The effect of prosthetic margin location on caries susceptibility. A systematic review and meta-analysis

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ABSTRACT

Background The prosthetic margin location relevant to the free gingival margin may influence the incidence of secondary caries due to the differences that exist between the micro-environment within the gingival crevice compared to the rest of the oral environment. Objective The purpose of this study was to systematically review the effect of prosthetic margin placement on caries susceptibility of abutment teeth. Method Two independent authors identified cohort studies using MEDLINE, EMBASE, CDSR, CENTRAL, Google Scholar, and Scopus through March 2012. Reference lists were also scanned. Included studies had to report on caries incidence with regard to location of prosthetic margins, with a minimum follow-up period of 2 years. Results A total of 5541 references were identified and, after application of the inclusion criteria, 22 studies were included in the systematic review. Data synthesis could be made in 2 studies, in which secondary caries incidence did not differ between margins placed subgingivally compared to equi- or supragingivally placed margins for a follow-up period up to 10 years. Indications were found of a possible lower secondary caries rate at 15 years of follow up, based on 1 study. Conclusion This systematic review and meta-analysis failed to detect a significantly different secondary caries rate of subgingivally located prosthetic margins in the short to mid-term (≤10 years). Due to the small number and the limitations of the included studies the results do not provide conclusive evidence as to the effect of prosthetic margin placement on the incidence of secondary caries.

INTRODUCTION

Dental caries is a progressive disease existing as a result of bacterial biological processes that affect dental tissues (enamel, dentin and cementum) and is dietary-dependent and host-specific.[1] If left untreated, it results in the formation of lesions on the tooth's surface (initially as chalky white spots), whose final stage is the development of cavities. Two bacteria species are mainly responsible for dental decay, *Streptococcus mutans*[2] (SM) and *Lactobacillus*[3] (LB), both found in the normal oral *microbiota*. Although the bacterial community in dental plaque is complex, evidence exists which suggests that mutant streptococci are associated with caries initiation, while Lactobacillus is associated with caries progression.[4-6] Caries is one of the most common reasons for tooth loss worldwide, while caries susceptibility depends upon age, diet, region, social status, race and many other parameters.[7-13] Caries and/or loss of retention have been reported to be the primary cause of failures of fixed prostheses.[14] Early and more extended adherence of SM on restoration margins has been found in patients presenting with high caries susceptibility.[15] Prosthetic restoration margins present with an increased risk compared to natural tooth surfaces for caries occurrence, even when the prostheses have acceptable fit.[16]

The tooth offers different sites for bacterial colonization both above the gingival margin (supragingival) and below it (subgingival). The *microflora* of the healthy gingival crevice tends to consist of relatively few cells and is predominated by Gram-positive organisms, mainly *Streptococcus* species and *Actinomyces* species. Many of these strains are thought to be commensals, and a smaller number, opportunistic pathogens.[17] Spirochaetes appear sporadically increased in 7- and 14-day-old subgingival plaque. Gram-positive rods are predominant in developing supragingival plaque, whereas motile rods and spirochaetes are found in slightly higher proportions in ageing subgingival plaque. Apart from these minor differences, the composition of supragingival and subgingival plaque during a 2 week period of plaque development was similar.[18,19] However, the micro-environment within the gingival crevice has some differences compared to the rest of the oral environment. The principal source of nutrients is not saliva but the gingival crevicular fluid, which is similar to plasma, from which it originates, in that

it contains protein, albumin, leukocytes, immunoglobulins and complement.[5] The subgingival conditions are anaerobic, and the gingival crevice is not exposed to dietary components and the buffering role of saliva. The alkaline ph of the gingival crevices/periodontal pockets may selectively induce the colonization by periodontopathogens.[5,20,21] These potential environmental differences may have an effect on caries susceptibility of abutment teeth with subgingival prosthetic margins. Another possible factor, that may possibly influence caries susceptibility at the margins of abutment teeth, is the fact that the subgingival placement of the crown margin may possibly, under controlled oral health conditions, delay the exposure of cementum to the bacteria, until gingival recession has proceeded. The colonization of root surfaces by acidogenic and aciduric bacteria creates an environment of low ph, which, when it reaches the critical ph range of 5.0 to 5.5,[22] favours the demineralization of the tooth's hard tissues.[5]

Textbooks[23,24] and published research[25] suggest the placement of the prosthetic restoration finish line supragingivally whenever possible, as utilization of the pocket space increases the risk of periodontal inflammation. Subgingival restorative margins have been advocated for patients in high caries-risk groups.[26] Other investigators have shown no influence of margin placement on caries incidence.[25,27] The evidence regarding the relationship between prosthetic margin placement in relation to the gingival crevice and caries susceptibility seems inconclusive.

