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Metal-free materials for fixed prosthodontic restorations (Review)

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[Intervention Review]

Metal-free materials for fixed prosthodontic restorations

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ABSTRACT

Background

Fixed prosthodontic treatment (crowns, fixed dental prostheses (FDPs), complete arch prostheses) involves the use of several different materials to replace missing tooth structure. Traditionally full metal or metal frameworks veneered with ceramic (metal-ceramic (MC)) have been used. In recent years several different metal-free systems have become available to clinicians and patients. In general, metal-free restorations should allow practitioners to better reproduce natural tooth colour, avoiding shortcomings of MC restorations. The comparative in service clinical performance of fixed prosthodontic treatments of different materials is unclear.

Objectives

To assess the effects of metal-free materials for prosthodontic restorations compared to metal-ceramic or other conventional all-metal materials.

Search methods

Cochrane Oral Health's Information Specialist searched the following databases: Cochrane Oral Health's Trials Register (searched 3 May 2017), Cochrane Central Register of Controlled Trials (CENTRAL; 2017, Issue 4) in the Cochrane Library (searched 3 May 2017), MEDLINE Ovid (1946 to 3 May 2017), and Embase Ovid (1980 to 3 May 2017). The US National Institutes of Health Trials Registry (ClinicalTrials.gov) and the World Health Organization International Clinical Trials Registry Platform were searched for ongoing trials (searched 3 May 2017). No restrictions were placed on the language or date of publication when searching the electronic databases.

Selection criteria

Randomised controlled trials (RCTs) in which the clinical performance of metal-free fixed prosthodontic restorations was compared with metal-ceramic (MC) or other conventional restorations in adult patients requiring prosthodontic treatment. RCTs in which the clinical performance of different kinds of metal-free systems were compared among themselves were also considered.

Data collection and analysis

We used standard methodological procedures expected by Cochrane. Screening of eligible studies, assessment of the methodological quality of the trials and data extraction were conducted independently and in duplicate. Trial authors were contacted for missing information. Available results for the outcomes of interest of the systematic review of the studies included were tabulated as they could not be included in a formal meta-analysis.

Main results

Nine trials involving a total of 448 participants were included. We judged two trials to be at unclear risk of bias and seven to be at high risk of bias. The majority of items of risk of bias were evaluated to be at unclear or high risk level in more than 50% of the included trials. Each trial except two was addressing a different type of intervention. All evidence was rated as being of very low quality due to problems with risk of bias and imprecision of results, the latter being due to very small sample sizes, low event rates, 95% confidence intervals including the possibility of benefit for both the test and control groups, or combinations of these problems. This means that we are very uncertain about all of the results presented in this review.

One trial compared metal-free single crowns (full contour zirconia) to cast gold single crowns in 224 participants and found insufficient evidence of a difference in failure rate after one year, but after five years there was some evidence of a benefit for the gold crowns. There was insufficient evidence of a difference for crown complications at either time of assessment.

One trial compared three-unit metal-free FDPs (lithium disilicate) to three-unit metal-ceramic FDPs in 37 participants. There was insufficient evidence of a difference in bridge failure at one and six years, but some evidence of a benefit for the lithium disilicate group in terms of bridge complications at six years. One trial compared zirconia-ceramic FDPs to metal-ceramic FDPs in 34 participants but found insufficient evidence of a difference in bridge failures (i.e. no failures in either treatment group), bridge complications or patients' aesthetic evaluation at any time of assessment up to three years.

One trial compared metal-free cantilevered FDPs to metal-ceramic cantilevered FDPs in 21 participants. There was insufficient evidence of a difference for any primary outcome: bridge failures (i.e. no failures in either treatment group), bridge complications, or patients' aesthetic evaluation at any time of assessment up to three years.

One trial compared metal-free implant-supported screw retained single crowns (zirconia veneered with feldspathic ceramic) to metal-ceramic implant-supported screw-retained single crowns in 20 participants. There was insufficient evidence of a difference for any primary outcome: crown failures (i.e. no failures in either treatment group), crown complications, or satisfaction/aesthetic evaluation at any time of assessment up to two years.

Two trials compared metal-free implant abutments (zirconia) to metal implant abutments both supporting single crowns in 50 participants. There was insufficient evidence of a difference in abutment failure at one year.

One trial compared metal-free implant-supported FDPs made of two different types of zirconia ceramic in 18 participants. There was insufficient evidence of a difference in failures at any time of assessment up to 10 years (i.e. no failures in either treatment group). There was some evidence of a benefit for the zirconia-toughened alumina group in terms of complications (chipping).

One trial compared metal-free tooth-supported FDPs made with two different veneering techniques (pressed versus layered) in 40 participants. There was insufficient evidence of a difference for failures (i.e. no failures in either treatment group) or complications at any time of assessment up to three years.

Authors' conclusions

There is insufficient evidence to support or refute the effectiveness of metal-free materials for fixed prosthodontic treatment over metal-ceramic or other type of standard restorations. The overall quality of existing evidence was very low, therefore great caution should be exercised when generalising the results of the included trials. Until more evidence becomes available clinicians should continue to base decisions on which material to use for fixed prosthodontic treatment on their own clinical experience, whilst taking into consideration the individual circumstances and preferences of their patients. There is urgent need of properly designed RCTs.

PLAIN LANGUAGE SUMMARY

Metal-free materials for making crowns and bridges

Review question

To compare the effects of metal-free materials to metal-ceramic or other conventional all-metal materials for prosthodontic treatments aimed to restore severely damaged teeth or to replace missing teeth.

Background

Fixed prosthodontic treatment is a routine dental procedure in which one or more missing or severely damaged teeth are replaced by artificial substitutes. The material used to make the prosthesis may be made of a metal framework with a veneering of an aesthetic material (ceramic) or entirely in metal or it can be made with different non-metal structures (metal-free materials). There is still uncertainty regarding metal-free long-term performance compared to metal-based crowns and bridges.

Study characteristics

This review of existing studies was carried out by Cochrane Oral Health authors and the evidence is current up to 3 May 2017. We searched scientific databases for randomised controlled trials (studies where people are randomly put into one of two or more treatment groups) comparing different types of materials for prosthodontic treatment in people who were followed up for at least one year.

Of the nine included trials three were conducted in Germany, one in Sweden, one in Spain, one in Switzerland and the USA, one in Denmark, one in Italy, and one in Switzerland. All the included trials were single-centre conducted at university dental clinics and had a parallel-group study design. All the included trials received support from industry.

Key results

The review included nine studies with 448 participants in which a total of 224 crowns and 132 bridges on natural teeth, and a total of 74 crowns and 25 bridges on implants were used. Each trial was addressing a different type of intervention. The studies had durations up to 10 years but included very small numbers of participants and were assessed as at unclear or high risk of bias. Based on these studies, there is currently insufficient reliable evidence to support which of these materials are more effective.

Quality of the evidence

Two trials were at unclear risk of bias and seven were at high risk of bias. The overall quality of evidence was very low, therefore caution should be exercised when generalising the results of the included trials. Future research should aim to provide more reliable information which can help clinicians to decide on appropriate materials for fixed prosthodontic treatment whilst taking into consideration the individual circumstances and preferences of their patients.

SUMMARY OF FINDINGS

Summary of findings for the main comparison. Summary of findings: all comparisons

Metal-free materials compared with metal-ceramic or other conventional all-metal materials for prosthodontic restorations

Patient or population: adults (18 years of age or older) with prosthodontic restorations

Settings: primary or secondary care

Intervention: metal-free materials

Comparison: metal-ceramic or other conventional all-metal materials

This review is made up almost entirely of single-study comparisons of very small studies. For each comparison, the evidence for the primary outcomes 'failure of the prosthesis', 'complications' and 'aesthetic evaluation' at all times of assessment was rated as being very low quality. All bodies of evidence were downgraded by 1 level for risk of bias and by 2 levels for imprecision (due to single-study comparisons with either very small sample sizes, low event rates, 95% CIs including the possibility of benefit for both the test and control groups, or combinations of these problems)

This review has included studies assessing the following comparisons

1) Metal-free single crowns compared to conventional crowns

2) Metal-free FDPs compared to metal-ceramic FDPs

3) Metal-free cantilevered FDPs compared to metal-ceramic cantilevered FDPs

4) Metal-free implant-supported single crowns compared to metal-ceramic implant-supported single crowns

5) Metal-free abutments compared to metal abutments supporting single crowns

6) Metal-free implant-supported FDPs made of different materials

7) Metal-free tooth-supported FDPs made of different materials

CI: confidence interval; **FDPs:** fixed dental prostheses.

GRADE Working Group grades of evidence
High quality: further research is very unlikely to change our confidence in the estimate of effect
Moderate quality: further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate
Low quality: further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate
Very low quality: we are very uncertain about the estimate

BACKGROUND

Description of the condition

Missing or severely damaged teeth may result in a functional and aesthetic deficit and have traditionally been replaced with fixed prosthodontic treatment (crowns or bridges).

Description of the intervention

When fabricating conventional metal–ceramic prosthodontic restorations (crowns, fixed dental prostheses (FDPs), complete arch prostheses), the presence of a metal framework makes it more difficult to imitate natural aesthetics, especially in anterior areas, where space is limited and challenging aesthetic demands need to be satisfied (high translucency). Metal-ceramic (MC) restorations have been widely used in fixed prosthodontics for more than 50 years. The aesthetic quality and functional longevity of MC restorations may vary, but the clinical performance of these restorations is rather predictable. Indeed, the long-term survival rate of MC restorations has been estimated to be approximately 92% after 10 years (Scurria 1998) and 75% after 15 years (Creugers 1994; Scurria 1998). In the search for more aesthetic restorations, alumina-reinforced porcelain jacket crowns were introduced in the mid1960s (McLean 1967), but they had a high failure rate. In the last 15 years many metal-free systems have been proposed (Conrad 2007; Manicone 2007). Many ceramics, such as spinel, alumina, ceramic reinforced with lithium disilicate, yttrium-stabilized zirconia have been proposed for the construction of metal-free restorations (Conrad 2007; Harder 2009). Polymeric materials have also been used both in tooth-supported crowns, FDPs and in implant-supported prostheses (Behr 2003; Bergendal 1995), due to their lower cost. Currently, several different metal-free systems are available to clinicians and patients. In general, metal-free restorations not only allow practitioners to better reproduce natural tooth colour, but also to avoid discolouration of the gingival tissues (greying or lower value), as often occurs with MC restorations.

Despite growing interest, however, concern exists about possible adverse outcomes of metal-free materials, such as an increased risk of failure of the restoration. Of course to be suitable for reliable clinical applications, long-term results similar to those of metal–ceramic reconstructions should be achieved with metal-free systems. Several systematic reviews attempted to calculate long-term survival of metal-free restorations in comparison to conventional therapies (Pjetursson 2007; Sailer 2007; Sailer 2009a, Schley 2010).

Why it is important to do this review

The choice of restorative material for fixed prosthodontic treatment is critical for long-term effectiveness. However, there is still uncertainty about the comparative clinical performance of crowns, FDPs, and complete arch prostheses made with different materials with or without metal used to restore severely damaged or missing teeth. The results of this review may better inform clinical decision making in the choice of either of these materials for different clinical situations. Moreover some patients are 'metalphobic', feeling that metals in their restorations could cause systemic health problems, although the possibility of such influence is not demonstrated.

OBJECTIVES

To assess the effects of metal-free materials for prosthodontic restorations compared to metal-ceramic or other conventional all-metal materials.

METHODS

Criteria for considering studies for this review

Types of studies

All randomised controlled trials (RCTs) were considered in which the clinical performance of metal-free fixed prosthodontic restorations was compared with metal-ceramic (MC) or other conventional restorations with a minimum follow-up of 12 months. RCTs in which the clinical performance of different kinds of metal-free systems were compared among themselves were also included. Trials performed in a primary or secondary care setting were included.

Types of participants

Adult patients (18 years of age or older) who received fixed prosthodontic restorative treatment.

Types of interventions

All types of metal-free materials for fixed prosthodontic treatment. Studies comparing metal-free systems (single crowns, fixed dental prostheses (FDPs), complete arch prostheses) among themselves and to MC systems or other conventional prosthodontic restorations were considered. Studies comparing metal-free prosthodontic components connected to implants (abutments, crowns, FDPs, complete arch prostheses) to all metal (gold, titanium, semiprecious, etc.) components were included.

Studies comparing implant materials were excluded.

Types of outcome measures

Primary outcomes

Failure of the prosthesis

The main primary outcome was longevity of the restoration. The nature of the outcome data is dichotomous. The following events were defined as failures.

1. Non-repairable fracture of the prosthesis.
2. Fracture or loss of supporting tooth.
3. Fracture or loss of implant abutment.
4. Non-restorable secondary caries on natural tooth.
5. Loosening of an implant abutment screw leading to replacement of the prosthesis.

Complications

The following adverse events were defined as complications.

1. Repairable fractures of the prosthesis (cracks, chipping, delamination).
2. Restorable secondary caries on natural tooth.
3. Severe unfavourable periodontal or peri-implant response or severe reaction of the adjacent mucosa.

4. Loosening of an implant abutment screw not leading to replacement of the prosthesis.

The nature of the outcome data is dichotomous.

Aesthetic evaluation

The following aesthetic parameters were considered.

1. Aesthetics evaluated by dentist by any validated aesthetic index (continuous or ordinal outcome).
2. Aesthetics evaluated by the patient (continuous or ordinal outcome).
3. Aesthetic preference evaluated by the patient in split-mouth design studies (ordinal outcome: better, no difference or worse).

Primary outcome data were recorded at 12 months (all studies), 36 months and 60 months (when available) time intervals.

Secondary outcomes

1. Periodontal or peri-implant status evaluated through:
   a. plaque index (PI, dichotomous outcome);
   b. bleeding on probing (BOP, dichotomous outcome);
   c. probing attachment level (PAL, continuous outcome);
   d. gingival recession (REC, continuous outcome);
   e. marginal bone level (MBL) around implants measured on intraoral radiographs taken with a parallel technique (continuous outcome).
2. Occlusal wear evaluated through any validated system (continuous outcome).

Secondary outcome data were recorded at 12 months (all studies), 36 months and 60 months (when available) time intervals.

Search methods for identification of studies

Electronic searches

Cochrane Oral Health's Information Specialist conducted systematic searches in the following databases for randomised controlled trials and controlled clinical trials. There were no language, publication year or publication status restrictions:

- Cochrane Oral Health's Trials Register (searched 3 May 2017) (Appendix 1);
- Cochrane Central Register of Controlled Trials (CENTRAL; 2017, Issue 4) in the Cochrane Library (searched 3 May 2017) (Appendix 2);
- MEDLINE Ovid (1946 to 3 May 2017) (Appendix 3);
- Embase Ovid (1980 to 3 May 2017) (Appendix 4).

Subject strategies were modelled on the search strategy designed for MEDLINE Ovid. Where appropriate, they were combined with subject strategy adaptations of the highly sensitive search strategy designed by Cochrane for identifying randomised controlled trials and controlled clinical trials as described in the *Cochrane Handbook for Systematic Reviews of Interventions* Chapter 6 (Lefebvre 2011).

Searching other resources

The following trial registries were searched for ongoing studies:

- US National Institutes of Health Ongoing Trials Register ClinicalTrials.gov (clinicaltrials.gov; searched 3 May 2017) (Appendix 5);
- World Health Organization International Clinical Trials Registry Platform (apps.who.int/trialsearch; searched 3 May 2017) (Appendix 6).

The reference lists of any articles about clinical trials identified and the review authors' personal lists of previously found articles were cross-checked for additional trials published outside the searched databases.

Authors of RCTs identified and personal contacts were written to in an attempt to identify unpublished or ongoing trials.

Metal-free system manufacturers were contacted to request information about possible ongoing trials.

Data collection and analysis

Selection of studies

The titles and abstracts (when available) of all reports identified through the electronic searches were examined independently by two review authors (Carlo E Poggio (CEP), Carlo Ercoli (CE)). Reports not matching the inclusion criteria were excluded. For studies appearing to meet the inclusion criteria, or for those for which there was insufficient data in the title and abstract to make a clear decision, the full report was obtained. The full reports obtained from all the electronic and other methods of searching were assessed independently by two review authors to establish whether the studies meet the inclusion criteria or not. Duplicate records of the same report were removed. When necessary, authors were contacted for clarification. Disagreements were resolved by discussion. Where resolution would not be possible, a third review author (Marco Esposito (ME)) was consulted. All irrelevant records were excluded and the details and the reasons for their exclusion were noted in the 'Characteristics of excluded studies' section of this review.

Data extraction and management

Study details were entered into the 'Characteristics of included studies' table in Review Manager 5 (Review Manager 2014).

Two review authors (CEP and Lorena Rispoli (LR)) extracted data independently and in duplicate using specially designed data collection forms. The data collection forms were piloted on several papers and modified as required before use. The review authors included data only if there was an independently reached consensus; any disagreements were resolved by consulting with a third review author (ME).

Where necessary, authors were asked for clarification or missing information.

We extracted the following details for each trial.

- Year of publication, country of origin and source of study funding.
- Details of the participants including demographic characteristics and criteria for inclusion.
- Details of the type of intervention.

- Details of the outcomes reported, including method of assessment and time intervals.
- Risk of bias assessment

Assessment of risk of bias in included studies

The recommended approach for assessing risk of bias in studies included in Cochrane Reviews was followed (Higgins 2011). A two-part tool was used, addressing the domains: sequence generation, allocation concealment, blinding, incomplete outcome data, selective outcome reporting and other bias. Each domain included one or more specific entries in a 'Risk of bias' table. Within each entry, the first part of the tool involved describing what was reported to have happened in the study. The second part of the tool involved assigning a judgement relating to the risk of bias for that entry.

Two review authors independently carried out the risk of bias assessment as part of the data extraction process (CEP, CE).

After taking into account the additional information provided by the authors of the trials, the studies were grouped into the following categories.

Risk of bias	Interpretation	Within a study	Across studies
Low risk of bias	Plausible bias unlikely to seriously alter the results	Low risk of bias for all key domains	Most information is from studies at low risk of bias
Unclear risk of bias	Plausible bias that raises some doubt about the results	Unclear risk of bias for one or more key domains	Most information is from studies at low or unclear risk of bias
High risk of bias	Plausible bias that seriously weakens confidence in the results	High risk of bias for one or more key domains	The proportion of information from studies at high risk of bias is sufficient to affect the interpretation of results

A 'Risk of bias' table was completed for each included study in the 'Characteristics of included studies' table and the results were presented graphically.

Measures of treatment effect

For dichotomous data, the estimates of effect of an intervention were expressed as odds ratios together with 95% confidence intervals.

For continuous outcomes, mean differences and 95% confidence intervals were used to summarise the data for each group where the mean difference and standard deviations were calculable from the data presented.

Unit of analysis issues

The statistical unit was the patient and not the prosthesis. No split-mouth studies were found.

Dealing with missing data

Whenever possible, we contacted the original investigators to request missing data. If no additional information was available no imputation was performed and data for only those participants whose results were known were included. The potential impact of the missing data was addressed in the assessment of risk of bias.

Assessment of heterogeneity

The paucity of studies included in this review did not permit any assessment of heterogeneity but in future updates and if further studies are included, the following methods will apply.

The significance of any discrepancies in the estimates of the treatment effects from the different trials will be assessed by means of Cochran's test for heterogeneity and the I^2 statistic, which describes the percentage total variation across studies that is due to heterogeneity rather than chance. Heterogeneity will be considered statistically significant if the P value is < 0.1. A rough guide to the interpretation of the I^2 statistic given in the *Cochrane Handbook for Systematic Reviews of Interventions* is: 0% to 40% might not be important, 30% to 60% may represent moderate heterogeneity, 50% to 90% may represent substantial heterogeneity, 75% to 100% considerable heterogeneity (Higgins 2011).

Assessment of reporting biases

If a sufficient number of studies assessing similar interventions had been identified for inclusion in this review we planned to assess publication bias according to the recommendations on testing for funnel plot asymmetry as described in Section 10.4.3.1 of the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011). If asymmetry was identified we would attempt to assess other possible causes and these would be explored in the discussion if appropriate.

Data synthesis

Available results for the outcomes of interest of the systematic review of the studies included were tabulated as they could not be included in a formal meta-analysis.

If future updates include a sufficient number studies (> 2) investigating similar interventions, the data analysis will be conducted in Review Manager 5 (Review Manager 2014) and the following methods will apply: odds ratios will be combined for dichotomous data, and mean differences for continuous data, using random-effects models if there are more than three trials, otherwise fixed-effect models will be used.

If future updates include data from split-mouth studies they will be combined with data from parallel-group trials with the method

outlined by Elbourne (Elbourne 2002), using the generic inverse variance method in Review Manager 5.

Subgroup analysis and investigation of heterogeneity

If sufficient data are available in future updates, a subgroup analysis for anterior (canine, lateral and central incisors) and posterior (premolars and molars) restorations (single crowns and fixed dental prostheses (FDPs)) will be conducted.

