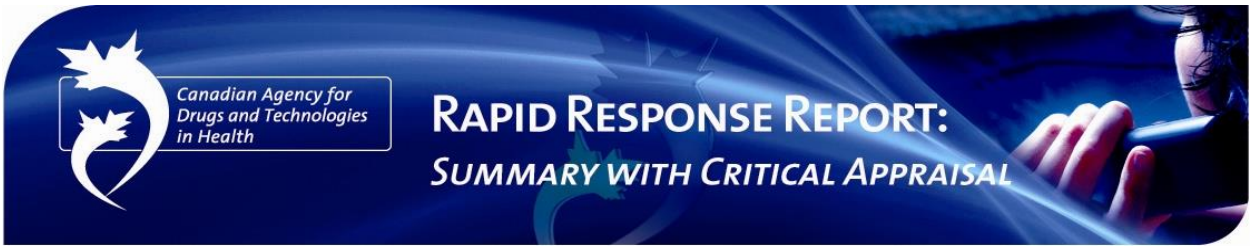

TITLE: Porcelain-Fused-to-Metal Crowns versus All-Ceramic Crowns: A Review of the Clinical and Cost-Effectiveness

DATE: 12 May 2016

CONTEXT AND POLICY ISSUES

High noble alloy porcelain-fused-to-metal (PFM) restorations are recognized as the gold standard for fixed dental prostheses (FDPs) due to their excellent mechanical properties, biocompatibility, and low technical complication rate.[1] However, the esthetic quality of PFM restorations is limited by the presence of the metal framework, which also terminates the translucence of veneering porcelain intended to mask the underlying metal.[2]

All-ceramic FDPs are considered an alternative to PFM restorations. Compared to PFM (also called metal-ceramic crowns), all-ceramic restoration have the advantaged of superior esthetics, more appealing to both patients and clinicians.[1,2] A major shortcoming of earlier all-ceramic FDPs was a lower mechanical stability, resulting in greater likeliness of chipping, cracking and ultimate failure. For this reason, the indications for restorations using all-ceramic FDPs were limited to single-units in the anterior regions where masticatory forces are lower compared to the posterior region.[3,4]

With the development of new dental ceramic materials and improvements in production technology in recent years, the overall stability of all-ceramic reconstructions have improved without losing their esthetic advantage.[2,4] Newer materials for all-ceramic fixed dental prostheses include leucite reinforced lithium-disilicate, leucite or lithium-disilicate reinforced glass ceramics, and oxide ceramics such as alumina and zirconia, from which single-units and multiple-unit FDP reconstructions have been made and placed at both anterior and posterior sites.[2-4]

The soaring costs of precious metals in recent times makes metal-ceramic crowns economically less desirable, while increasing the use of all-ceramic FDPs. The aim of this review is to summarize the available evidence concerning the clinical effectiveness measured by longevity and the costs-effectiveness of PFM and all-ceramic crowns to support reimbursement decisions.

RESEARCH QUESTIONS

1. What is the clinical evidence on the longevity of porcelain-fused-to-metal crowns?

2. What is the clinical evidence on the longevity of all-ceramic/porcelain crowns?

3. What is the clinical evidence on the longevity of porcelain-fused-to-metal crowns compared with all-ceramic crowns?

4. What is the long-term (eight years and longer) cost-effectiveness of porcelain-fused-to-metal crowns compared with all-ceramic crowns?

5. What are the contextual considerations for all-ceramic crowns or porcelain-fused-to-metal crowns that may affect their clinical or cost-effectiveness?

KEY FINDINGS

The 5-year survival of porcelain-fused-to-metal crowns ranged from 95.7% to 97.6%. The 5-year survival of all-ceramic crowns ranged from 90.7% to 96.6%. All-ceramic crowns made out of leucite or lithium-disilicate, densely sintered alumina, glass-infiltrated alumina, and densely sintered zirconia exhibit similar 5-year survival rates as metal-ceramic crowns. Feldspathic or silica glass-ceramics crowns had significantly lower 5-year survival rates compared with metal-ceramic crowns. The position of the crown in the mouth did not significantly alter the survival of metal-ceramic crowns or all-ceramic crowns made out of leucite or lithium-disilicate, densely sintered alumina, or glass-infiltrated alumina. However, feldspathic or silica glass-ceramics crowns had significantly lower survival rates in the posterior region than the anterior region and were only recommended for use in anterior regions with low functional load. There were inconsistent findings concerning the effect of the position in the mouth on zirconia-based crowns. The literature search for this review did not find any studies that evaluated the cost-effectiveness of porcelain-fused-to-metal crowns compared with all-ceramic crowns.

METHODS

Literature Search Methods

A limited literature search was conducted on key resources including PubMed, The Cochrane Library, University of York Centre for Reviews and Dissemination (CRD) databases, ECRI Institute, Canadian and major international health technology agencies, as well as a focused Internet search. For research questions 1, 2 and 5, methodological filters were applied to limit retrieval to health technology assessments, systematic reviews, meta-analyses, randomized controlled trials, non-randomized studies and economic studies. No filters were used to limit retrieval for questions 3 and 4. Where possible, retrieval was limited to the human population. The search was also limited to English language documents published between April 1, 2015 and March 16, 2016. Internet links were provided, where available.