The purpose of this study was to systematically review the effect of prosthetic margin placement, in relation to the gingival crevice, on caries susceptibility of abutment teeth.

METHODS

Methods of the review

The PRISMA statement was used as a protocol for the systematic review.[28]

1. Search strategy

The literature search was conducted by two reviewers (S.N.P. and A.P.P.) using

electronic databases (Medline via PubMed, Embase, Google Scholar, Cochrane Central Register of Database of Systematic reviews [CDSR], Cochrane Central Register of Controlled Trials [CENTRAL] and Scopus) for clinical studies on humans reporting on prosthetic margins' caries susceptibility and location in relation to the gingival crest. The search covered the time span between January 1980 and April 2012. The same search terms were applied in all databases and included the terms 'caries', 'decay' and 'cavity' combined with the following terms: 'crowns', 'fixed partial dentures', 'prosthetic restorations', 'subgingival', 'supragingival', 'margin', 'finish' and 'finish line' (Table 1). The search was augmented with the use of the "related articles" option and cross-reference checking.

Additionally, hand searching was applied to the following journals for the time period of the search: Journal of Prosthetic Dentistry, International Journal of Prosthodontics, Journal of Dentistry, and Caries Research.

2. Selection of studies

The selection process was conducted in two phases. During the first phase the titles and abstracts were screened by two of the authors (S.N.P. and A.P.P.) according to the following exclusion and inclusion criteria:

Exclusion criteria

1. Laboratory studies
2. Case reports
3. Technical articles
4. Studies in a language other than English or without an English abstract

Inclusion criteria

1. Clinical studies (Randomized controlled clinical trials, prospective or retrospective studies or case-control observational studies) reporting on caries susceptibility of teeth serving as abutments for prosthetic restorations.
2. Study results provided by follow-up of patients.

Disagreements were resolved by discussion and in case of doubt the full-text of the article was obtained; if no agreement could be reached, the third author was

consulted (H.P.P.). The full text of all articles that passed the first review phase was obtained. Additionally, manual search of the references of all full text articles selected, as well as hand searching of the selected dental journals was implemented at this point.

The second phase of the selection process was carried out by the two authors independently on the full-text of the studies obtained from the first phase using the following inclusion criteria:

1) Mean follow-up time of at least 2 years
2) Number of patients included in the study reported.
3) Number of restorations and abutment teeth or abutment surfaces included in the study reported.
4) Restorative margin location reported and associated to caries incidence.

The inter-reviewer agreement for the 4 inclusion criteria of the second phase of the selection process was determined using Cohen's kappa coefficient. In studies where only the minimum follow-up time was mentioned, that interval was used to measure the total exposure time of the restorations. In cases of multiple publications following the same cohort of patients, the study with the longest follow-up or the most complete record was taken into account. Restorative margin location was recorded as mentioned at the last clinical follow-up of each study.

3. Study quality assessment

The final included studies that passed the second review phase were classified according to the strength of evidence into four categories according to a previous published categorization[29]: A1 (controlled clinical trial with patient randomization), A2 (controlled clinical trial with split-mouth randomization), B (prospective controlled trial without randomization), and C (clinical studies with designs other than category A and B-retrospective, case series, etc.).

If no consensus was achieved on data selection and extraction, or methodological and descriptive assessment between the two independent observers (S.N.P. and A.P.P.), a third independent observer made the final decision (H.P.P.).