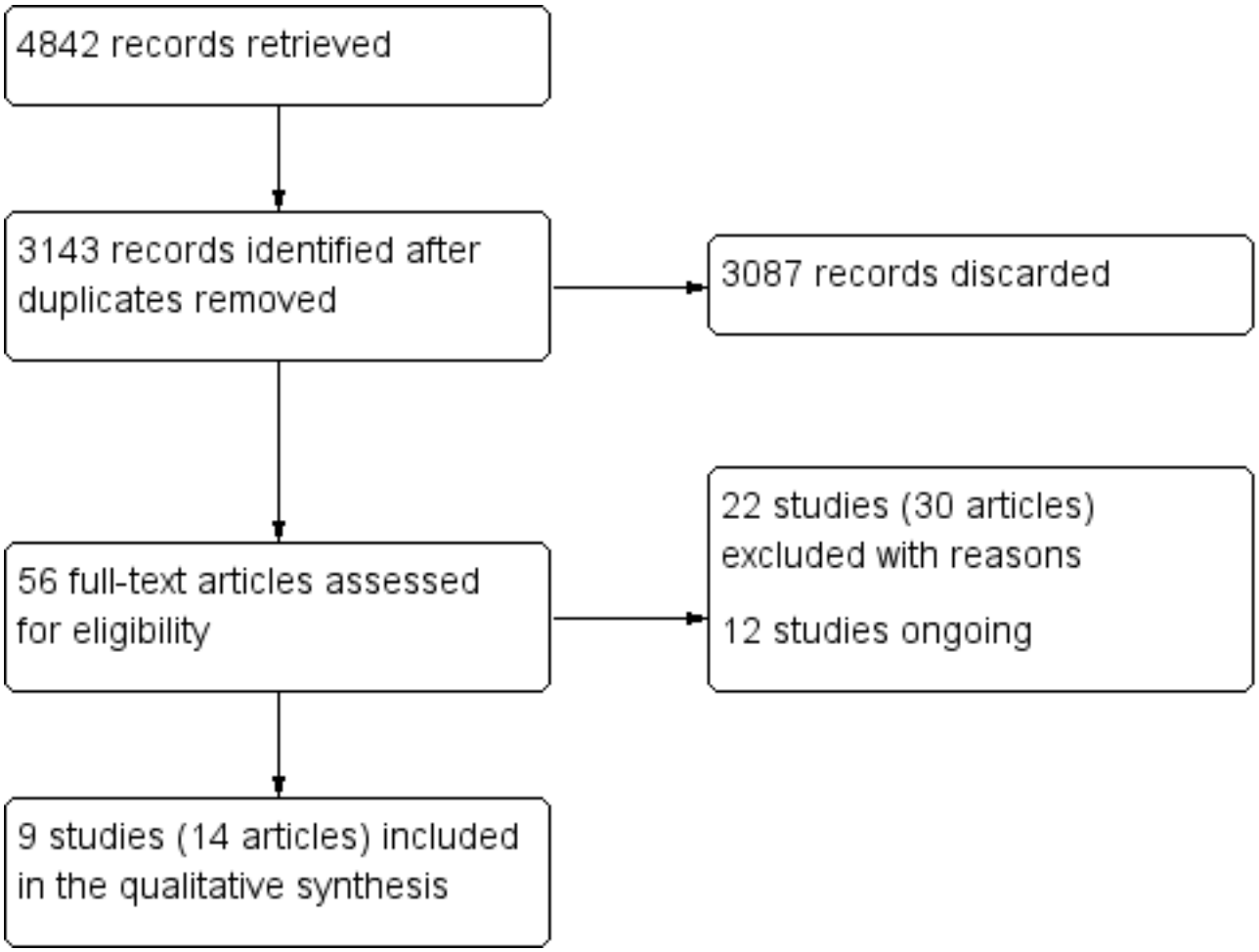
Sensitivity analysis

If there are sufficient included trials in future updates, sensitivity analyses will be undertaken to assess the robustness of the review results, excluding trials at high risk of bias on the assessment of the overall estimates of effect.

Presentation of main results

We intended to produce 'Summary of findings' tables for the main comparisons and primary outcomes of this review using GRADEpro GDT software (GRADEpro GDT 2015). However, there were too many comparisons with a very small amount of evidence and we decided to summarise everything in one table. To assess the quality of the evidence we considered the following factors: risk of bias, imprecision, inconsistency, indirectness and potential for publication bias.

Figure 1. Study flow diagram.



RESULTS

Description of studies

Results of the search

The electronic searches retrieved 3143 references to studies after de-duplication, out of which 3087 did not match our inclusion criteria, were clearly ineligible and were eliminated. We obtained full-text copies of the remaining potentially eligible 56 studies.
After evaluation 22 studies (30 reports) were excluded for reasons described in the Characteristics of excluded studies section of this review. We included nine studies (14 reports, five being follow-up articles of three trials (Encke 2009; Larsson 2006; Ohlmann 2012)). No additional study over and above those that had already been identified in the electronic search was found.

Our searches of the trial registries did identify 12 ongoing trials potentially relevant to this review (DRKS00005452; DRKS00010423; DRKS00011173; NCT01229995; NCT01729858; NCT01835821; NCT02175329; NCT02188212; NCT02272491; NCT02758457; NCT02937220; NCT03039985).

See Figure 1.

Included studies

See Characteristics of included studies table.

We identified nine trials to be included in this review (Albornoz 2014; Baldini 2016; Encke 2009; Gallucci 2011; Larsson 2006; Makarouna 2011; Naenni 2015; Nicolaisen 2016; Ohlmann 2012).

Characteristics of trial setting and investigators

- Of the nine included trials three were conducted in Germany (Encke 2009; Makarouna 2011; Ohlmann 2012), one in Spain (Albornoz 2014), one in Sweden (Larsson 2006), one in Switzerland and USA (Gallucci 2011), one in Switzerland (Naenni 2015), one in Italy (Baldini 2016), and one in Denmark (Nicolaisen 2016).
- All the included trials were single centre.
- All the included trials had a parallel-group study design.
- All the included trials were conducted at university dental clinics or hospitals.
- All the included trials received support from industry.

Characteristics of the participants

A total of 448 participants were included in the nine trials. All patients were adults.

Inclusion criteria

Generic inclusion/exclusion criteria were common to all studies (patients above 18 to 21 years of age, no relevant medical conditions).

Specific inclusion criteria were different according to the different types of interventions planned: need of a single crown in the molar or premolar region (Encke 2009), one missing tooth in the aesthetic zone for single implant supported crowns (Albornoz 2014; Baldini 2016; Gallucci 2011), need of an implant-supported bridge in the posterior region (Larsson 2006), need to replace one premolar or incisor (Ohlmann 2012), need of a three-unit bridge (Makarouna 2011; Naenni 2015; Nicolaisen 2016).

Inclusion criteria for each study are described in the Characteristics of included studies tables.

Exclusion criteria

Exclusion criteria for each study are described in the Characteristics of included studies tables.

Four trials indicated bruxism as an exclusion criteria (Albornoz 2014; Larsson 2006; Ohlmann 2012; Nicolaisen 2016), while one study generically indicated "pronounced parafunctions" as an exclusion criteria (Makarouna 2011).

Characteristics of the interventions

(1) Metal-free single crowns compared to conventional crowns.

- One trial (Encke 2009) compared metal-free single crowns (full contour zirconia, Everest HPC, KaVo Dental GmbH, Biberach/Riss, Germany) to cast gold single crowns (Degulor M, Degudent). Treatments were carried out in the University Dental Hospital Freiburg. Different standardized procedures for tooth preparation were used for the two groups: for the metal-free crowns a deep (1.2 mm) chamfer margin and an occlusal reduction of 1.5 mm while for the conventional metal crowns a 0.8 mm chamfer and an occlusal reduction of 1.2 mm. Zirconia crowns were milled out of KaVo Everest HPC blanks, and subsequently sintered before try-in and cementation.

(2) Metal-free fixed dental prostheses (FDPs) compared to metal-ceramic FDPs.

- One trial (Makarouna 2011) compared metal-free three-unit FDPs (lithium disilicate, Ivoclar Vivadent) to metal-ceramic three-unit FDPs. 37 patients treated in 2001 to 2003 were split into two groups. The metal-free group received 18 lithium disilicate FPDs, while the metal-ceramic group received 19 conventional FPDs. The clinical protocol was standardized for the two groups and comprised chamfer preparation with rounded smooth contours, a monophase impression with a custom tray, try-in and luting with Vivaglass CEM glass ionomer cement (Ivoclar Vivadent).
- One trial (Nicolaisen 2016) compared metal-free three-unit FDPs (zirconia framework, BEGO veneered with ceramic VITA Zahnfabrik) to metal-ceramic three-unit FDPs (gold platinum alloy framework, Bio Ponto Star BEGO, veneered with ceramic VITA Zahnfabrik). 34 patients split in two groups of 17 each received either an all ceramic or a metal-ceramic FDP. A chamfer preparation was used for the metal-free group while a mixed preparation with a shoulder and a chamfer was used for the metal-ceramic group. Frameworks were tried in and subsequently veneered and cemented with a resin enhanced glass ionomer cement (Ketac Cem Plus, 3M ESPE).

(3) Metal-free cantilevered FDPs compared to metal-ceramic cantilevered FDPs.

- One trial (Ohlmann 2012) compared metal-free cantilevered FDPs (Lava, 3M ESPE) to metal-ceramic cantilevered FDPs. Tooth preparation had for both groups same standards (minimal occlusal reduction 1.5 mm, axial reduction (chamfer design) 1.2 mm, convergence preparation angle 6 degrees). For the metal-free group frameworks were milled from prefabricated zirconia blanks and then sintered. Frameworks were veneered with feldspathic ceramic, tried-in, adjusted, repolished and cemented with a resin cement (Rely X Unicem, 3M ESPE). For the metal-ceramic group cantilevered FDPs were made according to standardized manufacturer's instructions.

(4) Metal-free implant-supported single crowns compared to metal-ceramic implant-supported single crowns.

- One trial (Gallucci 2011) compared metal-free implant-supported single crowns (zirconia) to metal-ceramic implant-supported single crowns. For the metal-free group, a screwed retained all ceramic crown was fabricated using a blank composed of 90% alumina with glass infiltration (synOcta, InCeram blank, and synOcta abutment, Straumann Co.) and veneered with alumina ceramic. For the metal-ceramic group, a screwed retained metal-ceramic crown was fabricated and veneered with feldspathic ceramic.

(5) Metal-free implant abutments compared to metal implant abutments.

- One trial (Albornoz 2014) compared metal-free implant abutments to metal implant abutments. For the metal-free group a zirconia abutment (SPIART; Thommen Medical AG, Grenchen, Switzerland) was used to support a metal-free single crown (feldspathic veneered zirconia). For the metal group a commercially pure titanium grade 4 abutment (CPTi Gr 4; SPIEASY; Thommen Medical AG, Grenchen, Switzerland) was used to support a metal-free single crown (feldspathic veneered zirconia).
- One trial (Baldini 2016) compared metal-free implant abutments to metal implant abutments. For the metal-free group a zirconia abutment (SPIART; Thommen Medical AG, Grenchen, Switzerland) was used to support a metal-free single crown (feldspathic veneered zirconia). For the metal group a commercially pure titanium grade 4 abutment (CPTi Gr 4; SPIEASY; Thommen Medical AG, Grenchen, Switzerland) was used to support a metal-ceramic single crown.

(6) Metal-free implant-supported FDPs made of different materials.

- One trial (Larsson 2006) compared metal-free implant-supported FDPs made of two different types of zirconia ceramic. Titanium implant abutments were prepared with a cervical shoulder depth of 1.2 mm and slightly rounded inner angles, a minimum occlusal thickness of 1.7 mm and minimum buccal, approximal, and lingual/palatal thicknesses of 1.5 mm. Frameworks of zirconia-toughened alumina (In-Ceram Zirconia, Vita Zahnfabrik) and of yttria-stabilized tetragonal zirconia polycrystal material (Denzir, Decim) were fabricated and veneered with porcelain. FDPs were cemented permanently with zinc phosphate cement (De Trey zinc crown and bridge Fixodont Plus, Dentsply) in one sitting.

(7) Metal-free tooth-supported FDPs made of different materials.

- One trial (Naenni 2015) compared metal-free tooth-supported FDPs made with two different techniques of veneering. 20 patients were allocated to two groups. Test group (20 patients) received a zirconia–ceramic FDP (IPS e.max ZirCAD, Ivoclar Vivadent) with pressed veneering ceramic, control group (20 patients) received a zirconia–ceramic FDP (IPS e.max ZirCAD, Ivoclar Vivadent) with conventionally layered veneering ceramic.

Characteristics of the outcome measures

- The primary outcome failure of the prosthesis was reported in all the included trials.
- The primary outcome complications not leading to replacement of the prosthesis was reported in all the included trials.
- The primary outcome aesthetics evaluated by the dentist was reported in three trials (Albornoz 2014; Baldini 2016; Gallucci 2011). The Implant Crown Aesthetic Index (ICAI) was calculated in Albornoz 2014 and in Baldini 2016. The ICAI was assessed at follow-ups by a blinded observer on standardized pictures. It included the following parameters: mesiodistal dimension of the crown, position of the incisal edge of the crown, labial convexity of the crown, colour and translucency of the crown, surface of the crown, position of the labial margin of the peri-implant mucosa, position of the interdental papilla, contour of the labial surface of the mucosa, colour and surface of the labial mucosa. When compared to the adjacent teeth, penalty points were assigned (0, excellent; 1 or 2, satisfactory; 3 or 4, moderate; 5 or more, poor). Pink aesthetic score (PES) and white aesthetic score (WES) were calculated in Gallucci 2011 for both groups by three independent observers at the end of the study. The PES included the following parameters: mesial and distal papilla, curvature of the facial mucosa, level of the facial mucosa, root convexity, soft-tissue colour, texture. The WES included: tooth form, tooth volume/outline, colour, translucency, and characterization. Both scores were recorded for each group and subsequently compared between groups.
- The primary outcome aesthetics evaluated by the patient was reported in three trials (Gallucci 2011; Naenni 2015; Ohlmann 2012). In Gallucci 2011 the patient answered on a visual analogue scale (VAS) to a question regarding the aesthetic outcome. In a 100 mm straight line where the left end read 'not satisfied at all' and the right end 'fully satisfied', participants were asked to mark a cross line representing their level of satisfaction. Answers were measured form left to right to obtain a numeric value for the patients' blinded answer. In Ohlmann 2012 the aesthetic performance of the FDPs was subjectively evaluated by the patient using a visual rating scale in which 0 = perfect and 5= completely inadequate. In Naenni 2015 aesthetics evaluated by the patient was reported dichotomous as yes or no. Two trials (Albornoz 2014; Baldini 2016) included a questionnaire and a VAS to rate the patient's aesthetics satisfaction but did not report data.
- The secondary outcome periodontal/peri-implant evaluation was reported in five trials (Albornoz 2014; Baldini 2016; Gallucci 2011; Naenni 2015; Ohlmann 2012). In Albornoz 2014 and in Baldini 2016 clinical and radiographic outcomes were reported: implant probing pocket depths, gingival/mucosal recession and probing attachment levels, radiographic vertical distance from the contact point to the bone crest at mesial and distal sides, radiographic vertical distance from the implant shoulder (1 mm supracrestally) to the most coronal bone in contact with the implant at mesial and distal sites, radiographic horizontal distance from the implant shoulder to the adjacent teeth at mesial and distal sides. In Gallucci 2011 the following secondary outcomes were available: (1) recession (expressed as changes in clinical crown length (CLi) at the implant site); (2) marginal bone level (expressed as first bone to implant contact (FBIC)). In Ohlmann 2012 plaque index and gingival index were analyzed and reported. In Naenni 2015 plaque index, bleeding on probing and pocket probing depth were analyzed and reported. Two trials (Larsson 2006 and Nicolaisen 2016) included in follow-up visit registration of pocket depth, bleeding on probing, and mobility but did not report the data. No information was reported in two other trials (Encke 2009; Makarouna 2011).
- The secondary outcome occlusal wear was not reported in any of the included trials.

Excluded studies

See Characteristics of excluded studies table.

Twenty-two studies were analyzed and excluded for the following main reasons:

- inadequate randomisation (Bindl 2005; Cehreli 2011; Christensen 2010; Henriksson 2004; Li 2007; Sagirkaya 2012; Vanoorbeek 2010);
- study design combining both parallel and split-mouth characteristics (Andersson 1999; Andersson 2001; Borg 2014;

Cehreli 2009; Chen 2008; Esquivel-Upshaw 2012; Esquivel-Upshaw 2014: Esquivel-Upshaw 2014b; Etman 2008; Ohlmann 2006; Pelaez 2012; Sailer 2009; Sailer 2009b; Vanoorbeek 2010);

- follow-up shorter than one year (Batson 2014; Jung 2008).

Risk of bias in included studies

The risk of bias of the included trials is summarised in Figure 2 and in Figure 3. Two studies were assessed as at unclear risk of bias (Naenni 2015; Ohlmann 2012), the remaining seven as at high risk of bias.

Figure 2. Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies.

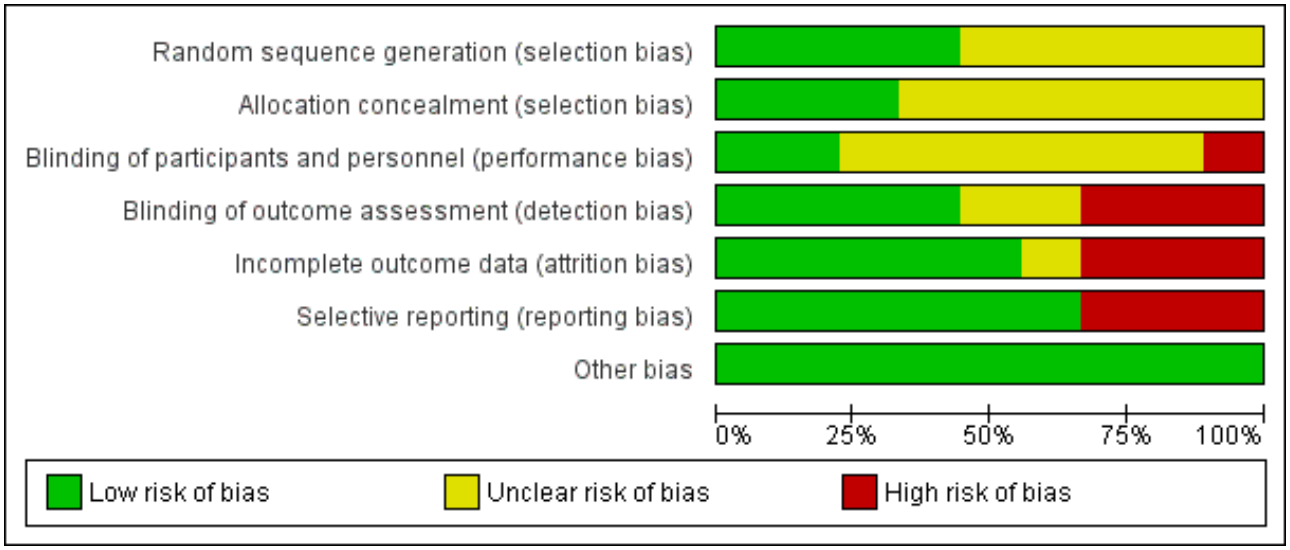


Figure 3. Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

Sequence generation

Four trials (Albornoz 2014; Baldini 2016; Encke 2009; Gallucci 2011) described an adequate method of sequence generation and were assessed as being at low risk of bias for this domain. The other five trials (Larsson 2006; Makarouna 2011; Naenni 2015; Nicolaisen 2016; Ohlmann 2012) did not provide an adequate description of sequence generation, therefore were judged to be at unclear risk of bias.

Allocation

Three trials (Albornoz 2014; Baldini 2016; Gallucci 2011) described an adequate method of allocation concealment and were assessed as being at low risk of bias for this domain. The other six trials (Encke 2009; Larsson 2006; Makarouna 2011; Naenni 2015; Nicolaisen 2016; Ohlmann 2012) did not provide an adequate description of allocation concealment, therefore were judged to be at unclear risk of bias.

Blinding

For one trial, Encke 2009, the comparison involved interventions that did not allow blinding (zirconia crowns compared to cast gold crowns), therefore both performance and detection bias were assessed to be at high risk of bias. In one trial (Gallucci 2011) performance bias was assessed to be at low risk of bias while detection bias was assessed to be at high risk of bias (zirconia crowns compared to metal abutments and metal-ceramic crowns). In one trial (Albornoz 2014) both performance and detection bias were assessed to be at low risk. In the remaining trials the description of blinding was assessed as unclear due to limited description (Baldini 2016; Larsson 2006; Makarouna 2011; Naenni 2015; Nicolaisen 2016; .Ohlmann 2012).

Incomplete outcome data

There were low numbers of dropouts in all but three trials (Albornoz 2014; Encke 2009; Makarouna 2011), which were assessed as at high risk of attrition bias.

Selective reporting

In one trial (Larsson 2006) follow-up visits included pocket depth, bleeding on probing and mobility assessment but data were not reported, therefore study was assessed as at high risk of bias. In two trials (Albornoz 2014; Baldini 2016) follow-up visits included questionnaires and a visual analogue scale to rate the patient's aesthetic satisfaction but data were not reported, therefore studies were assessed as at high risk of reporting bias.

Other potential sources of bias

No other potential sources of bias were identified.

Effects of interventions

See: **Summary of findings for the main comparison** Summary of findings: all comparisons

Comparison 1 Metal-free single crowns compared to conventional crowns

One trial (Encke 2009) compared full contour zirconia to cast gold single crowns. The study was assessed to be at high risk of bias.

Primary outcomes: failures and complications of the prosthesis

Data for primary outcome failure could be calculated at 12 and 60 months intervals.

At 12 months 194 participants were available for analysis. With regard to crown failure or crown complications there was insufficient evidence of a difference between either treatment approach (odds ratio (OR) 0.83 (95% confidence interval (CI) 0.05 to 13.44) and OR 4.31 (95% CI 0.49 to 37.57)) respectively (Analysis 1.1; Analysis 1.3).

At 60 months 158 participants were available for analysis. A difference was shown in terms of crown failure (OR 17.52 (95% CI 5.07 to 60.54) (Analysis 1.2) in favour of conventional metal crowns. There was insufficient evidence of a difference when evaluating crown complications (OR 1.44 (95% CI 0.59 to 3.52) (Analysis 1.4).

Primary outcomes: aesthetic evaluation

No data were presented with regard to aesthetics.

Secondary outcomes

No data were presented for any of the pre-specified secondary outcomes.

Comparison 2 Metal-free fixed dental prostheses (FDPs) compared to metal-ceramic FDPs

- One trial (Makarouna 2011) compared the clinical performance of lithium disilicate FDPs to metal-ceramic FDPs. The study was assessed to be at high risk of bias.