Rapid Response reports are organized so that the evidence for each research question is presented separately.

Selection Criteria and Methods

One reviewer screened citations and selected studies. In the first level of screening, titles and abstracts were reviewed and potentially relevant articles were retrieved and assessed for inclusion. The final selection of full-text articles was based on the inclusion criteria presented in Table 1.

Table 1: Selection Criteria

Population	Any individual requiring a crown
Intervention	• Porcelain-fused-to-metal crowns (metal-ceramic crowns) • All-ceramic dental crowns (including reinforced all-ceramic/porcelain dental crowns such as, but not limited to, alumina, zirconia, E-max, or CEREC crowns)
Comparator	*For research questions 1,2 & 5:* • No comparator *For research questions 3 & 4:* • Comparisons between crown types
Outcomes	Clinical effectiveness • longevity of crown • failure rates • wear of crowns or teeth • crown survival at 5, 10, or 15 years post-insertion Long-term Cost-effectiveness (eight years or longer) Contextual considerations
Study Designs	Health Technology Assessments, Systematic Reviews/Meta-Analyses, Randomized Controlled Trials, Non-Randomized Studies, Economic Evaluations

Exclusion Criteria

Articles were excluded if they did not meet the selection criteria outlined in Table 1, if they were duplicate publications, or were published prior to 2015. Articles were also excluded if they compared different types of the same kind of crown (metal-ceramic or all-ceramic/porcelain crowns), composite resin restorations, implant-supported crowns, bridges, dentures retained by special crowns, or where the follow-up duration was less than 5 years.

Critical Appraisal of Individual Studies

The included systematic review was critically appraised using the AMSTAR tool,[5] and the non-randomized studies were critically appraised using the Downs and Black checklist for measuring quality of studies.[6] Summary scores were not calculated for the included studies; rather, a review of the strengths and limitations of each included study were described narratively. The strengths and limitations of the individual studies are summarized in Appendix 3.

SUMMARY OF EVIDENCE

Quantity of Research Available

A total of 180 citations were identified in the literature search. Following screening of titles and abstracts, 154 citations were excluded and 26 potentially relevant reports from the electronic search were retrieved for full-text review. A grey literature search did not find any potentially relevant publications. Of the potentially relevant articles, 22 publications were excluded for various reasons, while four publications met the inclusion criteria and were included in this report. Appendix 1 describes the PRISMA flowchart of the study selection. The report of a previous CADTH review conducted in May 2015 on PFM crowns versus all-ceramic crowns[7] is referenced in Appendix 5. Unlike the current review, the previous review included implant-supported restorations, bridges, dentures retained by special crowns, and composite resin restorations.

Summary of Study Characteristics

A summary of the characteristics of the included studies is presented in Appendix 2.

Study Design

One systematic review with meta-analysis,[4] two prospective non-randomized studies[8,9] and a retrospective non-randomized study[10] were included in this review (Table A1). One study[8] was published in 2016 while the other studies[4,9,11] were published in 2015. The systematic review[4] included 67 primary studies published between 1991 and 2013, five of which were randomized controlled studies (RCTs) while the remaining were prospective (n=37) and retrospective (n=25) non-randomized studies.

Country of Origin

The systematic review (Sailer et al.)[4] was authored by investigators from Switzerland. One prospective study (Rinke et al.)[8] was conducted in Germany, while the retrospective study (Valenti et al.)[10] and other prospective study (Tartaglia et al.)[9] were conducted in Italy.

Patient Population

A total of 6,095 patients ranging in age from 15 to 91 years were included in the primary studies of the systematic review.[4] Fifty-nine patients were included in the study by Valenti et al.[10] while Rinke et al.[8] and Tartaglia et al.[9] included 45 patients and 88 patients in their respective studies. The mean age of patients in the studies by Rinke et al.[8] and Tartaglia et al.[9] were 49.6 years and 57.0 years respectively. Although the patients included in the study by Valenti et al.[10] were adults (described only as men and women) their ages were not specified.

Interventions and Comparators

The primary studies of the systematic review[4] evaluated a total of 14,097 tooth-supported single-crowns (4,663 metal-ceramic and 9,434 all-ceramic crowns). Rinke et al.[8] compared 50 metal-ceramic crowns with 55 zirconia crowns for up to six years. The study by Tartaglia et al.[9] involved a non-comparative evaluation of 303 zirconia crowns (150 single crowns and 153 multiple units up to 6 elements) for a follow-up time of up to seven years. One hundred-and-seventy-nine (59%) of the restorations in this study[9] were tooth-supported while the remaining were implant supported. A total of 110 lithium disilicate crowns with feather-edge finished line

margins were evaluated by Valenti et al.[10] over a period of nine years. The specifics of support for the crowns were not described.

Outcomes

The systematic review[4] assessed the 5-year survival and complication rates of crowns using Poisson's regression models. Survival was defined as the FDP remaining in situ with or without modification for the observation period.[4] Failure and complication rates were calculated by dividing the number of events (failures or complications) by the total FDP exposure time.[4] Complications were subdivided into technical and biological complications, with framework fracture, ceramic fracture, ceramic chipping, marginal discoloration, loss of retention and poor esthetics described as technical complication. Biologic complications referred to loss of abutment tooth vitality, abutment tooth fracture and secondary caries.