4. Data synthesis

Data of selected studies were tabulated according to demographical and clinical information. Caries incidence of prosthetic margins was studied at abutment or surface level, depending on study results. Trials were compared by grouping abutments teeth/abutment surfaces with subgingival margins as the experimental group and abutments teeth/abutment surfaces with equigingival or supragingival margins as the control group. Caries incidence was evaluated as a dichotomous variable. Direct analysis between experimental and control groups was performed whenever study design permitted, and when definite caries incidence (excluding null ones) was provided for both groups. The Risk Ratio (RR) for caries incidence of prosthetic margins was calculated for the direct comparisons based on the random-effects model,[30] with values below 1.0 favoring the experimental group (subgingival margins). Cumulative caries event rates/100 prosthesis years were reported for individual studies. The impact of statistical heterogeneity was assessed using the I^2 statistic[31] with I^2 values over 50% indicating a substantial level of heterogeneity. All *P* values were 2-sided with significance set at $p \leq 0.05$, except for $p < 0.10$ for the heterogeneity tests. Statistical analysis was performed using appropriate software (Review Manager 5.1, The Cochrane Collaboration, Oxford, UK). The quality of evidence supporting the association between secondary caries and margin placement was assessed using the Grading of Recommendations, Assessment, and Evaluation (GRADE) system.[32]

RESULTS

Preliminary search of databases yielded 5541 references (Table 1). One hundred sixteen additional references were identified through reference lists and manual searching. Exclusion of duplicate references according to the initial screening left 2490 references for evaluation. A total of 2233 and 351 references were eliminated by the criteria of phase I and phase II respectively. Twenty-two studies were finally included in the qualitative synthesis.[26,27,33-52] Inter-reviewer agreement during the second review phase ranged from ‘substantial agreement’ to ‘almost perfect

agreement' (kappa: 0.715 - 0.933) (Table 2). The flowchart of the results and the review process according to the PRISMA statement is provided in Figure 1.

The 22 included studies corresponded to a total of 2648 prosthetic restorations placed at 1242 patients with mean follow-up time ranging between 2 to 11.4 years. All selected studies were published between 1990 and 2012. Most of the studies were classified as category C according to the strength of evidence.[29] The majority of the selected studies were carried out in a university setting. The demographics and design of the included studies are described in detail in Tables 3-4.

The majority of the selected studies reported on the survival of fixed partial dentures (FPDs) and single crowns (SCs). Out of the 22 final studies only 5 reported that secondary caries had occurred.[26,27,35,36,52] One study[49] provided data for both porcelain-fused-to-metal crowns and porcelain laminate veneers, but only the latter were eligible to be included. One study reported data on both tooth-supported and implant-supported crowns, but only the former are here reported.[44] One study[26] reported on conical crowns used under overdentures. One study,[51] assessing single or multiple prosthetic crowns, reported margin location only for the buccal and lingual surfaces, and only those were included. The selected studies showed great variation regarding age of sample, examination methods, primary outcomes, statistical analysis and reporting of results. Only 3 studies[26,27,52] made a direct comparison of caries incidence between control and experimental groups, all on surface level. The study[26] on conical crowns under overdentures was judged to investigate a different microbiological environment compared to that of fixed prostheses and was excluded from the meta-analysis, finally leaving two eligible studies.[27,52]

The included studies were stratified according to whether location of margins on the abutment was reported at tooth level or at surface level. In most of the studies the location of the margins was placed at the gingival crest or above. Among the 14 studies measuring caries on abutment tooth level, in 5 studies[34-37,46] the margins were placed solely equigingivally/supragingivally, in 4 studies[39,42-44] solely subgingivally and in the last five[33,38,40,41,45] a combination of the above. Of the total of 2516 abutment teeth included, 2110 (83.9%) had the margins placed at or

above the gingival level whereas 406 (16.1%) had subgingival margins. Estimated caries rate per 100 years for abutment teeth in individual studies ranged from 0 to 2.40 in the control group, while in the subgingival group no caries was observed.

In all of the seven studies[27,47-52] measuring caries on abutment surface level the margins were placed both supragingivally/equigingivally and subgingivally. Of the total 3153 surfaces examined, 1607 (51.0%) had supragingival/equigingival margins, while 1546 (49.0%) had subgingival margins. Estimated caries rate per 100 years for surfaces in the control group ranged from 0 to 1.01, while in the subgingival group from 0 to 1.25 (Table 4).

Most of the studies used a standard index for clinical evaluation (CDA,[53] USPHS-Ryge criteria,[54] FDI WDF criteria[55]) whereas 8 studies did not use a specific clinical index.

