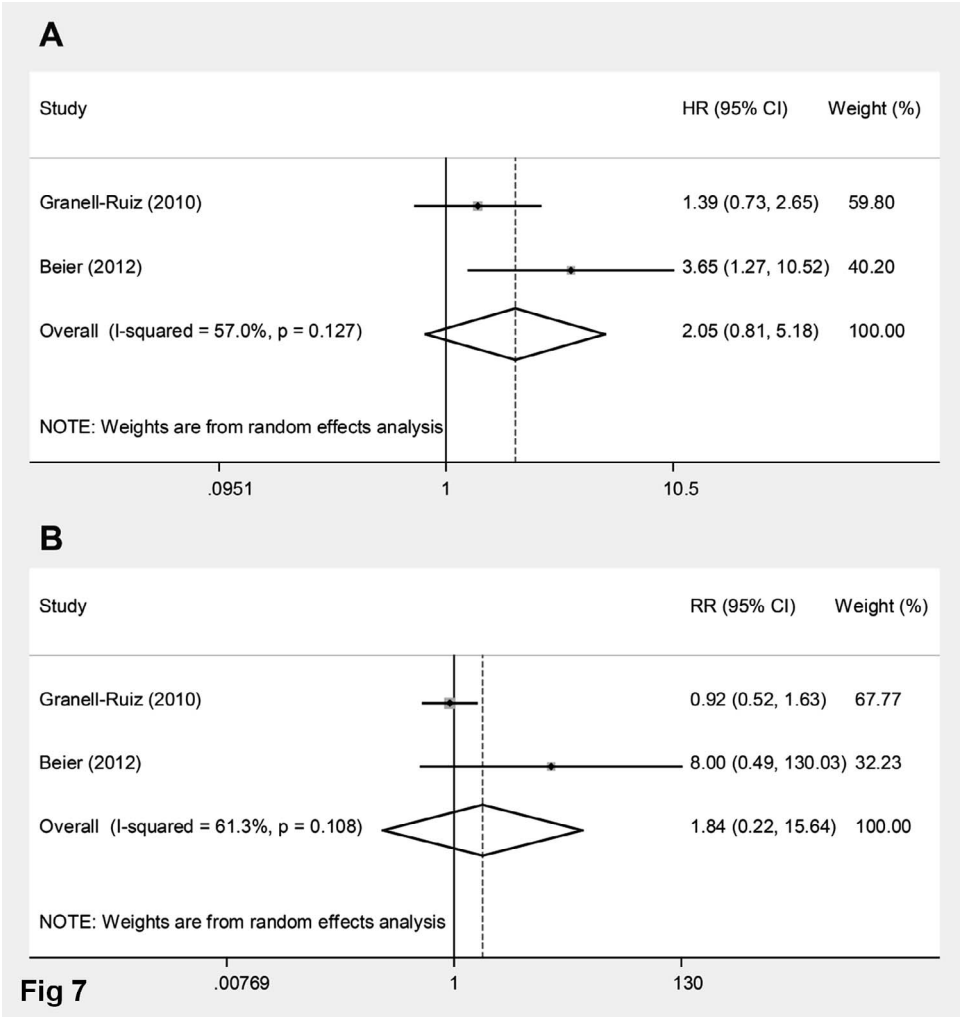

Figure 7. *Meta-analysis of pooled hazard ratios (HRs) (A) and risk ratios (RRs) (B) comparing overlap and window types.*

involving proximal preparation named "L." Thus, the butt-joint or overlap type with proximal preparation was named "U." Given that there was no evidence for the effect of proximal preparation on the survival of PLVs, the "ILU" classification was worth using.

It is worth mentioning that the HR was adopted as the effect statistic in the present meta-analysis. The failure of a veneer is a time-related variable or, rather, time-to-event data instead of a merely categorical variable. Time-to-event data can be treated as dichotomous data only when the observation duration of all investigated individuals is consistent.[33] Therefore, the HR was introduced to describe how many more times a PLV with a specific preparation design suffered failure at a particular time point than did a PLV with another design. As recommended by Parmar,[25] the log HR and its variance were the most appropriate for time-to-event data to improve the efficiency and reliability of meta-analysis. The HR can identify the intrinsic difference more effectively in dealing with time-to-event data than the RR, which is often used in cohort studies measuring dichotomous data. With this in mind, we preferentially extracted HR from Kaplan-Meier curves, lifetime tables, or original data from authors. The routinely used RR was also involved to determine whether results were similar.

Our study has some limitations. First, the number of included studies was limited, especially for detailed comparisons of different preparation designs. Although a variety of well-reported clinical trials or long-term observational studies were included, few involved more than one preparation design.[34-39] Second, in order to work out and reduce heterogeneity among included studies, subgroup analyses were performed in our systematic review. We performed the subgroup analyses stratified by tooth vitality because Coelho-de-Souza and others[40] had pointed out that veneers in nonvital teeth have two times higher risk of failure than those in vital

teeth. However, the heterogeneity was supposed to be reduced theoretically with reasonable grouping factors, some of which remained unaccountable even in subgroup analysis stratified by porcelain materials, location of prosthesis, and tooth vitality. This limitation was likely due to the different evaluation criteria for failure, follow-up duration, and whether one or more operators were involved among the analyzed studies. In addition, the different events of mechanical failure should be categorized into debonding and fracture, which could help categorize relative and absolute failures and determine whether a new porcelain veneer can be made.

Some extra findings were discovered, although not all studies have addressed as many confounding factors as possible. Preparation involving dentin exposure or, rather, the declined percentage of enamel vs dentin bonding surface[17,21,28,41,42] would reduce the long-term survival of PLVs. So did the preparation based on existing composite restorations.[36,43,44] Furthermore, no study has thus far investigated the impact of occlusion types and adhesive systems. Finally, but interestingly, we identified that three studies[15-17,28] published between 2012 and 2014 tended to generate a positive outcome. All of them had quite a large sample size and investigated nonfeldspathic PLVs. It was hypothesized that the failure risks among different preparation designs could be interpreted in ceramics with high strength since feldspathic porcelain is too fragile to survive any other risk factors.

In summary, further studies are needed to clarify the prognosis among overlap, butt-joint, and window types for PLV restoration. We recommend that porcelain materials, adhesive systems, location of prosthesis, tooth vitality, operator, different events of failure, and occlusion types be taken into consideration when designing a clinical trial or analyzing a follow-up study.

CONCLUSIONS

Current evidence indicates that preparations with incisal coverage for PLVs exhibit an increased failure risk compared to those without incisal coverage, whereas there is no difference between overlap and butt-joint types. With the limitation of the present study, well-designed clinical trials or observational studies are needed to confirm our results.

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Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of the Department of Prosthodontics, Guanghua School of Stomatology, Hospital of Stomatology, Sun Yat-sen University, and Guangdong Provincial Key Laboratory of Stomatology, Guangzhou, China. This study protocol was registered at the PROSPERO (CRD42016040166) and conformed to the proposed MOOSE (Meta-Analysis of Observational Studies in Epidemiology) guidelines.

Conflict of Interest

The authors of this article certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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