In the study by Rinke et al.,[8] Kaplan–Meier plots were used to compute the 5-year estimated cumulative outcomes for survival and success of the restorations, and for veneering ceramic success. Survival was defined as the reconstruction remaining in situ at the follow-up examination visit without presenting an absolute failure that required the replacement of the entire restoration or extraction of the tooth.[8] Success was defined as a reconstruction that remained unchanged and did not require any intervention to maintain function during the entire observational period.[8] The success of the veneering porcelain was defined as event-free survival without any veneering ceramic failure (VCF).[8] Assessed parameters were de-cementation, loss of vitality of the abutment teeth, secondary caries, tooth fracture, fracture of the framework and chipping of the ceramic veneer.[8]

The study by Valenti et al.,[10] assessed the overall survival probability of crowns for up to nine years using the Kaplan-Meier method, with survival time defined as the period of time starting at baseline and ending when the clinician estimated that an irreparable failure of the crown had occurred. Irreparable failure referred to exposure of the tooth structure caused mainly by infiltration due to abutment decay, core fracture, or partial debonding.

The study by Tartaglia et al.,[9] reported the 7-year Kaplan-Meier survival probability estimates for failures and complications, as well as the cumulative survival rate of crowns. Failure referred to situations where the prosthesis needed replacement or removal, while complications could be resolved without replacing the prosthesis. Survival rate was defined as surviving FDPs minus altered FDPs based on grades 2 and 3 of a 3-grade scale of chipping fractures, where surface chipping is graded 1 if the fractured surface is not extended into a functional area and polishing is possible. Further details of this scale were not provided.

Summary of Critical Appraisal

A summary of the critical appraisal of the included studies is presented in Appendix 3.

All included studies[4,8-10] clearly defined study objectives as well as the main outcomes measured. The interventions of interest and the main findings were also clearly described by all studies.[4,8-10] Two reviewers independently selected relevant studies for inclusion in the systematic review[4] based on well-defined criteria, following a comprehensive literature search of articles published from December 2006 up to and including December 2013. Two researchers independently performed data extraction, with disagreements resolved by consensus of three reviewers. The statistical analyses accounted for the risk of failure by restoration types in each

study during follow-up, and made long-term projections for each of the different types of crowns. However, the analyses of failure of restorations were based on assumption of a constant risk over time, which may not reflect what happens in practice. Most of the primary studies (62/67) in the systematic review[4] were non-randomized studies. Thus, the likelihood of uneven distribution of confounding factors between interventions that were compared create a greater potential for biases compared with randomized studies. In addition, without a comparator, it is difficult to accurately assess the incremental effect of an intervention under study. Furthermore, the methodological rigor and scientific quality of the included studies were not assessed.

While the studies by Rinke et al.[8] and Tartaglia et al.[9] provided inclusion and exclusion criteria and some demographic data, the study by Valenti et al.[10] did not adequately describe inclusion and exclusion criteria and patients demographics were poorly reported. All the restorations in the study by Rinke et al.[8] were placed by a single operator, thus reducing the potential for operator-related confounding risk. In the studies by Rinke et al.[8] and Valenti et al.,[10] a skilled dentist with appropriate training to assess outcomes, who was not involved with the restorative service and patient care, independently conducted follow-up clinical examinations to minimize evaluation bias. Except in one study[9] where one out of four authors had received lecture fees from a company which develops and produces materials, instruments and devices for dental laboratories, the authors of all the included studies[4,8-10] declared no conflict of interest.

None of the non-randomized studies[8-10] performed a calculation for sample sizes to provide sufficient power to determine relevant differences between the compared interventions. Thus, it is unknown whether the patient-based sample size and the associated number of restorations used in the various studies were enough to rule out type II errors. In the study by Rinke et al.,[8] eight patients (15.1%) were lost to follow-up, resulting in a 21.9% decrease in the number of metal-ceramic crowns and a 10.0% decrease in the number of zirconia crowns. The attrition rate and the resulting disproportionate reductions in types of crowns created an imbalance between the compared interventions and is a source of potential bias. There was a potential for a positive over-estimation of the cumulative survival and success outcomes as it is unclear whether patients who remained in the study were those who were satisfied with their treatment, while patients who dropped out were those who were not satisfied with their treatment.

In the study by Valenti et al.,[10] the posterior crowns were manufactured as monolithic while the anterior crowns were veneered. The different production techniques conferred different abilities to the crowns to withstand masticatory pressure. Thus it is difficult to accurately assess the survival ability of the restorations at the various sites based on the material alone.

The study by Tartaglia et al.[9] was an extension of an earlier published single center prospective study. However, analyses were based on only 88 of the original 138 patients without accounting for missing data of the 50 patients (36 %) with 142 crowns (32 %) from the original study who were lost to follow-up. Thus the potential for an error in the estimation of outcomes due to attrition cannot be ruled out.

The countries of origin of the primary studies of the systematic review[4] were not declared, and all non-randomized studies in this review were conducted at single private centers in Germany[8] or Italy.[9,10] Therefore, it is unknown whether the reported findings are generalizable to the Canadian context.

Summary of Findings

A summary of the findings of the included studies is presented in Appendix 4.