Meta-analysis

Two studies[27,52] detected marginal secondary caries both supra- or equigingivally and subgingivally and could directly compare caries incidence on abutment surface level (Table 5). The first[27] provided data after a mean follow-up of 3 years and the second[51] after a mean follow-up of 5, 10 and 15 years. The results of the 2 studies[27,52] were combined for the calculation of the 5-year RRs, whereas the 10 and 15 year RRs were based only on the study by Valderhaug et al.[52] The pooled RR for secondary caries of subgingival margins at up to 5 years of follow-up (Figure 2) using a random-effects model was 1.25 (95% CI: 0.70 to 2.22) with $p > 0.05$ and no heterogeneity ($I^2 = 0$). The respective RR at 10 years of follow-up was 1.22 (95% CI: 0.81 to 1.83) with $p > 0.05$. However, at 15 years of follow-up, the RR was 0.67 (95% CI: 0.45 to 1.00) with $p = 0.05$. Significant differentiation of the secondary caries incidence between the different follow-ups was found ($p = 0.08$). Since only observational studies were included, all assessments started as 'low quality', which was further downgraded to 'very low quality', due to imprecision of the observed effect estimates (i.e. both study effect estimates had wide 95% CIs that crossed the line of null effect) (Table 5).

The possibility of publication bias could not be assessed due to the small number of studies.

DISCUSSION

To the authors' knowledge this is the first time that a systematic approach has been adopted to address the question of whether the prosthetic margin location relevant to the free gingival margin can influence the incidence of secondary caries. The theory behind this question was founded on the differences that exist between the micro-environment within the gingival crevice compared to the rest of the oral environment.[5] This study included data from 22 studies following 2648 prosthetic restorations. The main finding of this systematic review was that placement of the crown margin subgingivally was not associated with lower secondary caries rate in the short to mid-term. Some indications existed however, that it may have influenced the long-term (> 10 years) incidence of marginal caries, although this finding was based on 1 study[52], and the quality of evidence was low. Nevertheless, the clinical significance of the results should be appraised. In the groups of patients followed in the included studies, secondary caries rates were very low. These rates are in agreement with caries rates reported in a review of complications of tooth-supported fixed prostheses.[14] The minimum follow-up time was set at 2 years as this period is considered as the minimum time required for the progression of caries on dentin surfaces.[56,57] In reality, very little is known about the mechanisms and progression of secondary caries in fixed prosthodontics. The low overall secondary caries incidence may be the result of properly designed and executed treatment planning protocols, as well as closer follow-up and maintenance of these cohorts of patients since most were treated in university settings. Therefore, for such groups of patients, under proper oral hygiene and maintenance protocols, the location of prosthetic margin placement may not be critical.

Certain limitations concerning the meta-analytical part must be acknowledged. This study included only published studies that had been peer-reviewed and could possibly provide a false estimate.[57] Few studies were detected with valid direct comparisons, diminishing the precision and power of the estimate. Most studies were of moderate quality; only one RCT was identified. Incomplete reporting of the studies precluded the analysis per patient mouth, as would be

more appropriate since individual abutment teeth or surfaces are not absolutely independent variables. The possibility, that the results were biased by publication bias, could not be ruled out. The included studies presented with clinical variability and different clinical indices, some of them non-standardized, were used for quality evaluation of prostheses. It is important for future studies to utilize standardized and validated criteria for quality evaluation of prostheses.

Another issue to consider was the classification of margin placement, which might partly explain the long-term differences observed between control and experimental groups. Margin placement was classified according to study reporting at the last recall. Taking into account the fact that, in many cases, a continuous gingival recession occurs around teeth[25,58] the results of this study may represent an underestimation of secondary caries occurring on subgingival prosthetic margins. Bearing that in mind, the comparison across different time-points of patient recall made in Figure 2 is of great interest. After a mean follow-up of 15 years a fair amount of gingival recession can be expected to have happened, enabling different cementum exposures to be expressed in the caries incidence. The possibility exists, that the lower long-term marginal caries rate for subgingival margins reflects the fact that cementum exposure is delayed until gingival recession has occurred beyond the crown margin to expose it. Another fact to consider is that carious lesions under the gingival margin (root caries) are more difficult to identify and to treat compared to coronal caries and so it might have been under-reported. Comparisons with other studies are limited, as the literature has mainly focused on the effect of prosthetic margin placement on various periodontal indices. Differences in gingival scores have been previously reported for crowns with subgingival finish lines compared to both crowns with equi-/supragingival margins and teeth without crowns.[59] This detrimental effect begins to appear 1-3 years after placement and improves concomitantly, possibly as some subgingival margins become equi- or supragingival.[60] A greater chance of gingival recession was recorded for subgingival restorations regardless of depth of sulcus penetration.[61] Thus, the role of subgingival placement of the prosthetic margins may diminish in the long-term.