Primary outcomes: failures and complications of the prosthesis

Data for primary outcome failure could be calculated at 12 and 72 months intervals.

At 12 months 37 participants were available for analysis. With regard to FDP failure there was insufficient evidence of a difference between either treatment approach (OR 9.00 (95% CI 0.96 to 84.50) (Analysis 2.1). Data for complications were not available at 12 months.

At 72 months 22 participants were available for analysis. There was insufficient evidence of a difference in terms of FDP failure (OR 6.86 (95% CI 0.66 to 71.72)) (Analysis 2.2) while a difference for complications was found in favour of metal-free FDPs (OR 0.07 (95% CI 0.01 to 0.75)) (Analysis 2.3).

Primary outcomes: aesthetic evaluation

No data were presented with regard to aesthetics.

Secondary outcomes

No data were presented for any of the pre-specified secondary outcomes.

- One trial (Nicolaisen 2016) compared the clinical performance of zirconia ceramic FDPs to metal-ceramic FDPs. The study was assessed to be at high risk of bias.

Primary outcomes: failures and complications of the prosthesis

Data for primary outcome failure could be calculated at 12 and 36 months intervals.

At 12 months 34 participants were available for analysis. No FDP failure was reported in either treatment approach. Data for complications were not available at 12 months.

At 36 months 34 participants were available for analysis. No FDP failure was reported in either treatment approach. There was insufficient evidence of a difference for complications (OR 1.94 (95% CI 0.38 to 9.88) (Analysis 2.6).

Primary outcomes: aesthetic evaluation

At 36 months, an analysis of 34 participants showed insufficient evidence of a difference in patient aesthetic satisfaction changes (OR 15.40 (95% CI 0.78 to 304.61) (Analysis 2.7).

Secondary outcomes

No data were presented for any of the pre-specified secondary outcomes.

Comparison 3 Metal-free cantilevered FDPs compared to metal-ceramic cantilevered FDPs

One trial (Ohlmann 2012) compared metal-free (feldspathic veneered zirconia) FDPs to metal-ceramic FDPs. The study was assessed to be at unclear risk of bias.

Primary outcomes: failures and complications of the prosthesis

At 12 months 19 participants were available for analysis. No failure and no complication were reported in either test and control group.

At 24 months 19 participants were available. While no failure was reported there was insufficient evidence of a difference in terms of occurrence of complications (OR 5.59 (95% CI 0.23 to 133.61)) (Analysis 3.4).

At 36 months 19 participants were still available. No failure was reported and there was insufficient evidence of a difference for complications (OR 2.00 (95% CI 0.15 to 26.73)) (Analysis 3.6).

Primary outcomes: aesthetic evaluation

Patients' subjective ratings for aesthetic performance through visual analogue scale (VAS) was provided at the 24 months time interval. No statistically significant difference was shown (mean difference (MD) -0.34 (95% CI -0.85 to 0.17)) (Analysis 3.9).

Secondary outcomes

Secondary outcomes Plaque Index (PI) and Gingival Index (GI) were available at two years. There was insufficient evidence of a difference for either outcome (PI 2 years MD -0.10 (95% CI -1.04 to 0.84); GI 2 years MD 0.03 (95% CI -0.75 to 0.81)) (Analysis 3.7; Analysis 3.8).

Comparison 4 Metal-free implant-supported single crowns compared to metal-ceramic implant-supported single crowns

One trial (Gallucci 2011) compared metal-free implant-supported single crowns (zirconia) to metal-ceramic implant-supported single crowns. The study was assessed to be at high risk of bias.

Primary outcomes: failures and complications of the prosthesis

At 12 and 24 months 18 participants were available. No failure was reported for the test or control groups at either 12 or 24 months.

At 24 months, there was insufficient evidence of a difference for complications (OR 6.33 (95% CI 0.26 to 152.86)) (Analysis 4.3).

Primary outcomes: aesthetic evaluation

VAS for patient satisfaction (mm) was provided at one- and two-year time intervals. There was insufficient evidence of any differences (VAS 1 year MD -4.65 (95% CI -18.75 to 9.45); VAS 2 years MD -0.03 (95% CI -7.65 to 7.59)) (Analysis 4.8; Analysis 4.9).

Aesthetic evaluation through pink aesthetic score (PES) and white aesthetic score WES total was provided at two years with insufficient evidence of a difference (MD -0.77 (95% CI -3.00 to 1.46)) (Analysis 4.10).

Secondary outcomes

First bone to implant contact (FBIC) mesial and distal to implant were available at one and two years. There was insufficient evidence of any differences (FBIC mesial 1 year MD -0.03 (95% CI -0.42 to 0.36); FBIC distal 1 year MD 0.09 (95% CI -0.28 to 0.46); FBIC mesial 2 years MD -0.01 (95% CI -0.93 to 0.91); FBIC distal 2 years MD -0.18 (95% CI -0.89 to 0.53)) (Analysis 4.4; Analysis 4.5; Analysis 4.6; Analysis 4.7).

Comparison 5 Metal-free implant abutments compared to metal implant abutments

Two trials (Albornoz 2014; Baldini 2016) compared metal-free implant abutments (zirconia) to metal implant abutments supporting single crowns. The studies were assessed to be at high risk of bias.

Primary outcomes: failures and complications of the prosthesis

At 12 months 47 participants were available. With regard to abutment failure there was insufficient evidence of a difference between either treatment approach (OR 7.63 (95% CI 0.33 to 177.14) (Analysis 5.1), whilst no complications were reported.

Primary outcomes: aesthetic evaluation

Primary outcome aesthetic evaluation data was reported as frequency of distribution of the Implant Crown Aesthetic Index (ICAI).

Secondary outcomes

Implant probing pocket depths (PPD), gingival/mucosal recession (REC), marginal bone level changes (MBLC) mesial and distal to implant were available at 12 months and there was insufficient evidence of any differences (PPD MD -0.22 (95% CI -0.60 to 0.16); REC MD 0.00 (95% CI -0.22 to 0.22); MBLC mesial MD -0.39 (95% CI -0.43 to -0.35); MBLC distal MD -0.05 (95% CI -0.15 to 0.04)) (Analysis 5.2; Analysis 5.3; Analysis 5.4; Analysis 5.5).

Comparison 6 Metal-free implant-supported FDPs made of different materials

One trial (Larsson 2006) compared metal-free implant-supported FDPs made of two different materials veneered with porcelain (zirconia-toughened alumina (In-Ceram Zirconia, Vita Zahnfabrik) and of yttria-stabilized tetragonal zirconia polycrystal material (Denzir, Decim). The study was assessed to be at high risk of bias

Primary outcomes: failures and complications of the prosthesis

At 12 months 18 participants were available. No FDPs failures were reported and with regard to complications there was a difference in favour of zirconia-toughened alumina (OR 0.04 (95% CI 0.00 to 0.48)) (Analysis 6.2).

At 36 months 18 participants were available. No FDPs failures were reported and with regard to complications there was a difference in favour of zirconia-toughened alumina (OR 0.02 (95% CI 0.00 to 0.30)) (Analysis 6.4).

At 60 months 18 participants were available. No FDPs failures were reported and with regard to complications there was a difference in favour of zirconia-toughened alumina (OR 0.02 (95% CI 0.00 to 0.42)) (Analysis 6.6).

At 120 months 17 participants were available. No FDPs failures were reported and with regard to complications there was a statistically significant difference in favour of zirconia-toughened alumina (OR 0.02 (95% CI 0.00 to 0.48)) (Analysis 6.8).

Primary outcomes: aesthetic evaluation

No data were presented with regard to aesthetics.

Secondary outcomes

No data were presented for any of the pre-specified secondary outcomes.

Comparison 7 Metal-free tooth-supported FDPs made of different materials

One trial (Naenni 2015) compared metal-free tooth-supported FDPs made with two different veneering techniques (pressed versus layered). The study was assessed to be at unclear risk of bias.

Primary outcomes: failures and complications of the prosthesis

At 12 months 40 participants were available. No FDPs failures were reported, no complications were reported.

At 36 months 36 participants were available. No FDPs failures were reported and with regard to complications there was insufficient evidence of a difference (OR 2.80 (95% CI 0.66 to 11.92) (Analysis 7.3).

Primary outcomes: aesthetic evaluation

No data were presented with regard to aesthetics.

Secondary outcomes

No data were presented for any of the pre-specified secondary outcomes.

DISCUSSION

Summary of main results

Nine trials involving a total of 448 participants were included. Each trial except two (Albornoz 2014; Baldini 2016) was addressing a different type of intervention: metal-free single crowns (full-contour zirconia) compared to cast gold single crowns (Encke 2009); metal-free implant-supported fixed dental prostheses (FDPs) made of two different types of zirconia ceramic (Larsson 2006); metal-free implant-supported single crowns (zirconia veneered with feldspathic ceramic) compared to metal-ceramic implant-supported single crowns (Gallucci 2011); metal-free cantilevered FDPs compared to metal-ceramic cantilevered FDPs (Ohlmann 2012); metal-free FDPs (lithium disilicate) compared to metal-ceramic FDPs (Makarouna 2011); metal-free FDPs (zirconia ceramic) compared to metal-ceramic FDPs (Nicolaisen 2016); metal-free tooth-supported FDPs made of two different types of zirconia ceramic (Naenni 2015); two trials (Albornoz 2014; Baldini 2016) investigated metal-free (zirconia) versus metal (titanium) abutments for single tooth implant-supported cemented crowns.

Except for one trial (Encke 2009) comparing metal-free with gold crowns which had a large number of participants (224) all the other studies had limited size ranging from 18 to 40 participants.

Overall completeness and applicability of evidence

There was insufficient evidence to draw any useful conclusions. In general, treatments were administered in university clinics and hospitals under strict follow-up regimens. The generalisation of the results to other clinical conditions should be considered with caution. It is unlikely to know if in different settings the results could be similar.

Quality of the evidence

The overall quality of evidence was very low. All bodies of evidence (i.e. for each comparison and primary outcome) were downgraded by one level for risk of bias and by two levels for imprecision (due to single-study comparisons with either very small sample sizes, low event rates, 95% confidence intervals including the possibility of benefit for both the test and control groups, or combinations of these problems). Therefore caution should be exercised when generalising the results of the included trials.

The most striking aspect is that only 9 out of 44 potentially eligible randomised controlled trials could be included in the present review. The most common problems were not being randomised and study designs combining the features of two different study designs (parallel and split-mouth) in the same study.

Investigators should design studies carefully deciding on either a parallel-group or a split-mouth design on outset, not combining the two different study designs in the same study as this leads to strong statistical limitations when willing to perform meta-analysis of data. 14 of the 22 excluded studies were potentially interesting trials which could not be included for this limitation (Andersson 1999; Andersson 2001; Borg 2014; Cehreli 2009; Chen 2008; Esquivel-Upshaw 2012; Esquivel-Upshaw 2014: Esquivel-Upshaw 2014b; Etman 2008; Ohlmann 2006; Pelaez 2012; Sailer 2009; Sailer 2009b; Vanoorbeek 2010).

Potential biases in the review process

No known potential bias was identified.

Agreements and disagreements with other studies or reviews

We identified no other systematic reviews with similar objectives and methodology.

AUTHORS' CONCLUSIONS

Implications for practice

Based on the results of the included randomised controlled trials (RCTs), there is insufficient evidence to support or refute the effectiveness of metal-free materials for fixed prosthodontic treatment over metal-ceramic or other type of standard restorations. The overall quality of existing evidence was very low, therefore great caution should be exercised when generalising the results of the included trials. Until more evidence becomes available clinicians should continue to base decisions on which material to use for fixed prosthodontic treatment on their own clinical experience, whilst taking into consideration the individual circumstances and preferences of their patients. There is urgent need of properly designed RCTs.

Implications for research

Future research should aim to provide more reliable information which can help clinicians to decide on appropriate material for fixed prosthodontic treatment whilst taking into consideration the individual circumstances and preferences of their patients. More well-designed, long-term RCTs are required to understand if metal-free materials have the same in-service clinical performance of conventional metal-based fixed prosthodontic treatments.

It is recommended that such trials include:

- test and control treatments performed in the same way when possible;
- a sufficient number of participants to disclose a true difference, if any;
- a proper group allocation concealment;
- independent outcome assessors when blinding is not possible to minimise detection bias.

Such trials should be reported according to CONSORT guidelines (www.consort-statement.org).

Investigators should design studies carefully deciding on either a parallel-group or a split-mouth design on outset, not combining the two different study designs in the same study.

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* Indicates the major publication for the study

CHARACTERISTICS OF STUDIES

Characteristics of included studies *[ordered by study ID]*

Albornoz 2014

Methods	1-year follow-up, single centre, parallel, double-blind clinical trial
Participants	38 subjects ≥18 years of age screened at the Periodontology Clinic of the Faculty of Odontology, Complutense University, Madrid, Spain, 7 patients excluded as they did not satisfy the inclusion/exclusion criteria, 1 patient withdrew before baseline data collection Inclusion criteria:

Albornoz 2014 *(Continued)*

- systemically and periodontally healthy subjects with good plaque control (< 25% PII) or subjects with a healthy periodontium if selected from a periodontal maintenance programme
- single tooth gap in the anterior maxilla (from second premolar)
- presence of ≥ 2 mm of keratinized tissue in the alveolar ridge and enough bone to insert an implant without the need of bone augmentation (minimum of 5.5 mm in width and 9 mm in height)

Exclusion criteria:

- unstable opposing dentition (including removable appliances)
- bruxism
- patients with a history of reoccurring periodontitis
- surgery resulting in inappropriate prosthetic-guided positions or if hard or soft tissue augmentation was needed

30 subjects were allocated after 3 months of healing to either test or control group, 26 received the allocated treatment

25 subjects were available at the 1-year examination: 11 (test group) and 14 (control group)

Interventions	Implant abutments made of 2 different materials supporting single crowns in the anterior maxilla Group 1: 12 zirconia abutment (SPIART; Thommen Medical AG, Grenchen, Switzerland) Group 2: 14 titanium abutment (SPIEASY; Thommen Medical AG, Grenchen, Switzerland) Implant insertion: • all patients received single implants (ELEMENT RC; Thommen Medical AG, Grenchen, Switzerland) in healed residual ridges (with a minimum period of 4 months post-extraction) Impressions and lab work: • after 3 months of healing subjects were allocated to either Group1 where an abutment composed of yttrium oxide stabilized zirconia (SPIART; Thommen Medical AG, Grenchen, Switzerland) was placed or to the Group 2 where a commercially pure titanium grade 4 abutment (CPTi Gr 4; SPIEASY; Thommen Medical AG, Grenchen, Switzerland) was placed. Both abutments were machined and designed for use with cemented restorations • a single experienced restorative dentist using 1 dental laboratory carried out all the prosthetic procedures. Full ceramic single crowns (3M ESPE LavaTM; Saint Paul, Minnesota, USA) were fabricated through CAD/CAM technology in all cases • restorations were cemented with hybrid glass ionomer permanent cement (3M ESPE RelyXTM Luting Cement; Saint Paul, Minnesota, USA)
Outcomes	• Abutment fracture • Loss of supra-structures • Veneer or framework fractures • Phonetic complications • Abutment and screw loosening • Loss of retention • Debonding • Loss of screw hole sealing • Veneer chipping • Implant Crown Aesthetic Index (ICAI) (primary outcome of the study) • Implant probing pocket depths, gingival/mucosal recession and probing attachment levels • Radiographic vertical distance from the contact point to the bone crest at mesial and distal sides • Radiographic vertical distance from the implant shoulder (1 mm supracrestally) to the most coronal bone in contact with the implant at mesial and distal sites • Radiographic horizontal distance from the implant shoulder to the adjacent teeth at mesial and distal sides

Albornoz 2014 *(Continued)*

- FMBS, FMPS, PPD, REC, PAL
- Mucosa thickness/height of the keratinized tissue and PI
- Patient-related outcomes (aesthetic appearance, phonetic ability, satisfaction)

Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "All subjects were randomized using computer-generated permuted block randomization with an allocation ratio of 1:1"
Allocation concealment (selection bias)	Low risk	Quote: "The treatment allocation was assigned by means of opaque sealed envelopes containing a code derived from the randomized list and handled directly to the restorative dentist responsible for placing the crown"
Blinding of participants and personnel (performance bias) All outcomes	Low risk	Quote: "the study examiner and the patient were blinded"
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "the study examiner and the patient were blinded"
Incomplete outcome data (attrition bias) All outcomes	High risk	5 dropouts were recorded. The reasons for the loss of patient follow-up were economic problems for crown placement in 3 subjects, the start of orthodontic therapy in 1 subject, and the move to another city in another 1 subject. 4 subjects were lost after allocation (3 in the test group and 1 in the control group) and 1 subject was lost at follow-up at 12 months. At 1 year, 25 of the 30 randomised patients were analysed: 11 (zirconia abutments) and 14 (titanium abutments). 2 patients in the test group were reported with fracture of the metal-free abutment at the time of insertion, but the study does not report them as failure
Selective reporting (reporting bias)	High risk	Follow-up visits included a written questionnaire for evaluating patient satisfaction with regard to aesthetic appearance, phonetic ability, and their overall satisfaction with treatment, graded using a 6-grade ordinal scale ranked from extremely negative to extremely positive and a VAS but data were not reported
Other bias	Low risk	

Baldini 2016

Methods	1-year follow-up, single centre, parallel, double-blind clinical trial
Participants	24 patients with mono-edentulism in the aesthetic zone of either the maxillary or mandibular region (from 1.5 to 2.5 or 3.5 to 4.5) screened at the Department of Periodontology of the University of Siena, Italy Inclusion criteria: • non-compromised systemic health • periodontal health or healthy periodontum after periodontal therapy • a minimum of 2 mm of keratinized gingiva at the edentulous site prior to surgery

Baldini 2016 *(Continued)*

	• no bone regenerative techniques required with implant surgery Exclusion criteria: • none known 24 subjects were screened, 24 subjects were allocated to the 2 treatment groups, all received the allocated treatment, 22 were available at the 1-year examination: 10 (test group) and 12 (control group)
Interventions	Implant abutments made of 2 different materials supporting single crowns in the anterior maxilla and mandible Group 1: 12 zirconia abutment (SPIART; Thommen Medical AG, Grenchen, Switzerland) Group 2: 12 titanium abutment (SPIEASY; Thommen Medical AG, Grenchen, Switzerland) Implant insertion: • all patients received single implants (SPI ELEMENT; Thommen Medical AG, Grenchen, Switzerland) in healed residual ridges (with a minimum period of 4 months post-extraction) Impressions and lab work: • after 3 months of healing subjects were allocated to either Group 1 where an abutment composed of yttrium oxide stabilized zirconia (SPIART; Thommen Medical AG, Grenchen, Switzerland) was placed or to the Group 2 where a commercially pure titanium grade 4 abutment (CPTi Gr 4; SPIEASY; Thommen Medical AG, Grenchen, Switzerland) was placed. Both abutments were machined and designed for use with cemented restorations • a porcelain fused-metal crown was made and cemented (no provisionals were made)
Outcomes	• Technical complications (major: requiring replacement of the restoration; medium or minor: to be corrected with small efforts) • Implant Crown Aesthetic Index (ICAI) (primary outcome of the study) • Implant probing pocket depths, gingival/mucosal recession and probing attachment levels • Radiographic vertical distance from the contact point to the bone crest at mesial and distal sides • Radiographic vertical distance from the implant shoulder (1 mm supracrestally) to the most coronal bone in contact with the implant at mesial and distal sites • Radiographic horizontal distance from the implant shoulder to the adjacent teeth at mesial and distal sides • FMBS, FMPS, PPD, REC, PAL • Mucosa thickness/height of the keratinized tissue and PI • Patient-related outcomes (aesthetic appearance, phonetic ability, satisfaction)
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "All patients were randomly assigned to the test or control group using a computer permuted block randomization system with an allocation ratio of 1:1"
Allocation concealment (selection bias)	Low risk	Quote: "The randomization was performed by the dentist responsible for the prosthetic restoration, by means of sealed envelopes containing a code: both patients and analysing statisticians were blinded"
Blinding of participants and personnel (performance bias)	Unclear risk	Quote: "...both patients and analysing statisticians were blinded"

Baldini 2016 *(Continued)*
All outcomes

Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "Two clinicians not involved in patient treatment were trained in calibration prior to the beginning of the study to record all outcome measurements. They were blinded about treatment group assignment; only one of the two examiners performed the aesthetic analysis (AC), the second examiner recorded all secondary outcome parameters (CD)"
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	2 dropout patients in test group, dropout reasons not explained
Selective reporting (reporting bias)	High risk	Follow-up visits included a written questionnaire for evaluating patient satisfaction concerning items such as the aesthetically related variables (harmonization of gingival margin, overall aesthetic satisfaction) and lifestyle related variables (confidence when smiling, phonic ability, comfort when chewing or biting) assessed using VAS but data were not reported
Other bias	Low risk	

Encke 2009

Methods	5-year follow-up, randomised, single-blind, parallel-group study
Participants	536 patients aged above 18 years recruited through newspaper advertisements Inclusion criteria: • a vital or successfully, endodontically treated tooth in need of a crown in the posterior region (premolar or molar) • no pathological signs on the X-ray • no clinical symptoms of inflammation • periodontal treatable abutment tooth: after pre-treatment PD < 4 mm, mobility < II, furcation involvement < 2 Exclusion criteria: • addiction to alcohol or drugs. Psychologically unstable patients. Patients with sufficiently treated teeth • patients with acute symptoms of functional disorders with the necessity of functional pre- treatment before prosthodontic therapy • ASA IV or higher patients • patients treated in the study who developed a severe systemic disease or a disease that would influence the treatment outcome, were not included in the statistical analysis. Patients who insisted on using a different crown system after explication 308 allocated to 2 groups (152 zirconia, 156 gold) with at least 1 tooth in the premolar or molar region in need of crowning. 224 patients received allocated intervention
Interventions	Single crowns on mandibular and maxillary premolars and molars Group 1: 123 patients with 123 all ceramic ZrSiO4 crowns (Everest HPC, KaVo Dental GmbH, Biberach/Riss, Germany) Group 2: 101 patients with 101 gold crowns (Degulor M, Degudent)