1. What is the clinical evidence on the longevity of porcelain-fused-to-metal crowns?

From a meta-analysis of 17 primary studies, one systematic review[4] reported that the estimated 5-year survival rate of metal-ceramic single crowns was 94.7% (95% confidence intervals [CI]: 94.1, 96.9). One prospective study[8] reported that the 5-year estimated cumulative survival (ECSv) of the metallic-ceramic crown was 97.6%, (95% CI: 93, 100). The study[8] also found that the 5-year estimated cumulative success (ECSc) of metal-ceramic crowns was 85.0% (95% CI: 77, 96), while the estimated cumulative veneering success (ECVCSc) was 95.0% (95% CI: 88; 100). The ECSs is a measure of event-free restorations, while the ECVCSc indicate the extent that ceramic veneers in meta-ceramic crowns remained intact without fractures.

2. What is the clinical evidence on the longevity of all-ceramic/porcelain crowns?

One systematic review[4] reported that based on an analysis of 55 primary studies, the overall estimated 5-year survival rates were between 90.7% and 96.6%, depending on the construction material. Feldspathic or silica crowns had the lowest survival rate of 90.7% (95% CI: 87.5, 93.1) while crowns made of leucite/lithium-disilicate reinforced glass had the highest survival rate of 96.6% (95% CI: 94.9, 97.7) followed by densely sintered alumina crowns (96.0%; 95% CI: 93.8, 97.5); glass-infiltrated alumina crowns (94.6%; 95% CI: 92.7, 96) and densely sintered zirconia (91.2%; 95% CI: 82.8, 95.6).

One prospective study[8] reported that the 5-year ECSv of all-ceramic (zirconia) crowns was 94.0%, (95% CI: 87, 100), with an event-free restoration rate (ECSc) of 74.3% (95% CI: 61, 87). During the observation period, 86.1% (95% CI: 75, 96) of ceramic veneers with zirconia crowns were intact without fractures.

One retrospective study[10] reported that, the overall survival probability of lithium disilicate crowns for up to nine years was 96.1%, with the anterior placed crowns having a higher survival probability (100%) compared to posterior crowns (94.5%).

One prospective study[9] reported that the 7-year cumulative survival rate in all-ceramic crowns was 94.7 %. All failures were observed in tooth-supported single crowns, with a significant difference ($P < 0.001$) between the kind of support (tooth versus implant), and number of crowns per restoration (single unit versus multiple unit). However, the position of the crown in the mouth (anterior versus posterior) did not influence the failure rates ($P = 0.316$).

3. What is the clinical evidence on the longevity of porcelain-fused-to-metal crowns compared with all-ceramic crowns?

One systematic review[4] reported that the estimated 5-year survival rates of all-ceramic crowns made of leucite/lithium-disilicate reinforced glass, densely sintered alumina, glass-infiltrated alumina, or densely sintered zirconia were not significantly different ($P > 0.05$) from the 5-year survival rate of porcelain-fused-to-metal crowns. However, the survival rate of feldspathic or silica ceramic crowns was significantly lower ($P < 0.05$) compared with meta-ceramic crowns.

One prospective study[8] found no significant differences between zirconia all-ceramic crowns and metal-ceramic crowns with respect to ECSv ($P = 0.51$), ECSc ($P = 0.43$) and ECVCSc ($P = 0.36$). Two (4.9%) metal-ceramic crowns and three (6.0%) zirconia crowns were replaced, and no fracture of a zirconia or a metallic framework was detected over the entire observational period.

4. *What is the long-term (eight years and longer) cost-effectiveness of porcelain-fused-to-metal crowns compared with all-ceramic crowns?*

The literature search for this review did not find any studies that evaluated the cost-effectiveness of porcelain-fused-to-metal crowns compared with all-ceramic crowns.

5. *What are the contextual considerations for all-ceramic crowns or porcelain-fused-to-metal crowns that may affect their clinical or cost-effectiveness?*

One systematic review[4] stated that mechanically weaker ceramics like the feldspathic or silica glass-ceramics can only be recommended in anterior regions with low functional load. In addition, the study[4] reported that densely sintered zirconia crowns exhibited significantly lower ($P < 0.05$) survival rates in the posterior region than the anterior region, with increased risk of chipping of the veneering ceramic and loss of retention. The authors stated that crowns made out of this material were therefore not recommended as a primary treatment option in the posterior location until further refinements to the production technology are made to overcome these limitations.[4] However, one prospective comparative study[8] did not find a statistically significant difference ($P = 051$) in the 5-year ECSv of metal-ceramic and zirconia-based molar crowns. In addition, one retrospective study[9] found that the position of the crown in the mouth did not influence failure rates of zirconia crowns ($P = 0.316$).

Limitations

It is unknown whether the reported findings of the included studies are generalizable to the Canadian context since all the non-randomized studies[8-10] were conducted at single private centers in countries other than Canada, and the countries of origin of the primary studies of the systematic review[4] were not declared.

The main limitation of included systematic review[4] is that its primary studies are predominantly non-randomized studies. Moreover, without an assessment of the methodological rigor and scientific quality of the included studies, the strength of evidence supporting its conclusions is indeterminate.