Bearing in mind that G.V. Black's principles of "extension for prevention" no

longer apply,[62] the choice of placing prosthetic margins subgingivally needs to be carefully justified, weighing accompanying risks like, more dentin removal, weakened teeth, higher operator skill requirements, root sensitivity, higher chance for pulpal exposure therefore compromising tooth vitality, more complex impression making, and difficulty of accurate assessment of margin integrity and tooth vitality.

Further well-designed randomized split-mouth clinical studies need to be conducted to analyze the effect of prosthetic margin placement on the risk of secondary caries.

CONCLUSIONS

This systematic review and meta-analysis failed to detect a significantly different secondary caries rate of subgingivally located prosthetic margins in the short to mid-term (≤10 years). Due to the small number and the limitations of the included studies the results do not provide conclusive evidence as to the effect of prosthetic margin placement on the incidence of secondary caries.

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Declaration of interests

The authors declare that they have no conflict of interest with respect to the submitted work.

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Table 1 Search strategy for the identification of articles

Database	Search strategy	Hits
MEDLINE searched via PubMed (1950 – week 2, April 2012) www.ncbi.nlm.nih.gov/sites/entrez/	(randomized controlled trial[pt] OR controlled clinical trial[pt] OR randomized controlled trials[mh] OR random allocation[mh] OR double-blind method[mh] OR single-blind method[mh] OR clinical trial[pt] OR clinical trials[mh] OR ("clinical trial"[tw]) OR comparative study OR evaluation studies OR follow-up studies[mh] OR prospective studies[mh] OR prospectiv*[tw]) AND (crowns OR "fixed partial dentures" OR "prosthetic restorations") AND ((caries susceptibility) OR (decay susceptibility) OR caries* OR decay* OR cavity*))	769
EMBASE searched via ScienceDirect (1974 – April, 2012) www.embase.com	(crowns OR "fixed partial dentures" OR "prosthetic restorations") AND ((caries susceptibility*) OR (decay susceptibility*) OR caries* OR decay* OR cavity*) Limited to Humans	82
Cochrane Database of Systematic Reviews searched via The Cochrane Library at April 13, 2012 www.thecochranelibrary.com	(crowns OR "fixed partial dentures" OR "prosthetic restorations") AND ((caries susceptibility*) OR (decay susceptibility*) OR caries* OR decay* OR cavity*) *in All Fields*	38
Cochrane Central Register of Controlled Trials searched via The Cochrane Library at April 13, 2012	(crowns OR "fixed partial dentures" OR "prosthetic restorations") AND ((caries susceptibility*) OR (decay susceptibility*) OR caries* OR decay* OR cavity*) *in All Fields*	149
Google Scholar Beta searched at April 13, 2012 www.scholar.google.com	(crowns OR "fixed partial dentures" OR "prosthetic restorations") ((caries susceptibility*) OR (decay susceptibility*) OR caries* OR decay* OR cavity*)) *Limited to Medicine, Pharmacology and Veterinary Science*	2111
Scopus searched at April 13, 2012 www.scopus.com	TITLE-ABS-KEY((crown* OR "fixed partial denture*" OR "prosthetic restoration*") AND ("caries susceptibility" OR "decay susceptibility" OR caries OR decay* OR cavity)) AND (LIMIT-TO(SUBJAREA, "DENT") OR LIMIT-TO(SUBJAREA, "MULT"))	2392
	SUM	5541

Table 2 Kappa score for the agreement between authors

Criterion	**Kappa**	**Interpretation**
Data selection procedure		
Mean follow-up period> 2years	0.933	Almost perfect agreement
Number of patients stated	0.879	Almost perfect agreement
Number of prostheses stated	0.832	Almost perfect agreement
Margin location provided related to caries	0.715	Substantial agreement
Data extraction procedure	0.851	Almost perfect agreement