Encke 2009 *(Continued)*

	All treatments were carried out in the University Dental Hospital Freiburg, Germany, by staff dentists Tooth preparation: • for metal-free crowns a deep chamfer margin was performed with 1.2 mm chamfer diamond burs, an occlusal reduction of 1.5 mm and rounded inner edges • for gold crowns a chamfer type of margin was performed with 0.8 mm chamfer diamond burs, an occlusal reduction of 1.2 mm and rounded edges • in both groups preparation margins were located at the gingival level or not more than 1 mm subgingival Provisionalization: • autopolymerizing acrylic provisional crowns cemented with a eugenol-free temporary cement Impressions and lab work: • custom-made trays and a silicone impression material • master models were manufactured out of type IV dental stone • models were mounted in a semi-adjustable articulator using a face bow transfer and check bites • for the metal-free group, dies and wax-ups of the crowns were scanned (KaVo Everest scan machine), then milled (KaVo Everest HPC blanks), subsequently sintered. Full crowns were fabricated without veneering • for the gold group crowns were conventionally waxed up and casted using a gold alloy (Degulor M, Degudent) and fitted on the master model Try-in and cementation: • in both groups at the try-in, proximal contacts and static and dynamic occlusions were checked and corrected with fine diamond burs with water cooling and silicone polishers • a radiograph of the abutment and the crown was taken prior to cementation to evaluate the marginal fit and periapical region. If a periapical lesion was detected, root canal treatment was performed prior to insertion • all crowns were cemented with a glass ionomer cement (Ketac Cem Maxicap)
Outcomes	• Loss of vitality of abutment • Surface roughness • Fractures • Marginal integrity • Secondary caries at the crown margin • Margin discolourations • Marginal gap • Crown loss
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "Eligible patients were assigned a unique identification number, which was forwarded to a statistician (Institute of Medical Biometry and Medical Informatics, University of Freiburg). Randomization was carried out using the Bernoulli distribution for each patient identification number. Accordingly, the patients received either the ceramic (test) or gold crown (control). No balancing was carried out"

Encke 2009 *(Continued)*

		Comment: of the 308 patients allocated to 2 groups (152 zirconia, 156 gold) only 224 patients received allocated intervention, resulting in 123 zirconia versus 101 gold crowns
Allocation concealment (selection bias)	Unclear risk	No information provided
Blinding of participants and personnel (performance bias) All outcomes	High risk	Due to the obvious differences between the 2 crown designs (gold versus ceramic), blinding was not possible
Blinding of outcome assessment (detection bias) All outcomes	High risk	Due to the obvious differences between the 2 crown designs (gold versus ceramic), blinding was not possible
Incomplete outcome data (attrition bias) All outcomes	High risk	In the ceramic crown group, 15 patients were not followed up at the 12-month examination, 24 patients at the 24-month follow-up, 50 patients at the 36-month recall and 46 patients at the 48- and 60-month follow-ups In the gold group, 7 patients were lost to follow-up at the 12-month recall, 16 patients at the 24-month follow-up, 27 patients at the 36-month recall examination, 18 patients after 48 months and 19 patients at the 60-month follow-up 2 patients allocated to gold group were not included in the analysis, but reasons were provided
Selective reporting (reporting bias)	Low risk	None identified
Other bias	Low risk	

Gallucci 2011

Methods	2-year follow-up, randomised, parallel-group study
Participants	20 patients with 1 missing tooth in the anterior maxilla (first bicuspid to first bicuspid) and presence of 2 intact adjacent teeth Inclusion criteria: • age > 21 years • absence of relevant medical conditions • absence of periodontal disease • availability for 24 months follow-up • 1 missing tooth in the anterior maxilla (first bicuspid to first bicuspid) • presence of 2 intact adjacent teeth • adequate native bone to achieve implant primary stability Exclusion criteria: • heavy smokers (more than 10 cigarettes/ day) • adjacent implants • presence of periapical radiolucency at the adjacent teeth • missing adjacent teeth
Interventions	2 different types of screw-retained single implant crowns

Gallucci 2011 *(Continued)*

	Group 1: 10 all ceramic single crowns Group 2: 10 PFM single crowns Implant insertion: • all patients received single implants in the anterior maxilla (Standard Plus, Straumann Co., Basel, Switzerland) Provisionalization: • during the healing phase, all patients wore a removable interim prosthesis • after implant loading all patients received a fixed screw-retained provisional prosthesis Impressions and lab work: • final impressions were taken at the implant level • for the metal-free group a screw-retained all ceramic crown was fabricated using a blank composed of 90% alumina with glass infiltration (synOcta, InCeram blank, Ø 9 mm, height 15 mm and synOcta abutment, height 2.5 mm, Straumann Co.). The ceramic block was reduced to the desired shape and dimension. In average, a 1.5 mm space was left for the ceramic veneering. All ceramic framework was glass infiltrated to reach its optimal mechanical strength. For the ceramic veneering, alumina ceramic was applied in a stratified fashion to mimic the volumetric composition of the natural tooth • for the metal-ceramic group, a screwed retained MC crown was fabricated using a cast-on gold coping (synOcta gold coping crown, height 4.5 mm, Ceramicor and synOcta abutment, height 2.5 mm, Straumann Co.). Desired framework shape and dimensions were waxed-up onto the cast-on gold coping and invested in a casting mold. Framework was casted using a high gold content alloy for PFM restorations (ISO 9693 standard). Ceramic veneering was performed in an average thickness of 1.5 mm with feldspathic ceramic
Outcomes	• Failure • Complication (chipping) • Periodontal/peri-implant measurements • Aesthetic evaluation through pink aesthetic score (PES) and white aesthetic score (WES) • VAS questionnaire for aesthetics assessed by patient, subjective aesthetic evaluation on photos by panel of clinicians
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "All participants were randomly assigned to one the two treatment options. A random permuted block system was generated by a collaborator not involved in the study. Six permuted blocks containing three test and three control subjects were generated and included in 24 sealed envelopes. A copy of the randomization sequence was preserved for accuracy assessment at the end of the study. The permuted block randomization system ensured the uniformity of the patient allocation during the clinical trial by randomly distributing three participants to the test and three participants to the control group every six treated patients"
Allocation concealment (selection bias)	Low risk	Quote: "Upon patient's enrolment, a sealed envelope was assigned by order of inclusion in the study. In order to avoid bias during the prosthodontic treatment, the individually assigned sealed envelopes were only opened after final impression taking and were subsequently sent to the dental laboratory for fabrication of the implant crowns"

Gallucci 2011 *(Continued)*

Blinding of participants and personnel (performance bias) All outcomes	Low risk	Quote: "For the objective assessment at baseline, the study design was double blinded because neither the investigators nor the patients were aware of the assigned group"
Blinding of outcome assessment (detection bias) All outcomes	High risk	Quote: "For the objective assessment at baseline, the study design was double blinded because neither the investigators nor the patients were aware of the assigned group. For the objective measurements at CI, 1Y, and 2Y, the study design was single-blinded being only the participants unaware of the group they were allocated. For the subjective evaluation, the trial design was double blinded. Neither the patients nor external expert clinicians were informed about the results of the randomization"
Incomplete outcome data (attrition bias) All outcomes	Low risk	Quote: "Three dropouts were recorded. Two patients moved abroad before receiving the final crowns and one patient was unreachable after completing the 1Y"
Selective reporting (reporting bias)	Low risk	None identified
Other bias	Low risk	None identified

Larsson 2006

Methods	10-year follow-up, randomised, parallel-group study
Participants	320 individuals responded to an advertisement in a local newspaper. After preliminary interview, and panoramic X-ray, 18 partially dentate patients (12 women, 6 men; age range: 37 to 70 years) in need of 1 or more 2- to 5-unit implant-supported FDPs with satisfactory oral hygiene were randomised to 2 groups Inclusion criteria: • indications for 1 or more 2- to 5-unit implant-supported FDP • satisfactory oral hygiene Exclusion criteria: • bone dimensions insufficient for implant placement • deep occlusion • diagnosed bruxism
Interventions	2- to 5-unit implant-supported FDPs Group 1: 9 patients with 12 FDPs of a zirconia-toughened alumina, 35 units (InZ) Group 2: 9 patients with 13 FDPs of a yttria-stabilized tetragonal zirconia polycrystal material, 31 units (DZ) Implant insertion: • 2 to 3 implants were inserted for each patient by 1 clinician at the Department of Oral and Maxillofacial Surgery, Malmo¨ University Hospital, Sweden Impressions and lab work: • full arch impressions were taken using a polyether impression material (Impregum, 3M ESPE) in disposable trays with open-tray technique. Impressions of opposing arch were taken using alginate in

Larsson 2006 *(Continued)*

	rigid standard stainless steel trays (Svedia, Svedia Dental Industri), interocclusal registrations in centric relation were recorded with aluminium wax (Alminax, Associated Dental Product, Kemdent Works) • preparable titanium abutments (Profile BiAbutment, Astra Tech) were prepared with a cervical shoulder depth of 1.2 mm and slightly rounded inner angles. The preparations allowed a minimum occlusal thickness of 1.7 mm and minimum buccal, approximal, and lingual/palatal thicknesses of 1.5 mm. The desired angle of convergence was 15 degrees. Preparations were performed using a parallelometer. All laboratory procedures were carried out at a dental laboratory (DP Nova) that had been authorized by the manufacturers of the material systems.Minimum acceptable diameter of the connection between crown and pontic was 3 mm for anterior and premolar replacements. In cases of molar replacement, the minimum diameter for the pontic connectors was 4 mm. For FDPs with no pontics minimum diameter between connecting abutments was 3 mm • after visual and radiographic inspection and approval, frameworks were veneered with porcelain and fired in calibrated furnaces. Espident Triceram (Dentaurum) veneering porcelain was used for DZ FDPs and Vitadur Alpha (Vita Zahnfabrik) for InZ Try-in and cementation: • the completed FDPs were fit, adjusted, and cemented permanently with zinc phosphate cement (De Trey zinc crown and bridge Fixodont Plus, Dentsply) in 1 sitting. The occlusion was checked using GHM Hanel single-sided occlusion foils (Hanel GHM Medizinal) and, if necessary, adjusted using fine grit diamond burs (Two striper VF grit, Abrasive Technology) in a high speed turbine handpiece cooled with copious water spray and polished with rubber points (Identoflex, Identoflex) and a polishing paste (Temrex Diamond, Temrex)
Outcomes	• Modified California Dental Association quality assessment system (registrations of the surface, anatomical form of the restoration, occlusion and articulation, marginal integrity, pocket depth, bleeding on probing, and mobility)
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quote: "Patients were randomized to the two groups by drawing lots"
Allocation concealment (selection bias)	Unclear risk	Patients were divided into 2 groups after healing of implants
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	No information
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Examinations were performed blindly and the examiners were not aware of which material system each patient had received
Incomplete outcome data (attrition bias) All outcomes	Low risk	No dropouts
Selective reporting (reporting bias)	High risk	Follow-up visits included PD, BOP and mobility assessment but data were not reported
Other bias	Low risk	None identified

Makarouna 2011

Methods	6-year follow-up, randomised, parallel-group study
Participants	37 patients in need of 3-unit FPDs treatment (23 women, 14 men; mean age: 47 years) received 1 FPD each Inclusion criteria: • need of 3-unit FPD treatment Exclusion criteria: • active periodontitis • pronounced parafunction • non-feasibility of adequate chamfer preparation
Interventions	Group 1: test group (n = 18) received lithium disilicate FPDs Group 2: control group (n = 19) received PFM FPDs Tooth preparation: • for both groups chamfer preparation with rounded smooth contours Impressions and lab work: • monophase impression with a custom tray Try-in and cementation: • fit check • for both groups luting with Vivaglass CEM glass ionomer cement (Ivoclar Vivadent)
Outcomes	• Failure • Complication (chipping)
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	No description available
Allocation concealment (selection bias)	Unclear risk	No description available
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	No description available
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	No description available
Incomplete outcome data (attrition bias)	High risk	A total of 15 patients were lost to follow-up (study group: n = 5, control: n = 10) for reasons unrelated to the dental treatment

Makarouna 2011 *(Continued)*
All outcomes

Selective reporting (reporting bias)	Low risk	None identified
Other bias	Low risk	None identified

Naenni 2015

Methods	3-year follow-up, multicentre, parallel, double-blind randomised controlled trial
Participants	40 patients in need of 1 maxillary or mandibular 3-unit FDP in second premolar or molar area recruited and treated at 2 separate centres at the University of Zurich, Switzerland Inclusion criteria: • good general health • periodontally healthy (plaque indices and BOP below 20% previously to treatment) • no signs or symptoms of bruxing and/or clenching • abutment teeth in need of reconstruction Exclusion criteria: • patients not willing or able to achieve sufficient oral hygiene
Interventions	Group 1 (test group): 20 patients received a zirconia–ceramic FDP with pressed veneering ceramic Group 2 (control group): 20 patients received a FDP with conventionally layered veneering ceramic Tooth preparation: • abutment teeth were prepared according to the guidelines for all-ceramic FDPs. After preparation vital teeth were treated with a dentine adhesive system (Syntac Classic, Ivoclar Vivadent AG, Schaan, Liechtenstein) Impressions and lab work: • double-mix technique with A-silicone impression material (President, Coltène Whaledent, Altstätten, Switzerland/Honigum, DMG, Hamburg, Germany) • impressions were poured with scan stone (Camtech-Roc, Picodent, Witterfürth, Germany) • casts scanned using CAD/CAM scanner (inEOS Scanner, Sirona, Bensheim, Germany) • frameworks were designed by software (Cerec V2.6 R2005 Sirona, Bensheim, Germany) milled out of Y-TZP partially sintered zirconia ceramic blanks (IPS e.max ZirCAD, Ivoclar Vivadent AG, Schaan, Liechtenstein) with chair-side milling unit of the CAD/CAM system (inLab milling unit, Sirona, Bensheim, Germany), after milling frameworks were sintered to full density in a high-temperature furnace (Nabertherm LHT02/16, Lilienthal, Germany) • test group received pressed veneering ceramic (IPS e.max ZirPress, Ivoclar Vivadent AG, Schaan, Liechtenstein) • control group received conventionally layered veneering ceramic (IPS e.max Ceram Margin, IPS e.max Ceram Dentin and Enamel, Ivoclar Vivadent AG, Schaan, Liechtenstein) Try-in and cementation: • frameworks were checked prior to veneering • FDPs were adhesively cemented with resin cement (Panavia 21 TC, Kuraray, Japan) • after cementation occlusion was adjusted and reshaped surfaces were polished with ceramic polishers (Komet nos. 9425, 9426, 9547, Brassele)

Naenni 2015 *(Continued)*

	All FDPs were evaluated at baseline, at 6 months and at 1 and 3 years of clinical service
Outcomes	• Failure • Technical complications assessed using modified United States Public Health Services (USPHS) criteria • Biological complications analyzed at abutment teeth and analogous non-restored teeth (probing pocket depth, plaque control record, bleeding on probing, tooth vitality (CO2)) • Patient satisfaction with the aesthetic outcome and the functionality of their FDP (yes/no)
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quote: "Patients were randomly assigned to the treatment modality and the respective clinic by means of a random list with even and uneven numbers"
Allocation concealment (selection bias)	Unclear risk	No information available
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	No information available concerning participants blinding
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "In order to avoid bias the FDPs were examined by two clinicians who were not involved in the reconstructive treatment"
Incomplete outcome data (attrition bias) All outcomes	Low risk	Quote: "Four patients (2 test and 2 control) were not available for the 3-year examination. They did show up for the 1-year recall and later moved away without giving notice"
Selective reporting (reporting bias)	Low risk	None known
Other bias	Low risk	

Nicolaisen 2016

Methods	3-year follow-up, single centre, parallel randomised trial
Participants	34 patients in need of replacement of a second premolar or first molar A convenience sample was obtained from the clinic at the Department of Dentistry, Aarhus University, Denmark and by referral from private practitioners in the Aarhus area Inclusion criteria: • moderate to large fillings in the teeth neighbouring the edentulous area • vertical dimensions at the treatment site allowing for a 2-mm occlusal reduction, maintaining a 4-mm preparation (in height) without risk of compromising the surrounding tissues Exclusion criteria • general diseases

Nicolaisen 2016 *(Continued)*

	• allergy to materials used in this study • malocclusion • manifest parafunctional habits (bruxism or clenching) or temporomandibular joint disorders • apical lesion at the abutment teeth (examined with periapical radiographs using paralleling technique), endodontic treatment of abutment teeth performed < 6 months prior to enrolment • insufficient oral hygiene • periodontally involved abutment teeth (bleeding on periodontal probing and probing pocket depth > 4 mm) • present caries activity or history of high caries incidence • present or prior xerostomia • major dental treatment (prosthodontic, endodontic, orthodontic, or implant treatment; or extractions) within the last 3 month comprehensive treatment need, patients with fewer than 20 teeth or removable denture
Interventions	Group 1: test group (n = 17) all-ceramic (AC) FDPs with a zirconia framework Group 2: control group (n = 17) metal-ceramic (MC) FDPs with a high-noble metal framework Tooth preparation: • AC-FDPs 0.8 mm deep circumferential chamfer • MC-FDPs 1 mm shoulder on facial aspect, 0.6 mm deep chamfer remaining circumference • both groups 2.0 mm to 2.5 mm occlusal tooth reduction with 120 degree occlusal cusp indentation. Axial convergence 15 degrees, supragingival finish line (when possible) Impressions and lab work: • single step, 2-phase impression with silicone (Extrude Wash and Heavy, Kerr) and customized tray (Novo Tray, Dansk Ædelmetal) • impressions poured with high-strength dental stone (Nova Die Stone, BK Giulini) • metal frameworks cast with high noble gold-platinum (Au-Pt) alloy (BioPontoStar, BEGO), lost wax technique, veneered with VITA VM 13 ceramic (VITA Zahnfabrik) • stone dies of AC-FDP preparations scanned with laboratory scanner (3Shape), zirconia frameworks milled (Medical Scan und Designcenter, BEGO) from presintered zirconia blocks (BeCe CAD Zirkon+, BEGO), veneered with VITA VM 9 (VITA Zahnfabrik) Try-in and cementation: • occlusal adjustment and corrections before the final glace firing • both groups cemented with resin-enhanced glass ionomer cement (Ketac Cem Plus, 3M ESPE) FDPs were examined at baseline, 6 months, 1, 2, and 3 years
Outcomes	• Failure (loss of FDP) • Technical complications (ceramic veneer chipping fracture, marginal ditching or discolourations, loss of retention, framework fracture, or post/core fracture not leading to failure/replacement of FDP) • Biological complications (presence of plaque, pocket probing depth as measured to the nearest mm, bleeding on periodontal probing, marginal bone level on bite-wings, post-cementation pain, dental caries, apical periodontitis on periapical radiographs, and abutment or root fracture). • Modified California Dental Association (CDA) assessment system for surface, colour, anatomical form, marginal integrity (most severe score for each parameter recorded for the individual FDP) • Functional and aesthetic satisfaction changes in oral health-related quality of life (OHRQoL) using the Oral Health Impact Profile (OHIP-14) after insertion of FDPs
Notes	
Risk of bias	

Nicolaisen 2016 *(Continued)*

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Not known. Quote: "The patients were randomly allocated..."
Allocation concealment (selection bias)	Unclear risk	Not known
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not known
Blinding of outcome assessment (detection bias) All outcomes	High risk	Quote: "The evaluations were performed by the operator and another clinician who had not been involved in the treatments"
Incomplete outcome data (attrition bias) All outcomes	Low risk	No dropouts
Selective reporting (reporting bias)	Low risk	None known
Other bias	Low risk	None known

Ohlmann 2012

Methods	3-year follow-up, randomised, parallel-group study
Participants	21 patients (12 women and 9 men) between 26 and 74 years of age, with a mean age of 56 years (SD 12.6 years) received a total of 21 cantilever FDPs Inclusion criteria: • need to replace 1 premolar or incisor (no canines) with a 3 or 4 units cantilever FDPs Exclusion criteria: • patients younger than 18 years of age or incapable of signing a contract • unacceptable oral hygiene • bruxism • non-vital abutment teeth • known allergic reaction to the applied materials • pregnant and lactating women
Interventions	Group 1: 11 patients with 1 zirconia cantilever FDPs Group 2: 10 patients with 1 metal-ceramic cantilever FDPs Tooth preparation: • for both groups 1.2 mm chamfer preparation with rounded smooth contours, minimal occlusal reduction 1.5 mm • attention was made to keep 6 degrees convergence angle • teeth were built up with composite when necessary (Tetric Bleach, Ivoclar Vivadent)

Ohlmann 2012 *(Continued)*

	Impressions and lab work: • impressions taken using polyether material (Impregum, 3M ESPE) • stone casts (Fujirock, GC Europe) were poured and mounted in an articulator • for the metal-free group frameworks were fabricated using prefabricated zirconia blanks made from Y-TZP (3 mol%) using the Lava scanning and milling machine (Lava Scan, Lava Form, 3M ESPE) and then sintered at 1500 °C (Lava Therm, 3M ESPE). Axial wall thickness of the zirconia cores was set to at least 0.6 mm in the anterior region and 0.7 mm in the posterior region. Connector area of the framework was designed with a cross-sectional plane of 8 mm^2 in the anterior region and 12 mm^2 in the posterior region. Frameworks were veneered with feldspathic ceramic (Lava Ceram) by trained dental technicians • for the metal-ceramic group cantilevered FDPs were made according to standardized manufacturer's instructions Try-in and cementation: • clinical occlusal adjustment performed at try-in subsequently all FDPÒ
Outcomes	• Failure, chipping, Gingival Index, Plaque Index • Modified United States Public Health Service criteria (caries, endodontic treatment, fractures of the facing or core material, debonding, discolouration, and marginal integrity) • Aesthetic performance subjectively evaluated by the patient using a VAS scale
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quote: "...were randomly divided"
Allocation concealment (selection bias)	Unclear risk	No description available
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	No description available
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Clinical evaluations were performed by a clinician not involved in the treatment of the individual patient
Incomplete outcome data (attrition bias) All outcomes	Low risk	2 patients left the study without providing a reason before the 2-year recall. Thus, a total of 19 FDPs (10 all-ceramic FDPs and 9 metal-ceramic FDPs) were included for further analysis
Selective reporting (reporting bias)	Low risk	None identified
Other bias	Low risk	None identified

CAD/CAM = computer-aided design and computer-aided manufacturing; FDPs = fixed dental prostheses; FMBS = full-mouth bleeding score; FMPS = full-mouth plaque score; MC = metal-ceramic; PAL = probing attachment levels; PD = pocket depth; PFM = porcelain-fused-to-metal; PI = plaque index; PII = prosthetic implant infection; PPD = probing pocket depth; REC = gingival/mucosal recession; SD = standard deviation; VAS = visual analogue scale.