Besides the potential for bias inherent in their design, none of the non-randomized studies[8-10] included this review performed sample size calculations to ensure adequate power and avoid a type II error. Furthermore, one study[8] had a 15.1% drop-out rate resulting in disproportionate decreases from baseline in the numbers of the interventions it compared, and another study[9] reported outcomes based on analyses that did not account for 36 % of patients and 32 % of crowns originally involved in the study. Moreover, one study[10] constructed posterior crowns as monolithic while the anterior crowns were veneered, making it difficult to accurately assess the survival ability of the restorations at the various sites based on the material alone.

CONCLUSIONS AND IMPLICATIONS FOR DECISION OR POLICY MAKING

One systematic review[4] reported that all-ceramic single crowns made out of leucite or lithium-disilicate, densely sintered alumina, glass-infiltrated alumina, and densely sintered zirconia exhibit similar 5-year survival rates as metal-ceramic single crowns. However, crowns made out of feldspathic or silica glass-ceramics were reported to have significantly lower 5-year survival rates compared with metal-ceramic crowns. One prospective study[8] found that the 5-year ECSv of metal-ceramic and zirconia-based molar crowns did not differ statistically. One retrospective study[10] and one prospective study[9] reported high overall survival probability rates for lithium disilicate crowns and zirconia-based crowns (96.1% for up to nine years and 94.7 % for seven years, respectively) which were comparable to those survival probability rates reported for metal-ceramic crowns in other studies.

The systematic review[4] found that densely sintered zirconia crowns exhibited increased risk of chipping of the veneering ceramic and loss of retention in the posterior region than in the anterior position. However, the prospective study[8] found that zirconia-based molar crowns did not exhibit a significantly increased risk of framework fracture for molar crowns compared to metal-ceramic crowns, and one retrospective study[9] found that the position of the crown in the mouth did not influence failures rates of zirconia crowns. One retrospective study[10] reported that the survival probability of anterior crowns made out of lithium disilicate was not statistically significantly higher than the posterior crowns of the same material.

Overall, the survival of all-ceramic crowns evaluated in the included studies were generally comparable to metal-ceramic crowns, except for ceramic crowns made out of feldspathic or silica glass-ceramics, which demonstrated significantly lower 5-year survival rates compared with metal-ceramic crowns. This comparability remained true for crowns made out of densely glass-infiltrated alumina, densely sintered alumina and leucite/lithium-disilicate reinforced regardless of whether they were in anterior of posterior region. However, crowns made out of feldspathic silica glass exhibited significantly lower survival rates in the posterior region than the anterior region. Further investigations are required to determine the association between the location and longevity of zirconia-based crowns since the findings from the included studies concerning this were not consistent.

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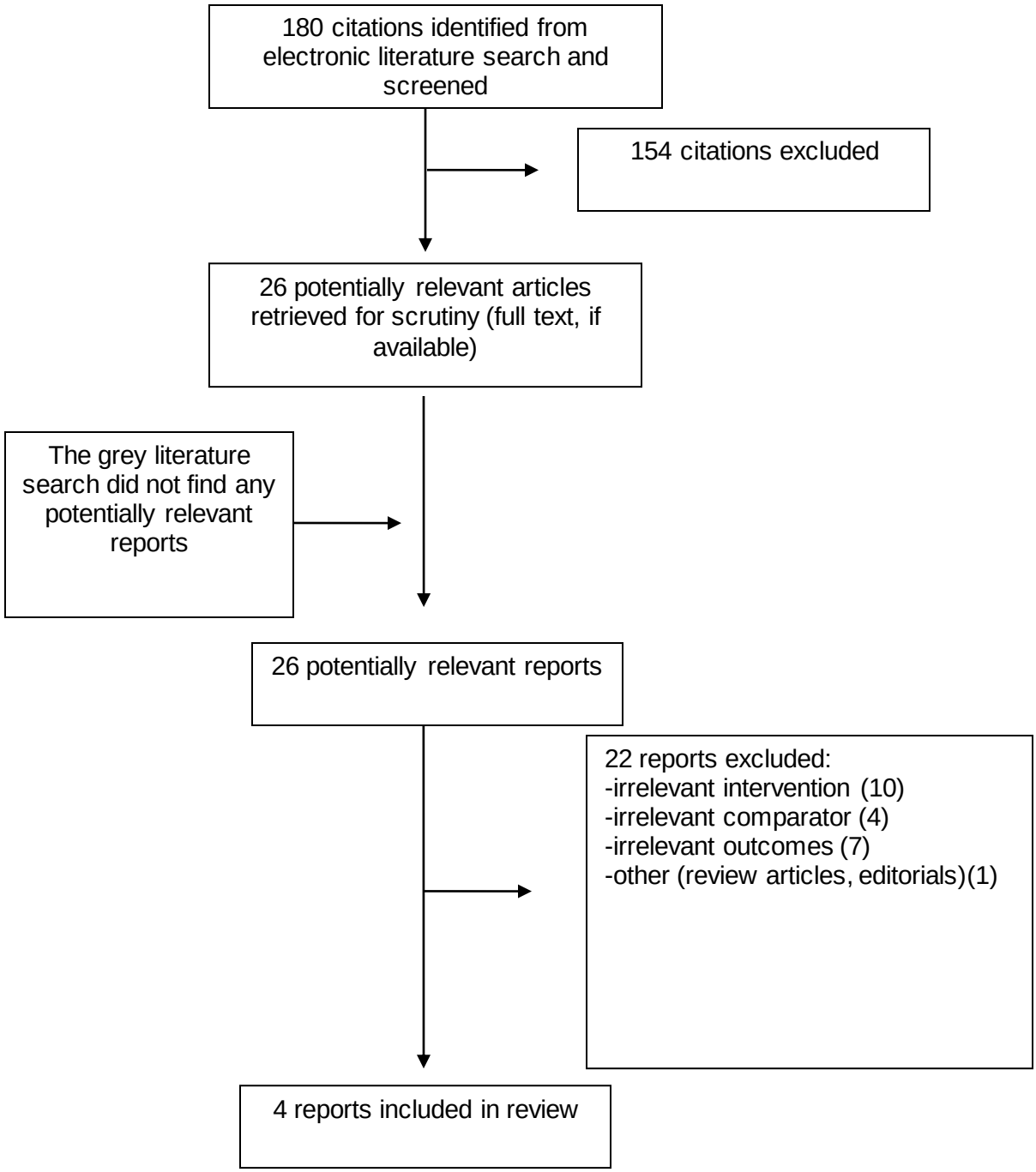
APPENDIX 1: Selection of Included Studies