Table 3 Characteristics of eligible trials

Study	Setting	Design	Planned sample (M/F)	Dropouts (%)	Actual sample	Mean age (range)	Measuring method
Abutment studies							
Burke *et al.*[33]	University	C(R)	30	17	25	37.3 (24.0-63.0)	USPHS
Burke *et al.*[34]	University	C(P)	16	19	16	37.5 (22.0-51.0)	USPHS
De Backer *et al.*[35]	University	C(R)	NR	NR	456	41.0 (18.0-82.0)	Custom
De Backer *et al.*[36]	University	C(R)	NR	NR	193	64.2 (33.6-94.2)	Custom
Guess and Stappert[37]	University	C(P)	25 (13/12)	64	9	44.44 (19-64)*	USPHS
Koch and García-Godoy[38]	University	C(R)	12	0	12	NR (6.0-8.0)	Custom
Kokubo *et al.*[39]	University	C(P)	57 (6/51)	19	46	46.4 (20-70)*	CDA
Molin and Karlsson[40]	University	C(P)	18 (6/12)	0	18	58.0 (48.0-84.0)	CDA
Näpänkangas *et al.*[41]	University	C(R)	60	50	30	41.3 (23.0-65.0)	Custom
Schmitt *et al.*[42]	University	C(P)	30 (17/13)	10	27	52.2 (NR)	CDA
Sorensen *et al.*[43]	University	C(P)	33	0	33	NR (17.0-69.0)	Custom
Sorrentino et al.[44]	University/Private	C(R)	112 (39/73)**	NR	NR	NR (18-69)*	CDA
Toksavul and Toman[45]	University	C(P)	21 (5/16)	0	21	38.28 (18.0-60.0)	USPHS
Vult von Steyern *et al.*[46]	University	C(P)	18 (9/9)	0	18	NR (37.0-76.0)	CDA
Surface studies							
Cehreli *et al.*[47]	NR	A1	20 (9/11)	0	20	36.2 (NR)	CDA
Ericson *et al.*[27]	University	C(P)	39	23	30	56.4 (27.0-80.0)	Custom
Molin *et al.*[26]	PDHS/Private	C(R)	74	23	57	64.4 (43.0-84.0)	Custom
Nilson *et al.*[48]	PDHS/Private	C(R)	24 (10/14)	8	22	47.8 (30-67)	CDA
Pippin *et al.*[49]	University	C(R)	30 (13/17)	0	30	36.0 (18.-77.0)	CDA
Raigrodski *et al.*[50]	University	C(P)	16 (3/13)	0	16	48 (36.0-60.0)	USPHS
Tartaglia *et al.*[51]	Private	C(P)	142 (69/73)	24	108	49.2 (28-82)	FDI
Valderhaug *et al.*[52]	University	B	102 (29/73)	46	55	48.0 (25.0-69.0)	Custom

*mean age was reported only for the initially planned sample, **including also patients with implant-supported crowns, which were not included in this study. PDHS: Public Dental Health Service. NR: Not reported. P: Prospective, R: Retrospective, M/F: male/female, CDA: California Dental Association, USPHS: United States Public Health System. FDI: Fédération Dentaire Internationale (World Dental Federation).

Table 4 Summary of clinical characteristics of participants in the eligible trials