Characteristics of excluded studies *[ordered by study ID]*

Study	Reason for exclusion
Andersson 1999	Study design is neither parallel-group nor split-mouth. 69 prosthetic abutments have been randomised in 60 patients to 2 interventions. Some patients had 1 intervention, some others had both interventions
Andersson 2001	Study design is neither parallel-group nor split-mouth. 103 prosthetic abutments have been randomised in 32 patients to 2 interventions. Some patients had 1 intervention, some others had both interventions
Batson 2014	Follow-up shorter than 1 year
Bindl 2005	Not randomised
Borg 2014	Study design is neither parallel-group nor split-mouth. 18 implant-supported FDPs have been randomised in 16 patients to 2 interventions. Some patients had 1 intervention, some others had both interventions
Cehreli 2009	Study design is neither parallel-group nor split-mouth. 30 prosthetic crowns have been randomised in 20 patients to 2 interventions. Some patients had 1 intervention, some others had both interventions
Cehreli 2011	It is unclear whether randomisation was done according to patients or restorations. 33 consecutive patients included in the study were randomised to 2 interventions, feldspathic porcelain crowns (12 patients, 50 crowns) and glass-infiltrated alumina all-ceramic crowns (21 patients, 51 crowns). Authors were contacted via mail but did not answer
Chen 2008	Study design is neither parallel-group nor split-mouth. 35 implants in 23 patients have been randomised to 2 interventions. Some patients had 1 intervention, some others had both interventions
Christensen 2010	Unclear randomisation. Study is described as randomised with 10 different treatment modalities but 2 "were not available initially." 2 other groups were limited in size compared to the others because of investigators "concern about framework fractures shortly after placement"
Esquivel-Upshaw 2012	Study design is neither parallel-group nor split-mouth. 36 posterior crowns in 31 patients have been randomised to 3 interventions. Some patients had 1 intervention, some others had more than 1 intervention
Esquivel-Upshaw 2014	Study design is neither parallel-group nor split-mouth. 72 FDPs in 55 patients have been randomised to 2 interventions. Some patients had 1 intervention, some others had more than 1 intervention
Esquivel-Upshaw 2014b	Study design is neither parallel-group nor split-mouth. 89 FDPs in 68 patients have been randomised to 2 interventions. Some patients had 1 intervention, some others had more than 1 intervention
Etman 2008	Study design is neither parallel-group nor split-mouth. 90 posterior crowns in 48 patients have been randomised to 3 interventions. Some patients had 1 intervention, some others had more than 1 intervention
Henriksson 2004	Not randomised
Jung 2008	Follow-up shorter than 1 year
Li 2007	Not randomised

Study	Reason for exclusion
Ohlmann 2006	Study design is neither parallel-group nor split-mouth. 120 prosthetic crowns have been randomised in 66 patients to 3 interventions. Some patients had 1 intervention, some others had more than 1 intervention
Pelaez 2012	Study design is neither parallel-group nor split-mouth. 40 3 units FPDs have been randomised in 37 patients to 2 interventions. Some patients had 1 intervention, some others had both interventions
Sagirkaya 2012	It is unclear how randomisation was done. 59 subjects with excessive loss of tooth structure requiring full veneer crowns, crowns/FPDs needing replacement, and missing tooth or teeth requiring tooth- or implant-supported crowns and/or 3 to 6 units FPDs were randomised to 4 interventions. According to materials and methods section patients were randomised, but the number of patient randomised to each group is not reported neither in materials and methods nor in results sections. Results report data according to units, and the 4 groups have large differences in size of reported units (Cercon, 24 units; ZirkonZahn, 118 units; Lava, 40 units; Katana, 85 units). Authors were contacted via mail but did not answer
Sailer 2009	Study design is neither parallel-group nor split-mouth. 40 implant sites have been randomised in 22 patients to 2 interventions. Some patients had 1 intervention, some others had both interventions
Sailer 2009b	Study design is neither parallel-group nor split-mouth. 76 FPDs have been randomised in 59 patients to 2 interventions. Some patients had 1 intervention, some others had both interventions
Vanoorbeek 2010	Study design is neither parallel-group nor split-mouth. 200 prosthetic crowns have been randomised in 130 patients to 2 interventions. Some patients had 1 intervention, some others had both interventions. Moreover randomisation was terminated after the first 120 restorations due to early complications in 1 group

FDPs = fixed dental prostheses.

Characteristics of ongoing studies *[ordered by study ID]*

DRKS00005452

Trial name or title	'Prospective randomized controlled interventional study of chair-side generated monolithic single implant supra-structures made of lithium disilicate ceramic'
Methods	Randomised, parallel-group study
Participants	30 adult patients with indication for single implant(s) in the posterior region
Interventions	Group 1: monolithic single implant suprastructures made of lithium disilicate Group 2: titanium abutment and crown made of lithium disilicate
Outcomes	Survival rate Complication rate over a time period of at least 3 years
Starting date	November 2013
Contact information	sreich@ukaachen.de
Notes	

DRKS00010423	
Trial name or title	'Monolithic zirconia fixed dental prosthesis in the posterior region: a randomized controlled clinical trial'
Methods	Randomised, parallel-group study
Participants	60 patients in need of a FDP in the posterior region
Interventions	Group 1: monolithic zirconia FDP (posterior region) Group 2: monolithic zirconia FDP (posterior region), buccaly and occlusaly veneered Group 3: monolithic zirconia FDP (posterior region), circumferentially veneered
Outcomes	Survival Technical complication rate after 3 years of clinical service by means of standardized USPHS criteria; secondary caries (assessed on a radiograph and by clinical examination), bleeding on probing, pocket depth, plaque score Wear rate of the FDP and the antagonists (assessed by means of a silicone impression)
Starting date	June 2016
Contact information	4c57314a5479396775667846314246536 35a75784f62586535535a65783445596f5338452f5947614546453d@drks.de
Notes	

DRKS00011173	
Trial name or title	'Different materials for posterior all-ceramic CAD/CAM generated single crowns: a randomized prospective controlled clinical trial'
Methods	Randomised, parallel-group study
Participants	45 patients in need of a single crown in the posterior region of the maxilla or mandible
Interventions	Group 1: monolithic CAD/CAM single crown: e.max CAD Group 2: monolithic CAD/CAM single crown: VITA Enamic Group 3: monolithic CAD/CAM single crown: VITABLOCS Mark II
Outcomes	Survival after 1, 3 and 5 years (the crown remained in situ) Technical and biological complication rates after 1, 3 and 5 years
Starting date	March 2017
Contact information	4c57314a5479396775667846314246536 35a75784f62586535535a65783445596f5338452f5947614546453d@drks.de
Notes	

NCT01229995

Trial name or title	'A comparison of zirconia CAD/CAM and conventionally fabricated single implant abutments and restorations in the aesthetic zone: a randomized controlled clinical trial'
Methods	Randomised, parallel-group study
Participants	30 adult patients in need of replacing 1 missing tooth in the aesthetic area
Interventions	Group 1: implant-supported single crowns made with CAD/CAM 'Etkon' technology (zirconia abutment and ceramic crown) Group 2: implant-supported single crowns made with conventional technique (crossfit titanium abutment and a ceramometal crown)
Outcomes	Failure, chipping, periodontal/peri-implant measurements, aesthetic evaluation through pink aesthetic score (PES) and white aesthetic score (WES), VAS questionnaire for aesthetics assessed by patient
Starting date	May 2009
Contact information	
Notes	

NCT01729858

Trial name or title	'Factors influencing the survival of implant-supported all-ceramic prostheses'
Methods	Randomised, parallel-group study
Participants	150 adult patients with partial edentulism
Interventions	Group 1: metal-ceramic prosthesis with press on veneer with different thicknesses, different diameters of curvature of gingival embrasure and connector heights Group 2: zirconia computer-aided design and computer-milled cores with press on veneers with different thicknesses, gingival embrasure diameters and connector heights
Outcomes	Primary: any fracture or chipping of the prostheses reported by the participant or noted at recall periods Secondary: wear of prosthesis and enamel antagonist
Starting date	December 2008
Contact information	
Notes	Preliminary data published 2012

NCT01835821

Trial name or title	'A clinical evaluation of hand-veneered, porcelain-fused NobelProcera crown shaded zirconia and NobelProcera(TM) full contour crown IPS e.Max CAD on molars'

NCT01835821 *(Continued)*

Methods	Randomised, split-mouth study
Participants	11 adult patients in need of at least 2 paired contralateral single-tooth full coverage molar restorations in the maxilla or mandible or both
Interventions	Group 1: single cemented ceramic crowns made with shaded zirconia (NobelProcera Shaded Zirconia) Group 2: single cemented full contour NobelProcera crowns made with IPS e.max CAD lithium disilicate
Outcomes	Success defined according to CDA (Canadian Dental Association) index (Romeo or Sierra; excellent or acceptable)
Starting date	March 2010
Contact information	
Notes	

NCT02175329

Trial name or title	'A randomized clinical trial of 3-unit posterior zirconia-ceramic fixed dental prosthesis (FDPs) veneered with layered and milled (CAD-on) veneering ceramics
Methods	Randomised, parallel-group study
Participants	60 adult patients
Interventions	Group 1: 3-unit posterior CAD/CAM fabricated zirconia bridge framework veneered with CAD/CAM fabricated lithium disilicate ceramic veneer Group 2: 3-unit posterior CAD/CAM fabricated zirconia bridge framework veneered manually layered ceramic
Outcomes	Clinical success
Starting date	January 2010
Contact information	
Notes	

NCT02188212

Trial name or title	'A clinical evaluation of hand-veneered, porcelain-fused NobelProceraTM crown shaded zirconia and NobelProceraTM full contour crown IPS e.Max CAD on molars'
Methods	Randomised, split-mouth study
Participants	143 adult patients in need of 2 single tooth restorations on contralateral teeth in the same arch (molars)

NCT02188212 *(Continued)*

Interventions	Group 1: single cemented ceramic crowns made with shaded zirconia (NobelProcera Shaded Zirconia) Group 2: single cemented full contour NobelProcera crowns made with IPS e.max CAD lithium disilicate
Outcomes	Longevity
Starting date	March 2010
Contact information	
Notes	

NCT02272491

Trial name or title	'Monolithic zirconia crowns for single implants in the molar region: a multicenter randomized controlled clinical trial'
Methods	Randomised, parallel-group study
Participants	80 adult patients in need of molar implant-supported single crowns
Interventions	Group 1: ZrO2 crown (Straumann CARES) The monolithic zirconia crown (Straumann CARES Full Contour Zerion HT) will be bonded to the titanium base (Straumann CARES Variobase Abutment RN) Group 2: PFM crown (Straumann Gold) Porcelain-fused-to-metal crown consisting of a gold abutment, a gold core, and veneering ceramic
Outcomes	"The primary outcome of the study is the technical complication rate. This outcome represents an indicator for the prosthetic success of the implant-supported crown. The main biological secondary outcomes are marginal bone level, histological signs of inflammation, and presence of pathogenic bacteria. Further outcomes are crown survival, wear of the crown and of the antagonist"
Starting date	October 2014
Contact information	research.kbtm@zzm.uzh.ch
Notes	

NCT02758457

Trial name or title	'Zirconia and metal-based single crown posterior restorations'
Methods	Randomised, parallel-group study
Participants	72 adult patients in need of a single posterior ceramic crown
Interventions	Group 1: a metal-based restorations (single crown with a metal framework and pressed ceramic)

NCT02758457 *(Continued)*

	Group 2: a zirconia-based restorations (single crown with a zirconia framework and pressed ceramic)
Outcomes	Survival Technical complication rate (time frame: 5 years) assessed by USPHS criteria Bleeding on probing, pocket probing depth
Starting date	January 2008
Contact information	carlo.monaco2@unibo.it
Notes	

NCT02937220

Trial name or title	'Influence of superstructure material on crestal bone resorption and aesthetic outcome of dental implants'
Methods	Randomised, parallel-group study
Participants	34 patients in need of a single implant-supported crown in the aesthetic region
Interventions	Group 1: implant-supported monolithic zirconia crown Group 2: implant-supported metal ceramic crown
Outcomes	Survival PES (time frame: 1 year, pink aesthetic scoring system for soft tissue aesthetics) Crestal bone resorption
Starting date	December 2016
Contact information	Ahmed Roshdy Radwan, Cairo University, Egypt
Notes	

NCT03039985

Trial name or title	'All-ceramic crowns in patients with sleep bruxism - a randomized clinical trial'
Methods	Randomised, parallel-group study
Participants	100 patients in need of a single molar crown
Interventions	Group 1: monolithic zirconia molar crowns (Prettau) in patients with bruxism Group 2: monolithic zirconia molar crowns (Prettau) in patients without bruxism Group 3: monolithic lithium disilicate molar crowns (IPSe.max) in patients with bruxism Group 4: monolithic lithium disilicate molar crowns (IPSe.max) in patients without bruxism

NCT03039985 *(Continued)*

Outcomes	Success of all ceramic crowns as determined by complication rate (time frame up to 5 years)
Starting date	February 2015
Contact information	Brigitte_Ohlmann@40med.uni-heidelberg.de
Notes	

CAD/CAM = computer-aided design and computer-aided manufacturing; FDPs = fixed dental prostheses; USPHS = United States Public Health Service; VAS = visual analogue scale.

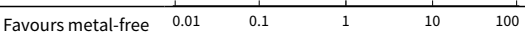
DATA AND ANALYSES

Comparison 1. Metal-free single crowns compared to conventional crowns

Outcome or subgroup title	No. of studies	No. of partici-pants	Statistical method	Effect size
1 Crown failure, 1 year	1	194	Odds Ratio (M-H, Fixed, 95% CI)	0.83 [0.05, 13.44]
2 Crown failure, 5 years	1	158	Odds Ratio (M-H, Fixed, 95% CI)	17.52 [5.07, 60.54]
3 Crown complications, 1 year	1	194	Odds Ratio (M-H, Fixed, 95% CI)	4.31 [0.49, 37.57]
4 Crown complications, 5 years	1	158	Odds Ratio (M-H, Fixed, 95% CI)	1.44 [0.59, 3.52]

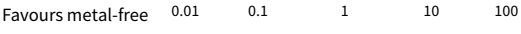
Analysis 1.1. Comparison 1 Metal-free single crowns compared to conventional crowns, Outcome 1 Crown failure, 1 year.

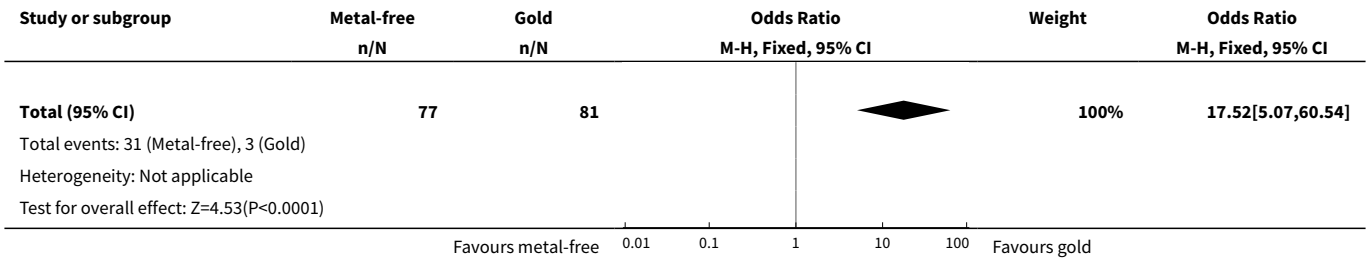
Study or subgroup	Metal-free n/N	Gold n/N	Odds Ratio M-H, Fixed, 95% CI	Weight	Odds Ratio M-H, Fixed, 95% CI
Encke 2009	1/106	1/88		100%	0.83[0.05,13.44]
Total (95% CI)	**106**	**88**		**100%**	**0.83[0.05,13.44]**
Total events: 1 (Metal-free), 1 (Gold)					
Heterogeneity: Not applicable					
Test for overall effect: Z=0.13(P=0.89)					



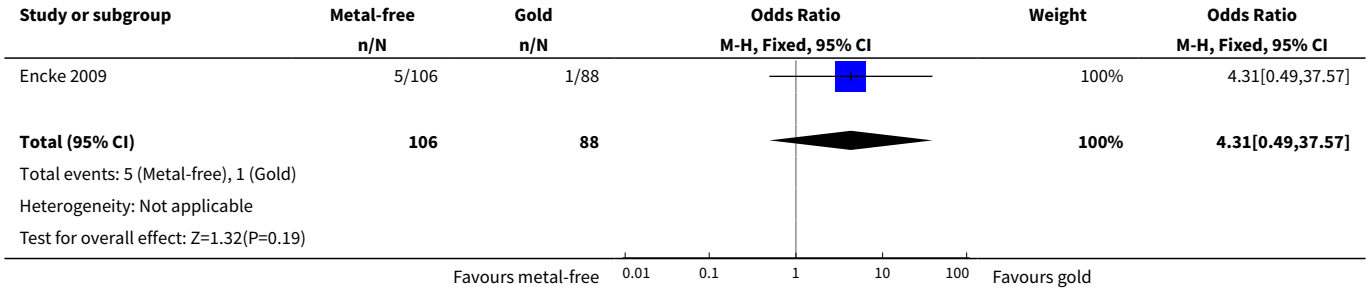
Analysis 1.2. Comparison 1 Metal-free single crowns compared to conventional crowns, Outcome 2 Crown failure, 5 years.

Study or subgroup	Metal-free n/N	Gold n/N	Odds Ratio M-H, Fixed, 95% CI	Weight	Odds Ratio M-H, Fixed, 95% CI
Encke 2009	31/77	3/81		100%	17.52[5.07,60.54]

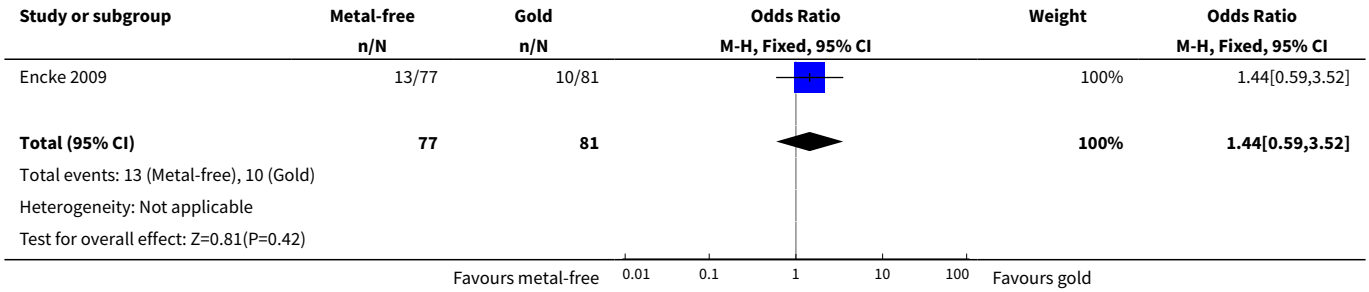




Analysis 1.3. Comparison 1 Metal-free single crowns compared to conventional crowns, Outcome 3 Crown complications, 1 year.



Analysis 1.4. Comparison 1 Metal-free single crowns compared to conventional crowns, Outcome 4 Crown complications, 5 years.