APPENDIX 2: Characteristics of Included Publications

Table A1: Characteristics of Included Systematic Reviews and Meta-Analyses

First Author, Publication Year, Country	Types and numbers of primary studies included	Population Characteristics	Intervention	Comparator(s)	Clinical Outcomes, Length of Follow-Up
Sailer 2015,[4] Switzerland	Sixty-seven studies including RCTs (n=5), prospective studies (n=37) and retrospective studies (n=25). The studies were published from 1991 to 2013.	A total of 6,095 patients aged between the 17 and 81 years old, suitable for tooth-supported FDP.	Metal-ceramic single crowns (n=4663)	All-ceramic single crowns (n=9434)	5-year survival rate of crowns; and the incidence of biological, and technical complications.

(FDP = fixed dental prostheses

Table A2: Characteristics of Included Clinical Studies

First Author, Publication Year, Country, Study Name	Study Design	Patient Characteristics	Intervention(s)	Comparator(s)	Clinical Outcomes
Rinke 2016[8] Germany	Prospective clinical study	Forty-three patients with mean age of 49.6 ± 9.9 years with antagonistic teeth in the area of the restoration, vital abutments or abutments with sufficient endodontic treatment.	Metal-ceramic crowns (n=50)	Zirconia crowns (n=55)	5-year cumulative survival, success, and veneering ceramic success.
			Mean observational period of 64.0 ± 4.8 months		
Tartaglia 2015,[9] Italy	Prospective clinical study	Eighty-eight patients aged 35 to 89 years (mean 57) who had indications for one or more fixed dentures and who received single and/or multiple-unit crowns.	A total of 303 zirconia crowns [a] (179 tooth-supported)	No comparators	7-years survival rate, and complication-free time

Table A2: Characteristics of Included Clinical Studies					
First Author, Publication Year, Country, Study Name	**Study Design**	**Patient Characteristics**	**Intervention(s)**	**Comparator(s)**	**Clinical Outcomes**
			Mean observation time was 83.89 ± 0.71 months.		
Valenti 2015,[10] Italy	Retrospective clinical study	Fifty-nine patients treated in a general practice (age data were not provided).	A total of 110 feather-edge LiDiSi-based crowns Up to nine years observation period	No comparators	Overall survival probability and failure rate up to nine years.

LiDiSi = lithium disilicate
[a] This study was included because majority of crowns (n=179) were tooth-supported (124 crowns implant-support).

APPENDIX 3: Critical Appraisal of Included Publications

Table A3: Strengths and Limitations of Systematic Reviews and Meta-Analyses using AMSTAR[5]	
Strengths	**Limitations**
Sailer 2015,[4]	
• The research questions and the objective of the study, as well as the inclusion and exclusion criteria were clearly stated. • A comprehensive literature search of articles published from December 1, 2006 up to and including December 31, 2013 was independently performed by two researchers for relevant studies. • Selection of studies for inclusion and data extraction were independently performed by two researchers, with disagreements resolved by consensus of three reviewers. • A list of included studies with study characteristics, and a list of excluded studies with reasons for exclusion were provided. • The statistical analyses accounted for time restorations in each study were exposed to the risk of failure, and made long-term projections for each of the different types of crowns. However, the assumption of a constant risk of failure to restorations over time may not be accurate, and the results obtained from the indirect comparison were not analyzed for consistency with the direct comparison results. • The authors reported they had no conflict of interest.	• Most of the primary studies (62/67) were non-randomized studies. Furthermore, the methodological rigor and scientific quality of the included studies were not assessed. Therefore, an objective assessment of the study conclusions for evidentiary strength is difficult.