Study	Restoration	Planned no. of restorations	Drop-outs (%)	Actual no. of restorations	No. of surfaces/teeth (Ctr/Subg)	Mean follow-up (range) y	Caries incidence	Estimated caries rate per 100 years (Ctr/Subg)
Tooth level studies								
Burke *et al.*[33]	SC	NR	NR	60	60 (49/11)	2.4 (2.0-5.0)	0/0	0/0
Burke *et al.*[34]	SC	59	19	48	48 (48/0)	3.9 (3.0-4.5)	0/NA	0/NA
De Backer *et al.*[35]	SC	1312	21	1037	1037 (1037/0)	10.0 (0.3-25.0)	249/NA	2.4/NA
De Backer *et al.*[36]	FPD	397	19	322	704 (704/0)	11.4 (0.5-26.3)	84/NA	1.05/NA
Guess and Stappert[37]	PLV	66	65	23	23 (23/0)	5.0	0/NA	0/NA
Koch and García-Godoy[38]	SC	41	0	41	41 (39/2)	3.0 (2.0-5.0)	0/0	0/0
Kokubo *et al.*[39]	SC	101	26	75	75 (0/75)	5.0	NA/0	NA/0
Molin and Karlsson[40]	FPD	19	0	19	38 (36/2)	5.0	0/0	0/0
Näpänkangas *et al.*[41]	SC/FPD	NR	NR	24FPD, 41SC	102 (95/7)	10.0	0/0	0/0
Schmitt *et al.*[42]	FPD	30	10	27	54 (0/54)	2.9	NA/0	NA/0
Sorensen *et al.*[43]	SC	75	0	75	75 (0/75)	3.0	NA/0	NA/0
Sorrentino et al.[44]	SC	128	2%	126	126 (0/126)	6.0	NA/0	NA/0
Toksavul and Toman[45]	SC	79	0	79	79 (23/56)	4.8 (1.0-5.0)	0/0	0/0
Vult von Steyern *et al.*[46]	FPD	20	0	20	56 (56/0)	2.0	0/0	0/NA
Surface level studies								
Cehreli *et al.*[47]	SC	30	0	30	120 (90/30)	2.0	0/0	0/0
Ericson *et al.*[27]	FPD	NR	NR	33	376 (216/160)	3.0	5/6	0.77/1.25
Molin *et al.*[26]	Conical crowns-retained overdenture	NR	NR	60	952 (327/625)	2.5 (0.3-6.3)	NC	NC
Nilson *et al.*[48]	SC	47	6	44	176 (83/93)	2.2 (2.2-2.5)	0/0	0/0
Pippin *et al.*[49]	PLV	60	0	60	120 (105/15)	3.5 (2.1-5.0)	0/0	0/0
Raigrodski *et al.*[50]	FPD	20	0	20	160 (120/40)	2.6 (1.5-3.0)	0/0	0/0
Tartaglia *et al.*[51]	SC/Multiple SC	283	6	265	890 (445/445)	3.0	0/0	0/0
Valderhaug *et al.*[52]	FPD	108	45	59	719 (258/461)	15.0	39/47	1.01/0.68*

Ctr: Control group. Subg: Group with subgingivally placed margins. FPD: Fixed partial denture. SC: Single crown. PLV: Porcelain laminate veneer. NR: Not reported. *:caries incidence reported for the maximum follow-up provided. NA: Not applicable. NC: Not calculated

Table 5 GRADE summary of findings table for caries rates of marginal surfaces

Patients: receiving fixed partial dentures for replacing missing teeth
Settings: university clinic
Intervention: prosthetic margin placed subgingivally
Comparison: prosthetic margin placed equi- or supragingivally

Outcome (follow-up)	Illustrative comparative risks (95% CI)		Relative effect (95% CI)	No of participants (trials)	Quality of evidence (GRADE)	Comments
	Assumed caries risk	Corresponding caries risk				
	Control margins	**Subgingival margins**				
Marginal caries incidence (follow-up: 3 to 5 years)	**2.8 per 100 margin surfaces**	**3.5 per 100 margin surfaces** (1.9 to 6.1)	**RR 1.25** (0.70 to 2.22)	85 (2)	⊕○○○ **very low**[1]	p = 0.460; I^2 = 0%
Marginal caries incidence (follow-up: 10 years)	**8.8 per 100 margin surfaces**	**10.7 per 100 margin surfaces** (7.1 to 16.1)	**RR 1.22** (0.81 to 1.83)	55 (1)	⊕○○○ **very low**[1]	p = 0.340
Marginal caries incidence (follow-up: 15 years)	**15.1 per 100 margin surfaces**	**10.1 per 100 margin surfaces** (6.8 to 15.1)	**RR 0.67** (0.45 to 1.00)	55 (1)	⊕○○○ **very low**[1]	**p = 0.050**

1-Downgraded by 1 for imprecision: both study effect estimates had wide 95% CIs that cross the line of null effect and no criteria for quality upgrade were met.
Test for subgroup differences between the three timepoints: **p = 0.080**; I^2 = 61%.
CI, confidence interval; RR, relative risk.

FIGURE LEGENDS

Fig. 1 Flow diagram of search results according to PRISMA statement.

Fig. 2 Incidence of secondary caries between abutment surfaces with subgingival and equigingival/supragingival margins. Direct data with surface as the measurement unit (Risk Ratio, Mantel-Haenszel, Random-effects model).