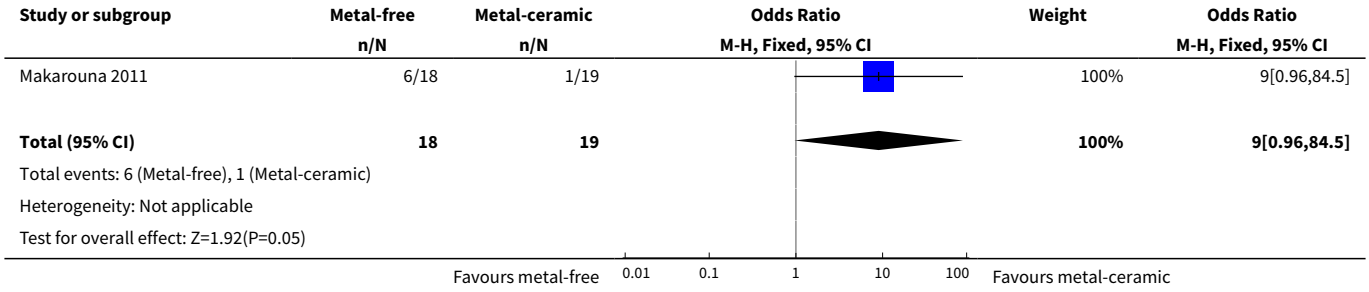


Comparison 2. Metal-free FDPs compared to metal-ceramic FDPs

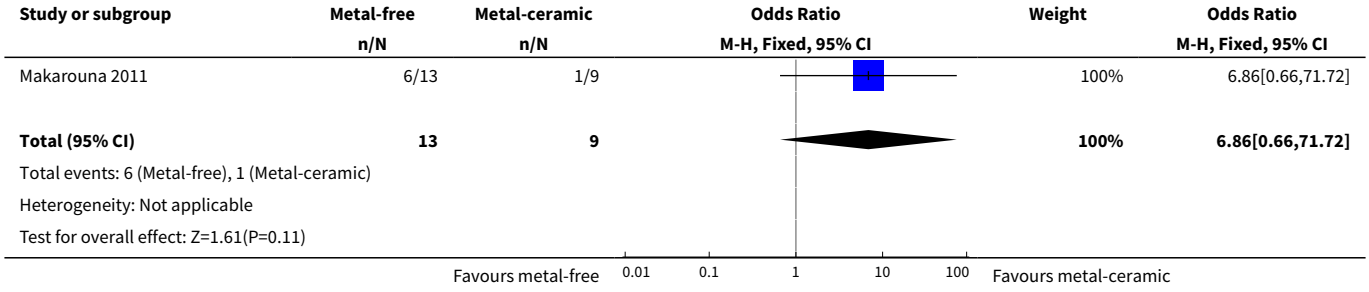
Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Bridge failure, lithium disilicate, 1 year	1	37	Odds Ratio (M-H, Fixed, 95% CI)	9.0 [0.96, 84.50]
2 Bridge failure, lithium disilicate, 6 years	1	22	Odds Ratio (M-H, Fixed, 95% CI)	6.86 [0.66, 71.72]
3 Bridge complications, lithium disilicate, 6 years	1	22	Odds Ratio (M-H, Fixed, 95% CI)	0.07 [0.01, 0.75]

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
4 Bridge failure, zirconia ceramic, 1 year	1	34	Odds Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]
5 Bridge failure, zirconia ceramic, 3 years	1	34	Odds Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]
6 Bridge complications, zirconia ceramic, 3 years	1	34	Odds Ratio (M-H, Fixed, 95% CI)	1.94 [0.38, 9.88]
7 Patient aesthetic satisfaction changes, zirconia ceramic, 3 years	1	34	Odds Ratio (M-H, Fixed, 95% CI)	15.4 [0.78, 304.61]

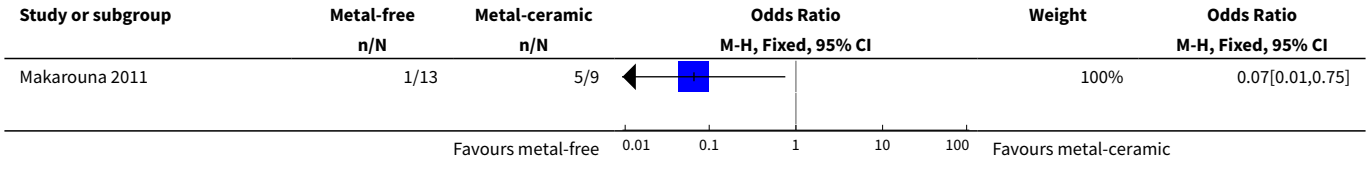
Analysis 2.1. Comparison 2 Metal-free FDPs compared to metal-ceramic FDPs, Outcome 1 Bridge failure, lithium disilicate, 1 year.

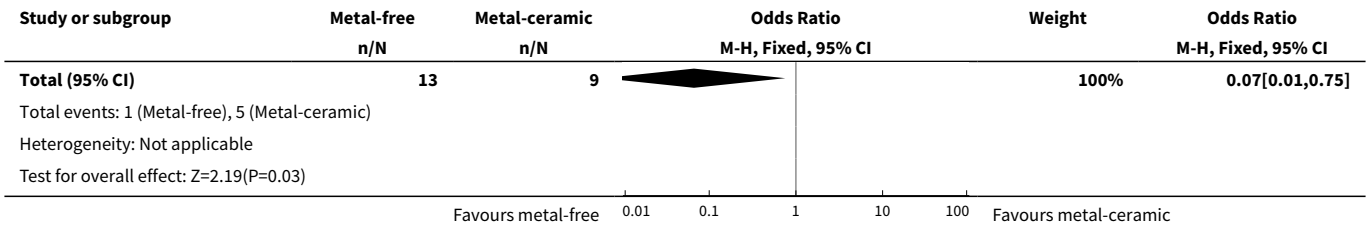


Analysis 2.2. Comparison 2 Metal-free FDPs compared to metal-ceramic FDPs, Outcome 2 Bridge failure, lithium disilicate, 6 years.

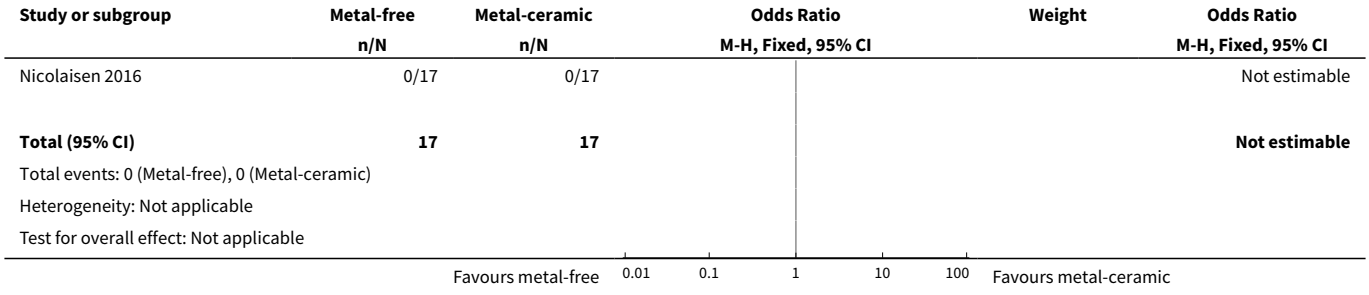


Analysis 2.3. Comparison 2 Metal-free FDPs compared to metal-ceramic FDPs, Outcome 3 Bridge complications, lithium disilicate, 6 years.

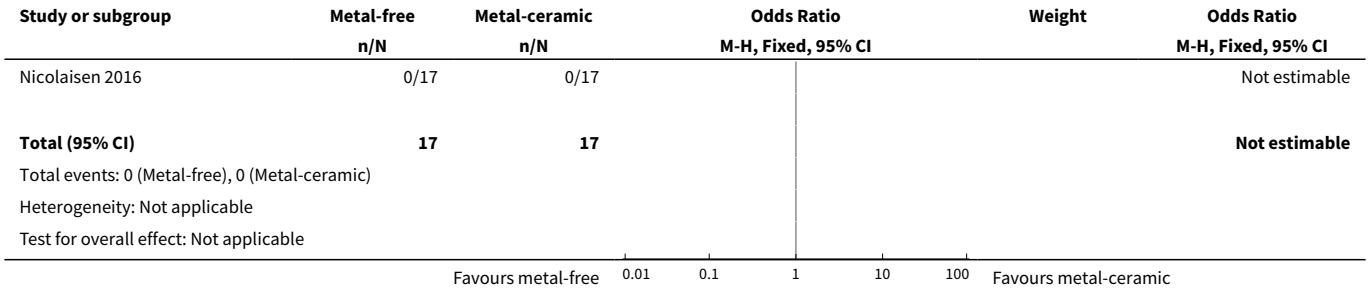




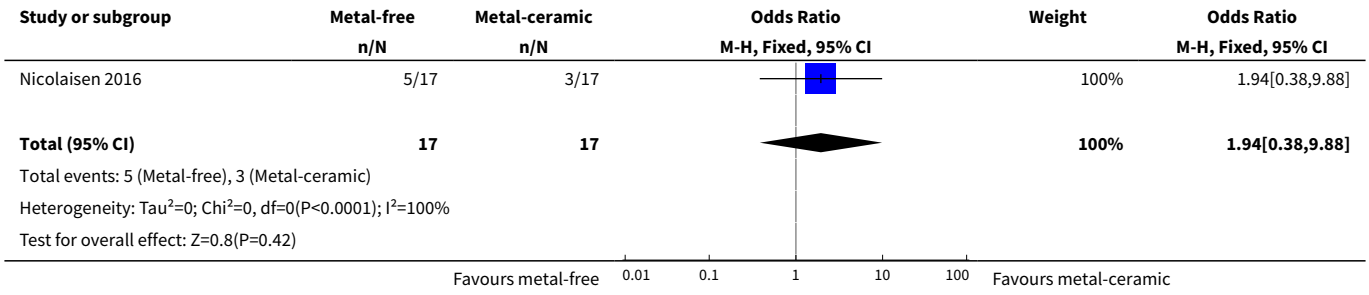
Analysis 2.4. Comparison 2 Metal-free FDPs compared to metal-ceramic FDPs, Outcome 4 Bridge failure, zirconia ceramic, 1 year.



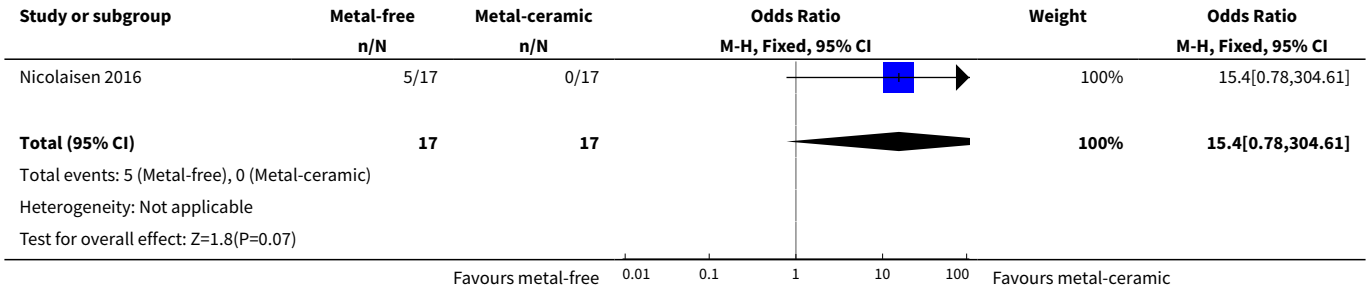
Analysis 2.5. Comparison 2 Metal-free FDPs compared to metal-ceramic FDPs, Outcome 5 Bridge failure, zirconia ceramic, 3 years.



Analysis 2.6. Comparison 2 Metal-free FDPs compared to metal-ceramic FDPs, Outcome 6 Bridge complications, zirconia ceramic, 3 years.



Analysis 2.7. Comparison 2 Metal-free FDPs compared to metal-ceramic FDPs, Outcome 7 Patient aesthetic satisfaction changes, zirconia ceramic, 3 years.

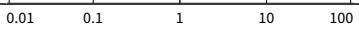


Comparison 3. Metal-free cantilevered FDPs compared to metal-ceramic cantilevered FDPs

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Cantilevered bridge failure, 1 year	1	19	Odds Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]
2 Cantilevered bridge complications, 1 year	1	19	Odds Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]
3 Cantilevered bridge failure, 2 years	1	19	Odds Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]
4 Cantilevered bridge complications, 2 years	1	19	Odds Ratio (M-H, Fixed, 95% CI)	5.59 [0.23, 133.61]
5 Cantilevered bridge failure, 3 years	1	19	Odds Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]
6 Cantilevered bridge complications, 3 years	1	19	Odds Ratio (M-H, Fixed, 95% CI)	2.0 [0.15, 26.73]
7 Plaque Index, 2 years	1	19	Mean Difference (IV, Fixed, 95% CI)	-0.10 [-1.04, 0.84]
8 Gingival Index, 2 years	1	19	Mean Difference (IV, Fixed, 95% CI)	0.03 [-0.75, 0.81]
9 Patient subjective rating for aesthetic performance, 2 years	1	19	Mean Difference (IV, Fixed, 95% CI)	-0.34 [-0.85, 0.17]

Analysis 3.1. Comparison 3 Metal-free cantilevered FDPs compared to metal-ceramic cantilevered FDPs, Outcome 1 Cantilevered bridge failure, 1 year.

Study or subgroup	Metal-free n/N	Metal-ceramic n/N	Odds Ratio M-H, Fixed, 95% CI	Weight	Odds Ratio M-H, Fixed, 95% CI
Ohlmann 2012	0/10	0/9			Not estimable
Total (95% CI)	**10**	**9**			**Not estimable**
Total events: 0 (Metal-free), 0 (Metal-ceramic)					
Heterogeneity: Not applicable					
Test for overall effect: Not applicable					



Analysis 3.2. Comparison 3 Metal-free cantilevered FDPs compared to metal-ceramic cantilevered FDPs, Outcome 2 Cantilevered bridge complications, 1 year.

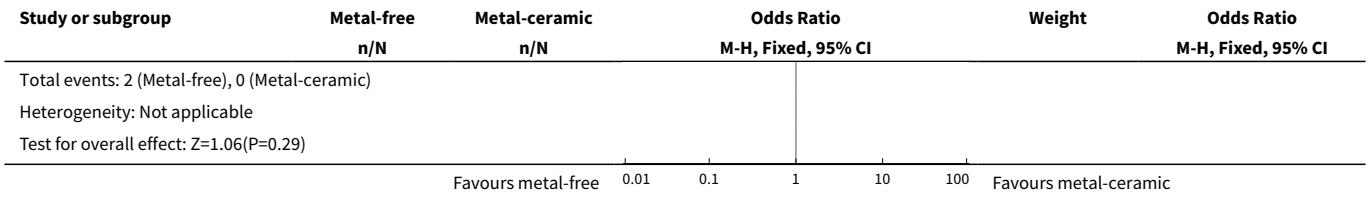
Study or subgroup	Metal-free n/N	Metal-ceramic n/N	Odds Ratio M-H, Fixed, 95% CI	Weight	Odds Ratio M-H, Fixed, 95% CI
Ohlmann 2012	0/10	0/9			Not estimable
Total (95% CI)	**10**	**9**			**Not estimable**
Total events: 0 (Metal-free), 0 (Metal-ceramic)					
Heterogeneity: Not applicable					
Test for overall effect: Not applicable					

Analysis 3.3. Comparison 3 Metal-free cantilevered FDPs compared to metal-ceramic cantilevered FDPs, Outcome 3 Cantilevered bridge failure, 2 years.

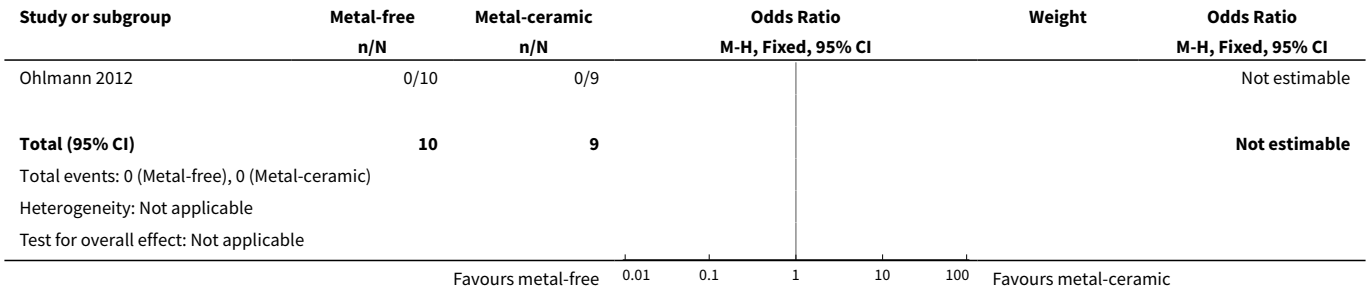
Study or subgroup	Metal-free n/N	Metal-ceramic n/N	Odds Ratio M-H, Fixed, 95% CI	Weight	Odds Ratio M-H, Fixed, 95% CI
Ohlmann 2012	0/10	0/9			Not estimable
Total (95% CI)	**10**	**9**			**Not estimable**
Total events: 0 (Metal-free), 0 (Metal-ceramic)					
Heterogeneity: Not applicable					
Test for overall effect: Not applicable					

Analysis 3.4. Comparison 3 Metal-free cantilevered FDPs compared to metal-ceramic cantilevered FDPs, Outcome 4 Cantilevered bridge complications, 2 years.

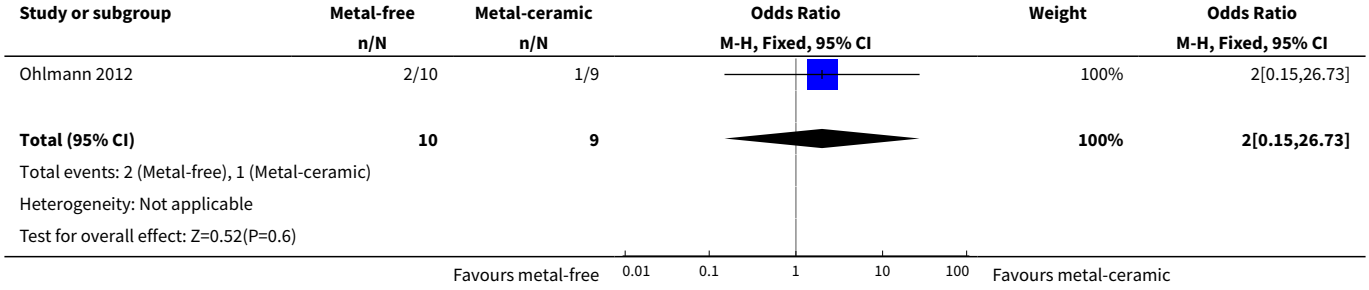
Study or subgroup	Metal-free n/N	Metal-ceramic n/N	Odds Ratio M-H, Fixed, 95% CI	Weight	Odds Ratio M-H, Fixed, 95% CI
Ohlmann 2012	2/10	0/9		100%	5.59[0.23,133.61]
Total (95% CI)	**10**	**9**		**100%**	**5.59[0.23,133.61]**



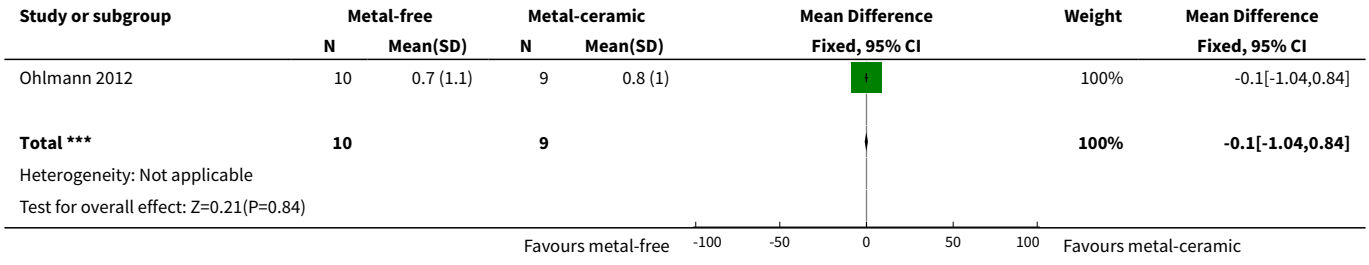
Analysis 3.5. Comparison 3 Metal-free cantilevered FDPs compared to metal-ceramic cantilevered FDPs, Outcome 5 Cantilevered bridge failure, 3 years.



Analysis 3.6. Comparison 3 Metal-free cantilevered FDPs compared to metal-ceramic cantilevered FDPs, Outcome 6 Cantilevered bridge complications, 3 years.

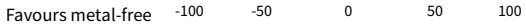


Analysis 3.7. Comparison 3 Metal-free cantilevered FDPs compared to metal-ceramic cantilevered FDPs, Outcome 7 Plaque Index, 2 years.



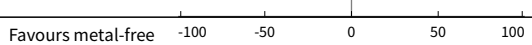
Analysis 3.8. Comparison 3 Metal-free cantilevered FDPs compared to metal-ceramic cantilevered FDPs, Outcome 8 Gingival Index, 2 years.

Study or subgroup	Metal-free N	Metal-free Mean(SD)	Metal-ceramic N	Metal-ceramic Mean(SD)	Mean Difference Fixed, 95% CI	Weight	Mean Difference Fixed, 95% CI
Ohlmann 2012	10	0.7 (0.9)	9	0.7 (0.8)		100%	0.03[-0.75,0.81]
Total ***	**10**		**9**			**100%**	**0.03[-0.75,0.81]**
Heterogeneity: Not applicable							
Test for overall effect: Z=0.08(P=0.94)							



Analysis 3.9. Comparison 3 Metal-free cantilevered FDPs compared to metal-ceramic cantilevered FDPs, Outcome 9 Patient subjective rating for aesthetic performance, 2 years.