Table A4: Strengths and Limitations of Randomized Controlled Trials using Downs and Black Checklist[b]	
Strengths	**Limitations**
Rinke 2016,[8]	
• The aim and hypothesis of the study, as well as the main outcomes measured were clearly defined. • Inclusion and exclusion criteria were provided, and the interventions of interest and the main study findings were clearly described. • All of the restorations were placed by a single operator, thus reducing the potential for operator-related confounding risk. • Follow-up clinical examinations were carried out independently by a skilled dentist not involved in the restorations of prostheses to reduce bias. • Being a practice-based study, the staff, settings, and facilities employed are likely to be representative of treatment available to majority of patients. However, the study was conducted in Germany and the generalizability to Canadian context is not certain.	• A non-randomized study in which patients determined the type of restorations selected for use after receiving information on the two types of restorations. However, it is unknown whether the difference between the number of metal-ceramic crowns (n = 41) and zirconia crowns (n = 50) was large enough to result in bias of the study outcomes. • There was no calculation to assess the sample size that would provide the study sufficient power to determine relevant differences between the compared interventions. Thus, it is unknown whether the patient-based sample size and the number of restorations used in the study were enough to avoid the risk of a type II error. • Further, eight patients (15.1%) were lost to follow-up, resulting in a 21.9% decrease in the number of metal-ceramic crowns and a 10% decrease in the number of zirconia crowns. To the extent that patients who were satisfied with their treatment remained while those who were not satisfied dropped out, there is a potential for a positive over-estimation of the estimated cumulative survival and success outcomes. • One of the four authors had received lecture fees from a company which develops and produces materials, instruments and devices for dental laboratories. However, the other authors declared no conflicts of interest.
Tartaglia 2015,[9]	
• The objectives of the study and the main outcomes of to be measured were clearly defined. • Inclusion and exclusion criteria were provided, and the interventions of interest and the main study findings were clearly described. • The effects of location and preparation design on crown failure were appropriately analyzed, and adjustments were made to account for potential confounding	• This was an extension of an earlier published non-randomized study. However, only 88 of the original 138 patients continued their treatment. Thus 50 patients (36%) with 142 crowns (32%) of the original study population were lost to follow-up, and analysis did not account for missing data. Thus the potential for an error in the estimation of outcomes cannot be ruled out. • The study was based on patients recruited from a single center in Italy; therefore it is unknown is its finding are generalizable in

Table A4: Strengths and Limitations of Randomized Controlled Trials using Downs and Black Checklist[b]	
Strengths	**Limitations**
resulting from the use of more than one restoration per patient. • The authors declare that they have no conflicts of interest.	Canada
Valenti 2015,[10]	
• The objectives of the study and the main outcomes of to be measured were clearly defined. • The interventions of interest and the main study findings were clearly described. • To minimize evaluation bias, the clinical evaluation process involved a clinician from a different dental clinic who was not involved with providing restorative service and patient care.	• The posterior crowns were manufactured as monolithic while the anterior crowns were veneered. The different production technologies confer different abilities to the crowns to withstand masticatory pressure. Thus it is difficult to accurately assess the survival ability of the restorations at the various sites based on the material alone. • Inclusion and exclusion criteria, as well as patients' characteristics were inadequately described.

APPENDIX 4: Main Study Findings and Author's Conclusions

Table A5: Summary of Findings of Included Studies

Main Study Findings	Author's Conclusions
Sailer 2015,[4]	
• Except for feldspathic or silica crowns, the survival rate of single all-ceramic crowns were not statistically significantly different from the survival rates for metal-ceramic crowns. • Analysis of 17 primary studies with a mean follow-up of 7.3 years showed that metal-ceramic crowns had an estimated overall annual failure rate of 0.88, translating into an estimated mean (95% CI) 5-years survival of 95.7% (94.1%, 96.9). • Analysis of 55 primary studies showed that the annual failure rates of all-ceramic crowns ranged between 0.69 and 1.96, translating into overall estimated 5-year survival rates ranging between 90.7% and 96.6%, depending on the construction material. • Using metal-ceramic crowns as reference the mean (95% CI) 5-year survival rates of all-ceramic crowns were reported for specific construction materials as follows; 90.7% (87.5%, 93.1%; $P < 0.001$) for feldspathic/silica (10 studies); 91.2% (82.8%, 95.6%; $P = 0.055$) for densely sintered zirconia (nine studies); 94.6% (92.7, 96.0; $P = 0.276$) for glass-infiltrated alumina (15 studies); 96.0% (93.8%, 97.5%; $P = 0.761$) for densely sintered alumina (eight studies) and 96.6% (94.9%, 97.7% $P = 0.373$) for leucite/LiDiSi reinforced glass (12 studies). • The survival of crowns made out of glass-infiltrated alumina, densely sintered alumina and leucite/LiDiSi reinforced did not differ significantly regardless of whether they were in anterior or posterior region ($P > 0.05$). • Crowns in the posterior region exhibited significantly lower survival rates than those in anterior sites if they were made	• "All-ceramic single crowns exhibit similar survival rates as metal-ceramic single crowns after a mean observation period of at least 3 years. However, this is solely true for SCs are made out of leucite or lithium-disilicate reinforced glass ceramics or oxide ceramics. Those materials perform similarly well in anterior and posterior regions. Crowns made out of densely sintered zirconia, however, cannot be recommended as primary treatment option, due to an increased risk of chipping of the veneering ceramic and loss of retention. These limitations must first be overcome by further refinements of the production technology. Finally, the mechanically weaker ceramics like the feldspathic or silica glass-ceramics can only be recommended in anterior regions with low functional load."[4] Page 621