Study or subgroup	Metal-free N	Metal-free Mean(SD)	Metal-ceramic N	Metal-ceramic Mean(SD)	Mean Difference Fixed, 95% CI	Weight	Mean Difference Fixed, 95% CI
Ohlmann 2012	10	0.1 (0.3)	9	0.4 (0.7)		100%	-0.34[-0.85,0.17]
Total ***	**10**		**9**			**100%**	**-0.34[-0.85,0.17]**
Heterogeneity: Not applicable							
Test for overall effect: Z=1.3(P=0.19)							

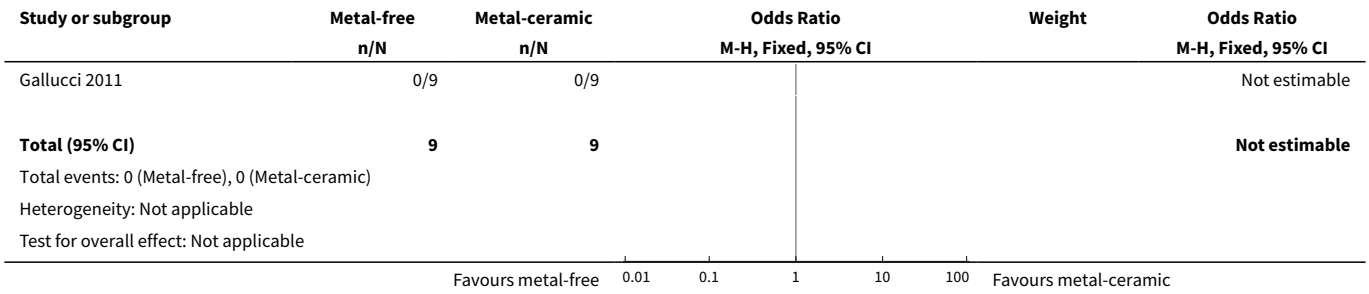


Comparison 4. Metal-free implant-supported single crowns compared to metal-ceramic implant-supported single crowns

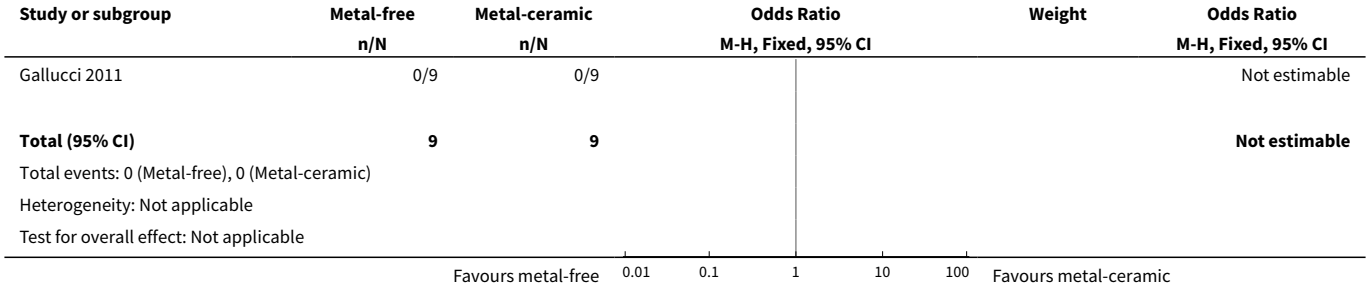
Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Implant crown failure, 1 year	1	18	Odds Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]
2 Implant crown failure, 2 years	1	18	Odds Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]
3 Implant crown complications, 2 years	1	18	Odds Ratio (M-H, Fixed, 95% CI)	6.33 [0.26, 152.86]
4 First bone to implant contact, mesial to crown, 1 year	1	18	Mean Difference (IV, Fixed, 95% CI)	-0.03 [-0.42, 0.36]
5 First bone to implant contact, distal to crown, 1 year	1	18	Mean Difference (IV, Fixed, 95% CI)	0.09 [-0.28, 0.46]
6 First bone to implant contact, mesial to crown, 2 years	1	18	Mean Difference (IV, Fixed, 95% CI)	-0.01 [-0.93, 0.91]
7 First bone to implant contact, distal to crown, 2 years	1	18	Mean Difference (IV, Fixed, 95% CI)	-0.18 [-0.89, 0.53]
8 VAS for patient satisfaction, 1 year	1	18	Mean Difference (IV, Fixed, 95% CI)	-4.65 [-18.75, 9.45]

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
9 VAS for patient satisfaction, 2 years	1	18	Mean Difference (IV, Fixed, 95% CI)	-0.03 [-7.65, 7.59]
10 PES and WE scores, total, 2 years	1	18	Mean Difference (IV, Fixed, 95% CI)	-0.77 [-3.00, 1.46]

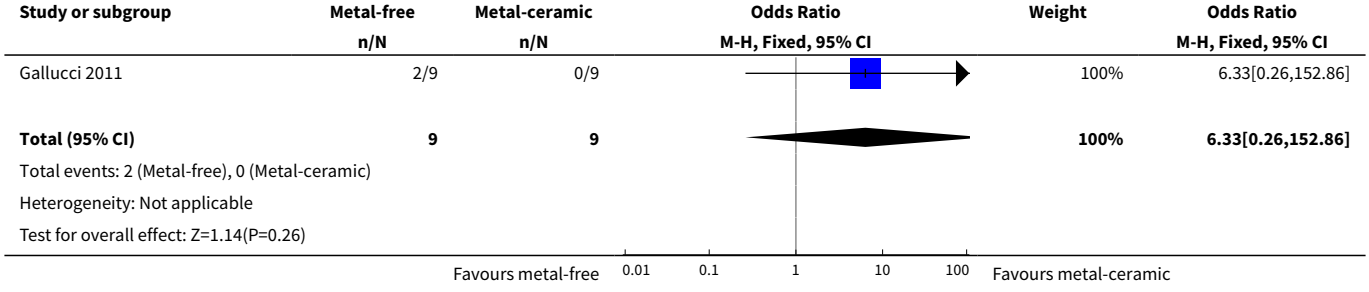
Analysis 4.1. Comparison 4 Metal-free implant-supported single crowns compared to metal-ceramic implant-supported single crowns, Outcome 1 Implant crown failure, 1 year.



Analysis 4.2. Comparison 4 Metal-free implant-supported single crowns compared to metal-ceramic implant-supported single crowns, Outcome 2 Implant crown failure, 2 years.

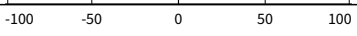


Analysis 4.3. Comparison 4 Metal-free implant-supported single crowns compared to metal-ceramic implant-supported single crowns, Outcome 3 Implant crown complications, 2 years.



Analysis 4.4. Comparison 4 Metal-free implant-supported single crowns compared to metal-ceramic implant-supported single crowns, Outcome 4 First bone to implant contact, mesial to crown, 1 year.

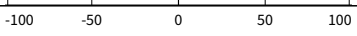
Study or subgroup	Metal-free N	Metal-free Mean(SD)	Metal-ceramic N	Metal-ceramic Mean(SD)	Mean Difference Fixed, 95% CI	Weight	Mean Difference Fixed, 95% CI
Gallucci 2011	9	1.6 (0.5)	9	1.6 (0.4)		100%	-0.03[-0.42,0.36]
Total ***	**9**		**9**			**100%**	**-0.03[-0.42,0.36]**
Heterogeneity: Not applicable							
Test for overall effect: Z=0.15(P=0.88)							



Favours metal-free | Favours metal-ceramic

Analysis 4.5. Comparison 4 Metal-free implant-supported single crowns compared to metal-ceramic implant-supported single crowns, Outcome 5 First bone to implant contact, distal to crown, 1 year.

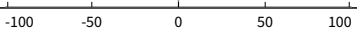
Study or subgroup	Metal-free N	Metal-free Mean(SD)	Metal-ceramic N	Metal-ceramic Mean(SD)	Mean Difference Fixed, 95% CI	Weight	Mean Difference Fixed, 95% CI
Gallucci 2011	9	1.8 (0.4)	9	1.8 (0.4)		100%	0.09[-0.28,0.46]
Total ***	**9**		**9**			**100%**	**0.09[-0.28,0.46]**
Heterogeneity: Not applicable							
Test for overall effect: Z=0.47(P=0.64)							



Favours metal-free | Favours metal-ceramic

Analysis 4.6. Comparison 4 Metal-free implant-supported single crowns compared to metal-ceramic implant-supported single crowns, Outcome 6 First bone to implant contact, mesial to crown, 2 years.

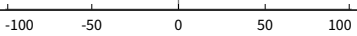
Study or subgroup	Metal-free N	Metal-free Mean(SD)	Metal-ceramic N	Metal-ceramic Mean(SD)	Mean Difference Fixed, 95% CI	Weight	Mean Difference Fixed, 95% CI
Gallucci 2011	9	2.2 (1.1)	9	2.3 (0.9)		100%	-0.01[-0.93,0.91]
Total ***	**9**		**9**			**100%**	**-0.01[-0.93,0.91]**
Heterogeneity: Not applicable							
Test for overall effect: Z=0.02(P=0.98)							



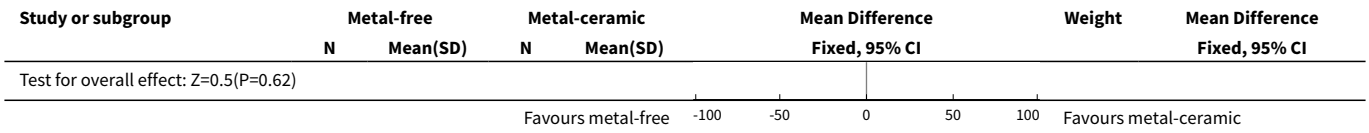
Favours metal-free | Favours metal-ceramic

Analysis 4.7. Comparison 4 Metal-free implant-supported single crowns compared to metal-ceramic implant-supported single crowns, Outcome 7 First bone to implant contact, distal to crown, 2 years.

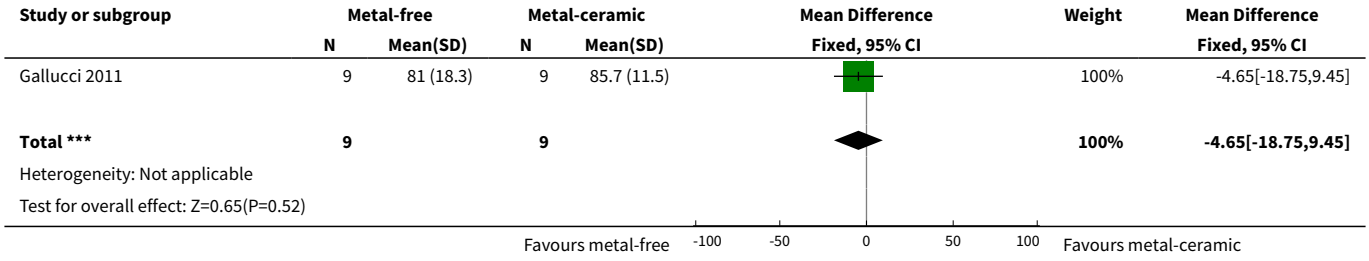
Study or subgroup	Metal-free N	Metal-free Mean(SD)	Metal-ceramic N	Metal-ceramic Mean(SD)	Mean Difference Fixed, 95% CI	Weight	Mean Difference Fixed, 95% CI
Gallucci 2011	9	2.3 (0.9)	9	2.5 (0.6)		100%	-0.18[-0.89,0.53]
Total ***	**9**		**9**			**100%**	**-0.18[-0.89,0.53]**
Heterogeneity: Not applicable							



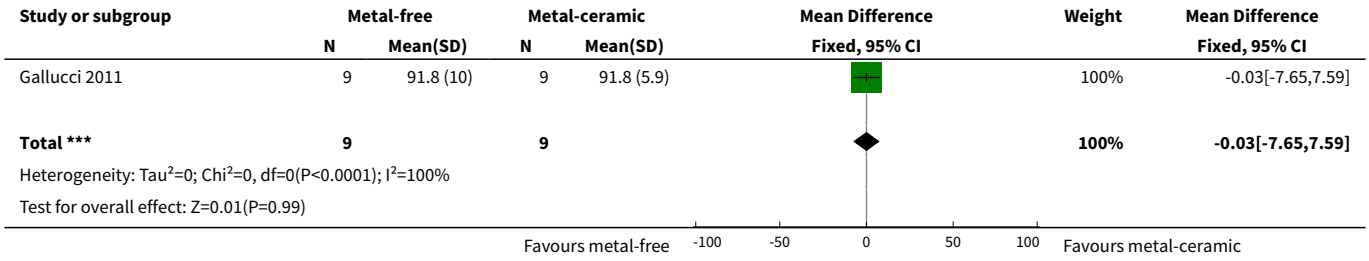
Favours metal-free | Favours metal-ceramic



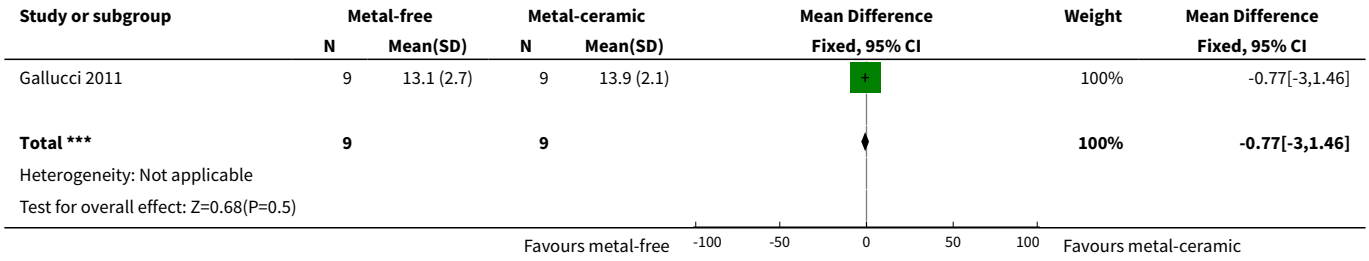
Analysis 4.8. Comparison 4 Metal-free implant-supported single crowns compared to metal-ceramic implant-supported single crowns, Outcome 8 VAS for patient satisfaction, 1 year.



Analysis 4.9. Comparison 4 Metal-free implant-supported single crowns compared to metal-ceramic implant-supported single crowns, Outcome 9 VAS for patient satisfaction, 2 years.



Analysis 4.10. Comparison 4 Metal-free implant-supported single crowns compared to metal-ceramic implant-supported single crowns, Outcome 10 PES and WE scores, total, 2 years.

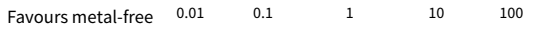


Comparison 5. Metal-free abutments compared to metal abutments supporting single crowns

Outcome or subgroup title	No. of studies	No. of partici-pants	Statistical method	Effect size
1 Abutment failure, 1 year	2	47	Odds Ratio (M-H, Fixed, 95% CI)	7.63 [0.33, 177.14]
2 PPD implant, 1 year	2	47	Mean Difference (IV, Fixed, 95% CI)	-0.22 [-0.60, 0.16]
3 REC implant, 1 year	2	47	Mean Difference (IV, Fixed, 95% CI)	0.0 [-0.22, 0.22]
4 Marginal bone level change mesial, 1 year	2	47	Mean Difference (IV, Fixed, 95% CI)	-0.39 [-0.43, -0.35]
5 Marginal bone level change distal, 1 year	2	47	Mean Difference (IV, Fixed, 95% CI)	-0.05 [-0.15, 0.04]

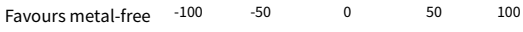
Analysis 5.1. Comparison 5 Metal-free abutments compared to metal abutments supporting single crowns, Outcome 1 Abutment failure, 1 year.

Study or subgroup	Metal-free n/N	Metal n/N	Odds Ratio M-H, Fixed, 95% CI	Weight	Odds Ratio M-H, Fixed, 95% CI
Albornoz 2014	2/11	0/14		100%	7.63[0.33,177.14]
Baldini 2016	0/10	0/12			Not estimable
Total (95% CI)	**21**	**26**		**100%**	**7.63[0.33,177.14]**
Total events: 2 (Metal-free), 0 (Metal)					
Heterogeneity: Not applicable					
Test for overall effect: Z=1.27(P=0.21)					



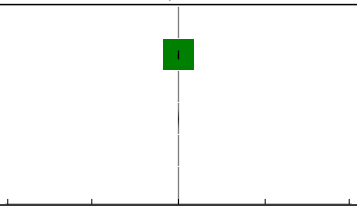
Analysis 5.2. Comparison 5 Metal-free abutments compared to metal abutments supporting single crowns, Outcome 2 PPD implant, 1 year.

Study or subgroup	Metal-free N	Metal-free Mean(SD)	Metal N	Metal Mean(SD)	Mean Difference Fixed, 95% CI	Weight	Mean Difference Fixed, 95% CI
Albornoz 2014	11	2.9 (0.5)	14	3.3 (0.8)		54.96%	-0.4[-0.91,0.11]
Baldini 2016	10	2.7 (0.4)	12	2.7 (0.9)		45.04%	-0.01[-0.58,0.56]
Total ***	**21**		**26**			**100%**	**-0.22[-0.6,0.16]**
Heterogeneity: Tau^2=0; Chi^2=1, df=1(P=0.32); I^2=0.1%							
Test for overall effect: Z=1.16(P=0.25)							



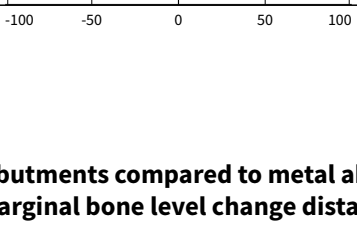
Analysis 5.3. Comparison 5 Metal-free abutments compared to metal abutments supporting single crowns, Outcome 3 REC implant, 1 year.

Study or subgroup	Metal-free		Metal		Mean Difference	Weight	Mean Difference
	N	Mean(SD)	N	Mean(SD)	Fixed, 95% CI		Fixed, 95% CI
Albornoz 2014	11	0 (0)	14	0 (0.1)			Not estimable
Baldini 2016	10	0.2 (0.3)	12	0.2 (0.2)		100%	0[-0.22,0.22]
Total ***	**21**		**26**			**100%**	**0[-0.22,0.22]**
Heterogeneity: Not applicable							
Test for overall effect: Not applicable							



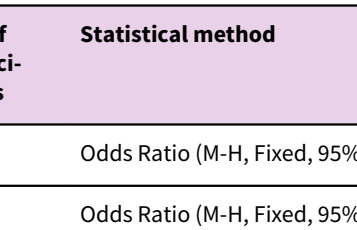
Analysis 5.4. Comparison 5 Metal-free abutments compared to metal abutments supporting single crowns, Outcome 4 Marginal bone level change mesial, 1 year.

Study or subgroup	Metal-free		Metal		Mean Difference	Weight	Mean Difference
	N	Mean(SD)	N	Mean(SD)	Fixed, 95% CI		Fixed, 95% CI
Albornoz 2014	11	0.1 (0.1)	14	0.5 (0)		99.5%	-0.39[-0.43,-0.35]
Baldini 2016	10	1.1 (0.8)	12	2 (0.6)		0.5%	-0.87[-1.47,-0.27]
Total ***	**21**		**26**			**100%**	**-0.39[-0.43,-0.35]**
Heterogeneity: Tau^2=0; Chi^2=2.44, df=1(P=0.12); I^2=59%							
Test for overall effect: Z=18.07(P<0.0001)							



Analysis 5.5. Comparison 5 Metal-free abutments compared to metal abutments supporting single crowns, Outcome 5 Marginal bone level change distal, 1 year.

Study or subgroup	Metal-free		Metal		Mean Difference	Weight	Mean Difference
	N	Mean(SD)	N	Mean(SD)	Fixed, 95% CI		Fixed, 95% CI
Albornoz 2014	11	-0 (0.1)	14	0 (0.1)		98.17%	-0.05[-0.14,0.04]
Baldini 2016	10	1.4 (0.9)	12	1.7 (0.7)		1.83%	-0.31[-0.99,0.37]
Total ***	**21**		**26**			**100%**	**-0.05[-0.15,0.04]**
Heterogeneity: Tau^2=0; Chi^2=0.55, df=1(P=0.46); I^2=0%							
Test for overall effect: Z=1.17(P=0.24)							



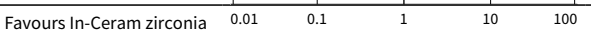
Comparison 6. Metal-free implant-supported FDPs made of different materials

Outcome or subgroup title	No. of studies	No. of partici-pants	Statistical method	Effect size
1 Bridge failure, 1 year	1	18	Odds Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]
2 Bridge complications, 1 year	1	18	Odds Ratio (M-H, Fixed, 95% CI)	0.04 [0.00, 0.48]

Outcome or subgroup title	No. of studies	No. of partici-pants	Statistical method	Effect size
3 Bridge failure, 3 years	1	18	Odds Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]
4 Bridge complications, 3 years	1	18	Odds Ratio (M-H, Fixed, 95% CI)	0.02 [0.00, 0.30]
5 Bridge failure, 5 years	1	18	Odds Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]
6 Bridge complications, 5 years	1	18	Odds Ratio (M-H, Fixed, 95% CI)	0.02 [0.00, 0.42]
7 Bridge failure, 10 years	1	17	Odds Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]
8 Bridge complications, 10 years	1	17	Odds Ratio (M-H, Fixed, 95% CI)	0.02 [0.00, 0.48]

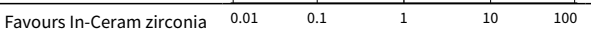
Analysis 6.1. Comparison 6 Metal-free implant-supported FDPs made of different materials, Outcome 1 Bridge failure, 1 year.

Study or subgroup	In-Ceram zirconia n/N	Denzir n/N	Odds Ratio M-H, Fixed, 95% CI	Weight	Odds Ratio M-H, Fixed, 95% CI
Larsson 2006	0/9	0/9			Not estimable
Total (95% CI)	**9**	**9**			**Not estimable**
Total events: 0 (In-Ceram zirconia), 0 (Denzir)					
Heterogeneity: Not applicable					
Test for overall effect: Not applicable					



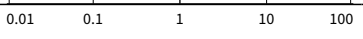
Analysis 6.2. Comparison 6 Metal-free implant-supported FDPs made of different materials, Outcome 2 Bridge complications, 1 year.

Study or subgroup	In-Ceram zirconia n/N	Denzir n/N	Odds Ratio M-H, Fixed, 95% CI	Weight	Odds Ratio M-H, Fixed, 95% CI
Larsson 2006	1/9	7/9		100%	0.04[0,0.48]
Total (95% CI)	**9**	**9**		**100%**	**0.04[0,0.48]**
Total events: 1 (In-Ceram zirconia), 7 (Denzir)					
Heterogeneity: Not applicable					
Test for overall effect: Z=2.51(P=0.01)					



Analysis 6.3. Comparison 6 Metal-free implant-supported FDPs made of different materials, Outcome 3 Bridge failure, 3 years.

Study or subgroup	In-Ceram zirconia n/N	Denzir n/N	Odds Ratio M-H, Fixed, 95% CI	Weight	Odds Ratio M-H, Fixed, 95% CI
Larsson 2006	0/9	0/9			Not estimable
Total (95% CI)	**9**	**9**			**Not estimable**
Total events: 0 (In-Ceram zirconia), 0 (Denzir)					
Heterogeneity: Not applicable					
Test for overall effect: Not applicable					



Favours In-Ceram zirconia | Favours Denzir

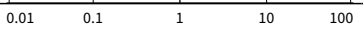
Analysis 6.4. Comparison 6 Metal-free implant-supported FDPs made of different materials, Outcome 4 Bridge complications, 3 years.

Study or subgroup	In-Ceram zirconia n/N	Denzir n/N	Odds Ratio M-H, Fixed, 95% CI	Weight	Odds Ratio M-H, Fixed, 95% CI
Larsson 2006	1/9	8/9		100%	0.02[0,0.3]
Total (95% CI)	**9**	**9**		**100%**	**0.02[0,0.3]**
Total events: 1 (In-Ceram zirconia), 8 (Denzir)					
Heterogeneity: Not applicable					
Test for overall effect: Z=2.77(P=0.01)					

Favours In-Ceram zirconia | Favours Denzir

Analysis 6.5. Comparison 6 Metal-free implant-supported FDPs made of different materials, Outcome 5 Bridge failure, 5 years.

Study or subgroup	In-Ceram zirconia n/N	Denzir n/N	Odds Ratio M-H, Fixed, 95% CI	Weight	Odds Ratio M-H, Fixed, 95% CI
Larsson 2006	0/9	0/9			Not estimable
Total (95% CI)	**9**	**9**			**Not estimable**
Total events: 0 (In-Ceram zirconia), 0 (Denzir)					
Heterogeneity: Not applicable					
Test for overall effect: Not applicable					



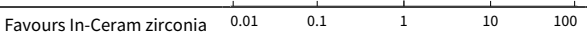
Favours In-Ceram zirconia | Favours Denzir

Analysis 6.6. Comparison 6 Metal-free implant-supported FDPs made of different materials, Outcome 6 Bridge complications, 5 years.

Study or subgroup	In-Ceram zirconia n/N	Denzir n/N	Odds Ratio M-H, Fixed, 95% CI	Weight	Odds Ratio M-H, Fixed, 95% CI
Larsson 2006	2/9	9/9		100%	0.02[0,0.42]
Total (95% CI)	**9**	**9**		**100%**	**0.02[0,0.42]**
Total events: 2 (In-Ceram zirconia), 9 (Denzir)					
Heterogeneity: Not applicable					
Test for overall effect: Z=2.49(P=0.01)					

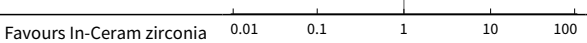
Analysis 6.7. Comparison 6 Metal-free implant-supported FDPs made of different materials, Outcome 7 Bridge failure, 10 years.

Study or subgroup	In-Ceram zirconia n/N	Denzir n/N	Odds Ratio M-H, Fixed, 95% CI	Weight	Odds Ratio M-H, Fixed, 95% CI
Larsson 2006	0/9	0/8			Not estimable
Total (95% CI)	**9**	**8**			**Not estimable**
Total events: 0 (In-Ceram zirconia), 0 (Denzir)					
Heterogeneity: Not applicable					
Test for overall effect: Not applicable					



Analysis 6.8. Comparison 6 Metal-free implant-supported FDPs made of different materials, Outcome 8 Bridge complications, 10 years.

Study or subgroup	In-Ceram zirconia n/N	Denzir n/N	Odds Ratio M-H, Fixed, 95% CI	Weight	Odds Ratio M-H, Fixed, 95% CI
Larsson 2006	2/9	8/8		100%	0.02[0,0.48]
Total (95% CI)	**9**	**8**		**100%**	**0.02[0,0.48]**
Total events: 2 (In-Ceram zirconia), 8 (Denzir)					
Heterogeneity: Not applicable					
Test for overall effect: Z=2.41(P=0.02)					



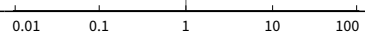
Comparison 7. Metal-free tooth-supported FDPs made of different materials

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Bridge failure, 1 year	1	40	Odds Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
2 Bridge failure, 3 years	1	36	Odds Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]
3 Bridge complications, 3 years	1	36	Odds Ratio (M-H, Fixed, 95% CI)	2.8 [0.66, 11.92]

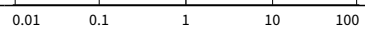
Analysis 7.1. Comparison 7 Metal-free tooth-supported FDPs made of different materials, Outcome 1 Bridge failure, 1 year.

Study or subgroup	Pressed n/N	Layered n/N	Odds Ratio M-H, Fixed, 95% CI	Weight	Odds Ratio M-H, Fixed, 95% CI
Naenni 2015	0/20	0/20			Not estimable
Total (95% CI)	**20**	**20**			**Not estimable**
Total events: 0 (Pressed), 0 (Layered)					
Heterogeneity: Not applicable					
Test for overall effect: Not applicable					



Analysis 7.2. Comparison 7 Metal-free tooth-supported FDPs made of different materials, Outcome 2 Bridge failure, 3 years.

Study or subgroup	Pressed n/N	Layered n/N	Odds Ratio M-H, Fixed, 95% CI	Weight	Odds Ratio M-H, Fixed, 95% CI
Naenni 2015	0/18	0/18			Not estimable
Total (95% CI)	**18**	**18**			**Not estimable**
Total events: 0 (Pressed), 0 (Layered)					
Heterogeneity: Not applicable					
Test for overall effect: Not applicable					



Analysis 7.3. Comparison 7 Metal-free tooth-supported FDPs made of different materials, Outcome 3 Bridge complications, 3 years.

Study or subgroup	Pressed veneering n/N	Layered veneering n/N	Odds Ratio M-H, Fixed, 95% CI	Weight	Odds Ratio M-H, Fixed, 95% CI
Naenni 2015	8/18	4/18		100%	2.8[0.66,11.92]
Total (95% CI)	**18**	**18**		**100%**	**2.8[0.66,11.92]**
Total events: 8 (Pressed veneering), 4 (Layered veneering)					
Heterogeneity: Not applicable					
Test for overall effect: Z=1.39(P=0.16)					

APPENDICES

Appendix 1. Cochrane Oral Health's Trials Register search strategy

From March 2015, searches of the Cochrane Oral Health's Trials Register for this review were undertaken using the Cochrane Register of Studies and the search strategy below:

1 ((crown* or "full cast*" or full-cast* or "indirect restor*" or abutment* or prosthes* or denture* or bridge* or pontic*):ti,ab) AND (INREGISTER)
2 ((prosthodontic* AND fix* AND restor*):ti,ab) AND (INREGISTER)
3 (#1 or #2) AND (INREGISTER)
4 ((ceramic* or porcelain* or alumina or "aluminium oxide" or zirconium or zirconia or "lithium disilicate" or leucite or polymer* or compomer* or "composite resin*"):ti,ab) AND (INREGISTER)
5 ((fibre-reinforced or "fibre reinforced" or fiber-reinforced or "fiber reinforced" or spinell or spinel or metal-free or "metal free" or "non metal" or non-metal):ti,ab) AND (INREGISTER)
6 (#4 or #5) AND (INREGISTER)
7 (#3 and #6) AND (INREGISTER)

Previous searches for this review were undertaken using the Procite software and the search strategy below:

((crown* or "full cast*" or full-cast* or "indirect restor*" or abutment* or prosthes* or denture* or bridge* or pontic* or (prosthodontic* AND fix* AND restor*)) AND (ceramic* or porcelain* or alumina or "aluminium oxide" or zirconium or zirconia or "lithium disilicate" or leucite or polymer* or compomer* or "composite resin*" or fibre-reinforced or "fibre reinforced" or fiber-reinforced or "fiber reinforced" or spinell or spinel or metal-free or "metal free" or "non metal" or non-metal))

Appendix 2. Cochrane Central Register of Controlled Clinical Trials (CENTRAL) search strategy

#1 MeSH descriptor Crowns explode all trees
#2 MeSH descriptor Denture, Partial, Fixed explode all trees
#3 MeSH descriptor Dental Prosthesis, Implant-Supported this term only
#4 MeSH descriptor Dental Abutments this term only
#5 ((dental in All Text near/5 crown* in All Text) or (oral in All Text near/5 crown* in All Text) or (implant* in All Text near/5 crown* in All Text))
#6 ((dental in All Text or oral in All Text or implant* in All Text) and (full-cast in All Text or "full cast*" in All Text))
#7 "indirect restor*" in All Text
#8 ((dental in All Text near/5 abutment* in All Text) or (implant* in All Text near/5 abutment* in All Text))
#9 (dental* in All Text and (arch* in All Text near/5 prosthes* in All Text))
#10 (denture* in All Text near/5 partial in All Text)
#11 ("fixed partial denture*" in All Text or "fixed dental prosthes*" in All Text)
#12 ((dental in All Text or dentist* in All Text or implant* in All Text or teeth in All Text or tooth in All Text) and (bridge* in All Text or pontic* in All Text))˜
#13 (prosthodontic* in All Text near/3 fix* in All Text near/3 restor* in All Text)
#14 (#1 or #2 or #3 or #4 or #5 or #6 or #7 or #8 or #9 or #10 or #11 or #12 or #13)
#15 MeSH descriptor Ceramics explode all trees
#16 ((dental* in All Text or implant* in All Text or oral* in All Text) and (ceramic* in All Text or porcelain* in All Text))
#17 MeSH descriptor Aluminum Oxide this term only
#18 (alumina in All Text or "aluminium oxide" in All Text)
#19 MeSH descriptor Zirconium this term only
#20 (zirconium in All Text or zirconia in All Text)
#21 ("lithium disilicate" in All Text or leucite in All Text)
#22 MeSH descriptor Polymers this term only
#23 MeSH descriptor Composite resins explode all trees
#24 ((dental in All Text near/6 polymer* in All Text) or (oral in All Text near/6 polymer* in All Text) or (implant* in All Text near/6 polymer in All Text) or (crown* in All Text near/6 polymer* in All Text))
#25 ((dental in All Text near/6 compomer* in All Text) or (oral in All Text near/6 compomer* in All Text) or (implant* in All Text near/6 compomer in All Text) or (crown* in All Text near/6 compomer* in All Text))
#26 ((dental in All Text near/6 "composite resin*" in All Text) or (oral in All Text near/6 "composite resin*" in All Text) or (implant* in All Text near/6 "composite resin*" in All Text) or (crown* in All Text near/6 "composite resin*" in All Text))
#27 (fibre-reinforced in All Text or "fibre reinforced" in All Text or fiber-reinforced in All Text or "fiber reinforced" in All Text)
#28 (spinell in All Text or spinel in All Text)
#29 (metal-free in All Text or "metal free" in All Text or non-metal in All Text or "non metal" in All Text
#30 (#15 or #16 or #17 or #18 or #19 or #20 or #21 or #22 or #23 or #24 or #25 or #26 or #27 or #28 or #29)

#31 (#14 and #30)

Appendix 3. MEDLINE Ovid search strategy

1. exp Crowns/
2. exp Fixed Partial Denture/
3. Dental Prosthesis, Implant-Supported/
4. Dental Abutments/
5. ((dental$ or oral$ or implant) adj5 crown$).ti,ab.
6. ((dental$ or oral or implant$) adj5 ("full cast$" or full-cast$)).ti,ab.
7. "indirect restor$".ti,ab.
8. ((dental$ or implant$) adj5 abutment$).ti,ab.
9. (dental$ and (arch adj5 prosthesis)).ti,ab.
10. (dental$ and (arch adj5 prostheses)).ti,ab.
11. ("complete arch prosthesis" or "complete arch prostheses").ti,ab.
12. (denture$ adj partial).ti,ab.
13. "fixed dental prosthes$".ti,ab.
14. ((dental or dentist$ or implant$ or teeth or tooth) adj5 (bridge$ or pontic$)).ti,ab.
15. (prosthodontic adj3 fix$ adj3 restor$).ti,ab.
16. or/1-15
17. exp Ceramic/
18. ((dental$ or implant$ or oral$) and (ceramic$ or porcelain$)).ti,ab.
19. Alumina/
20. (alumina or "aluminium oxide").ti,ab.
21. Zirconium/
22. (zirconium or zirconia).ti,ab.
23. ("lithium disilicate" or leucite).ti,ab.
24. Polymers/
25. exp Composite Resins/
26. ((dental$ or oral$ or implant$ or crown$) adj6 (polymer$ or compomer$ or "composite resin$")).ti,ab.
27. (fibre-reinforced or "fibre reinforced" or fiber-reinforced or "fiber reinforced").ti,ab.
28. (spinell or spinel).ti,ab.
29. (metal-free or "metal free" or "non metal" or non-metal).ti,ab.
30. or/17-29
31. 16 and 30

The above subject search was linked to the Cochrane Highly Sensitive Search Strategy (CHSSS) for identifying randomised trials (RCTs) in MEDLINE: sensitivity maximising version (2008 revision) as referenced in Chapter 6.4.11.1 and detailed in box 6.4.c of the*Cochrane Handbook for Systematic Reviews of Interventions* Version 5.1.0 (updated March 2011) (Higgins 2011).

1. randomized controlled trial.pt.
2. controlled clinical trial.pt.
3. randomized.ab.
4. placebo.ab.
5. drug therapy.fs.
6. randomly.ab.
7. trial.ab.
8. groups.ab.
9. or/1-8
10. exp animals/ not humans.sh.
11. 9 not 10

Appendix 4. Embase Ovid search strategy

1. exp Tooth crown/
2. Tooth prosthesis/
3. Denture/
4. ((dental$ or oral$ or implant) adj5 crown$).ti,ab.
5. ((dental$ or oral or implant$) adj5 ("full cast$" or full-cast$)).ti,ab.
6. "indirect restor$".ti,ab.
7. ((dental$ or implant$) adj5 abutment$).ti,ab.
8. (dental$ and (arch adj5 prosthesis)).ti,ab.
9. (dental$ and (arch adj5 prostheses)).ti,ab.

10. ("complete arch prosthesis" or "complete arch prostheses").ti,ab.
11. (denture$ adj partial).ti,ab.
12. "fixed dental prosthes$".ti,ab.
13. ((dental or dentist$ or implant$ or teeth or tooth) adj5 (bridge$ or pontic$)).ti,ab.
14. (prosthodontic adj3 fix$ adj3 restor$).ti,ab.
15. or/1-14
16. exp Ceramics/
17. ((dental$ or implant$ or oral$) and (ceramic$ or porcelain$)).ti,ab.
18. Aluminium oxide/
19. (alumina or "aluminium oxide").ti,ab.
20. Zirconium/
21. (zirconium or zirconia).ti,ab.
22. ("lithium disilicate" or leucite).ti,ab.
23. Polymers/
24. exp Resin/
25. ((dental$ or oral$ or implant$ or crown$) adj6 (polymer$ or compomer$ or "composite resin$")).ti,ab.
26. (fibre-reinforced or "fibre reinforced" or fiber-reinforced or "fiber reinforced").ti,ab.
27. (spinell or spinel).ti,ab.
28. (metal-free or "metal free" or "non metal" or non-metal).ti,ab.
29. or/16-28
30. 15 and 29

The above subject search was linked to the Cochrane Oral Health filter for identifying RCTs in Embase via Ovid:

1. random$.ti,ab.
2. factorial$.ti,ab.
3. (crossover$ or cross over$ or cross-over$).ti,ab.
4. placebo$.ti,ab.
5. (doubl$ adj blind$).ti,ab.
6. (singl$ adj blind$).ti,ab.
7. assign$.ti,ab.
8. allocat$.ti,ab.
9. volunteer$.ti,ab.
10. CROSSOVER PROCEDURE.sh.
11. DOUBLE-BLIND PROCEDURE.sh.
12. RANDOMIZED CONTROLLED TRIAL.sh.
13. SINGLE BLIND PROCEDURE.sh.
14. or/1-13
15. (exp animal/ or animal.hw. or nonhuman/) not (exp human/ or human cell/ or (human or humans).ti.)
16. 14 NOT 15

Appendix 5. US National Institutes of Health Ongoing Trials Register (ClinicalTrials.gov) search strategy

(dental and ceramic and (crown or prosthesis))
(tooth and ceramic and (crown or prosthesis))
(dental and porcelain and (crown or prosthesis))
(tooth and porcelain and (crown or prosthesis))
(dental and alumina and (crown or prosthesis))
(tooth and alumina and (crown or prosthesis))
(dental and “aluminium oxide” and (crown or prosthesis))
(tooth and “aluminium oxide” and (crown or prosthesis))
(dental and zirconium and (crown or prosthesis))
(tooth and zirconium and (crown or prosthesis))
(dental and zircona and (crown or prosthesis))
(tooth and zircona and (crown or prosthesis))
(dental and leucite and (crown or prosthesis))
(tooth and leucite and (crown or prosthesis))
(dental and “lithium disilicate” and (crown or prosthesis))
(tooth and “lithium disilicate” and (crown or prosthesis))
(dental and polymer and (crown or prosthesis))
(tooth and polymer and (crown or prosthesis))
(dental and compomer and (crown or prosthesis))
(tooth and compomer and (crown or prosthesis))

(dental and composite and (crown or prosthesis))
(tooth and composite and (crown or prosthesis))
(dental and fibre and (crown or prosthesis))
(tooth and fibre and (crown or prosthesis))
(dental and fiber and (crown or prosthesis))
(tooth and fiber and (crown or prosthesis))
(dental and spinel* and (crown or prosthesis))
(tooth and spinel* and (crown or prosthesis))

Appendix 6. WHO International Clinical Trials Registry Platform search strategy

dental and crown and ceramic or tooth and crown and ceramic or dental and prosthesis and ceramic or tooth and prosthesis and ceramic
dental and crown and porcelain or tooth and crown and porcelain or dental and prosthesis and porcelain or tooth and prosthesis and porcelain
dental and crown and alumina or tooth and crown and alumina or dental and prosthesis and alumina or tooth and prosthesis and alumina
dental and crown and aluminium oxide or tooth and crown and aluminium oxide or dental and prosthesis and aluminium oxide or tooth and prosthesis and aluminium oxide
dental and crown and zirconium or tooth and crown and zirconium or dental and prosthesis and zirconium or tooth and prosthesis and zirconium
dental and crown and zirconia or tooth and crown and zirconia or dental and prosthesis and zirconia or tooth and prosthesis and zirconia
dental and crown and leucite or tooth and crown and leucite or dental and prosthesis and leucite or tooth and prosthesis and leucite
dental and crown and lithium disilicate or tooth and crown and lithium disilicate or dental and prosthesis and lithium disilicate or tooth and prosthesis and lithium disilicate
dental and crown and polymer or tooth and crown and polymer or dental and prosthesis and polymer or tooth and prosthesis and polymer
dental and crown and compomer or tooth and crown and compomer or dental and prosthesis and compomer or tooth and prosthesis and compomer
dental and crown and composite or tooth and crown and composite or dental and prosthesis and composite or tooth and prosthesis and composite
dental and crown and fibre or tooth and crown and fibre or dental and prosthesis and fibre or tooth and prosthesis and fibre
dental and crown and fiber or tooth and crown and fiber or dental and prosthesis and fiber or tooth and prosthesis and fiber
dental and crown and spinel or tooth and crown and spinel or dental and prosthesis and spinel or tooth and prosthesis and spinel

WHAT'S NEW

Date	Event	Description
21 November 2019	Review declared as stable	This Cochrane Review is currently not a priority for updating. However, following the results of Cochrane Oral Health's latest priority setting exercise and if a substantial body of evidence on the topic becomes available, the review would be updated in the future

CONTRIBUTIONS OF AUTHORS

Development of the protocol: Carlo E Poggio (CEP), Carlo Ercoli (CE), Marco Esposito (ME).
Examination of titles and abstracts: CEP, CE, Lorena Rispoli (LR).
Retrieval of full-text reports: CEP, CE, LR, Carlo Maiorana (CM).
Linking multiple reports of the same study: CEP, LR.
Examination of full-text reports and final decisions on study inclusion: CEP, CE, LR, ME.
Data extraction and management: CEP, CE, LR, CM, ME.
Risk of bias assessment: CEP, LR, ME.
Drafting the final review: CEP.

DECLARATIONS OF INTEREST

- Carlo E Poggio: none known.
- Carlo Ercoli: Carlo has received consulting fees from Ivoclar NA in the past.
- Lorena Rispoli: none known.
- Carlo Maiorana: none known.

- Marco Esposito: from April 2011 Marco Esposito became a full-time freelance consultant in dentistry specialising in implantology. Therefore he receives funding for conducting clinical trials and presenting the results of trials/Cochrane Reviews at international dental meetings. This funding comes from universities, companies (in alphabetical order: Apollonia e Fama Implant, Biomax, Biomet 3i, Bioteck, Bone System, Branemark Integration, CMS Dental, Dentsply-Friadent, Geistlich Pharma, Geass, Keystone Dental, MegaGen Implant, Mozo-Grau, Nano Bridging molecules, Nobel Biocare, Ricerfarma, Saint Jude Medical, Southern Implants, Supercharched production, Techoss Dental Thommen Medical, Tutogen Medical, Zimmer Dental, Z-Systems), scientific societies, publishing companies, and private dentists. This list of companies was provided by Marco on Friday 4 November 2011 and the funders will change all the time.

This is to certify that: a) Marco does not own stock in companies that produce products included in the reviews of which he is an author; b) he does not have patents on any of the products included in the reviews; c) his salary will not be affected by company sales of any of the products included in the reviews.

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DIFFERENCES BETWEEN PROTOCOL AND REVIEW

The search of the International Association for Dental Research (IADR) abstracts was planned in the protocol but not completed in the final review due to poor yield in preliminary phase.

NOTES

This Cochrane Review is currently not a priority for updating. However, following the results of Cochrane Oral Health's latest priority setting exercise and if a substantial body of evidence on the topic becomes available, the review would be updated in the future.

INDEX TERMS

Medical Subject Headings (MeSH)

*Crowns; Dental Alloys [therapeutic use]; Dental Materials [*therapeutic use]; Dental Restoration, Permanent [*instrumentation] [methods]; Randomized Controlled Trials as Topic; Zirconium [therapeutic use]

MeSH check words

Humans