Table A5: Summary of Findings of Included Studies	
Main Study Findings	**Author's Conclusions**
out of feldspathic/silica: 87.8% (85.1%, 90.0%) versus 94.6% (92.2%, 96.4%), respectively; or densely sintered zirconia – 95.0% (92.6%, 96.7%) versus 98.5% (97.7%, 99.1%), respectively ($P < 0.0001$ for both comparisons).	
Rinke 2016,[8]	
• No fracture of a zirconia or a metallic framework was detected over the entire observational period; and there were no significant differences ($P > 0.05$) between the two types of crowns with regards to 5-year ECSv, ECSc, and ECVCSc. • The 5-year ECSv for zirconia crowns was 94.0% (95% CI: 87%, 100%) compared with 97.6%, (93%, 100%) for metal-ceramic crowns ($P = 0.51$). HR (95% CI) was 0.56 (0.10, 3.16). • The 5-year ECSc was 74.3% (95% CI: 61%, 87%) for zirconia crown compared with 85.0% (77%, 96%) for metal-ceramic crown ($P = 0.43$). HR (95% CI) was 0.67 (0.24, 1.82) • The 5-year ECVCSc for zirconia crowns was 86.1% (95% CI: 75%, 96%) compared with 95.0% (88%, 100%) for metal-ceramic crowns ($P = 0.36$). HR (95% CI) was 0.5 (0.12, 2.18). • However, compared with restorations placed on tooth-neighbored abutments, terminal restorations exhibited a significantly lower ECVCSc (95% CI): 95.7% (90%, 100%) versus 85.2% (74%, 96%); $P = 0.035$. HR (95% CI) was 5.47 (1.13; 26.45) • A total of 10 VCFs requiring a clinical intervention to maintain function were observed, with five restorations each for zirconia and metal-ceramic crowns. • Three complete failures were observed with the zirconia crowns compared with two metal-ceramic crowns	• "Considering the limitations of the study, the following conclusions can be drawn: 1. 5-year ECSv of metal-ceramic and zirconia-based molar crowns did not differ statistically, demonstrating no increased risk of framework fracture for molar ZCs. 2. Technical complications rates (veneer ceramic fractures) of ZCs with a pronounced anatomical core design and ceramic veneering firing with a 6-min cooling period compared to molar MCCs (high-noble alloy/low-fusing ceramic) were not significantly different. 3. Ceramic-veneered crowns placed on terminal abutments bear a significantly increased risk of VCFs (Hazard ratio: 545) compared to crowns placed on tooth-neighboured abutments, regardless of the fabrication technique used. • Nevertheless, clinical investigations with an increased number of restorations are needed to verify these findings."[8] Page 143

Table A5: Summary of Findings of Included Studies	
Main Study Findings	**Author's Conclusions**
Tartaglia 2015,[9]	
• No complications were observed in 287 (94.7 %) of the 303 crowns during the 7 years follow-up period. • The 7-year cumulative survival rate was 94.7 %, and the survival probability estimate of failures was 0.966 (95 % CI: 0.932, 0.983). • A total of nine failures were reported, 7 (2.3%) extraction of abutment tooth and 2 (0.7%) secondary caries. All failures were observed in tooth-supported single crowns, with a significant difference between the kind of support, and the type of crowns (single versus multi-unit), *P* <0.001 for both measures. • The position of the crown in the mouth did not influence failures rates (*P* = 0.316), although one (0.01 %) failure was found in anterior prostheses compared with eight (0.04 %) failures in posterior prostheses. • A total of seven complications made up of 3 (1%) veneer fractures, and 4 (1.3%) loss of retention of the crowns (all of them minor) were reported. All complications and failures were on teeth-supported prostheses, except one loss of retention of an implant-support crown.	• "In conclusion, even after 7 years of service, zirconia core crowns appear to be a good clinical solution for both single and multiple-unit prostheses, with favorable functional properties."[9] Page 1144
Valenti 2015,[10]	
• The overall survival probability of all the LiDiSi crowns (n=110) was 96.1% (overall failure rate of 1.8%) up to nine years. • The survival probability was 100% for all the anterior crowns and 94.5% for the posterior crowns (failure rate of 2.81% [2/71]).	• "Within the limitations of this retrospective clinical analysis of 110 LiDiSi crowns with feather-edge marginal preparation in a private general practice, an overall failure rate of 1.8% was achieved. This result is similar to the failure rate reported for single-crown restorations with other margin designs and different metal-free materials"[10] Page 255

CI = confidence intervals; ECSc = estimated cumulative success; ECSv = estimated cumulative survival; ECVCSc = estimated cumulative veneering ceramic success; HR = hazard ratio; LiDiSi = lithium disilicate; MCCs = metal-ceramic crowns; PFM = porcelain fused to metal; SCs = single crowns; VCF = veneering ceramic failure. ZC = zirconia

APPENDIX 5: Additional References of Potential Interest

Studies excluded for short (<5 years) follow-up periods

1. Napankangas R, Pihlaja J, Raustia A. Outcome of zirconia single crowns made by predoctoral dental students: a clinical retrospective study after 2 to 6 years of clinical service. J Prosthet Dent. 2015 Apr;113(4):289-94.

2. Sulaiman TA, Delgado AJ, Donovan TE. Survival rate of lithium disilicate restorations at 4 years: a retrospective study. J Prosthet Dent. 2015 Sep;114(3):364-6.

A previous CADTH review report with broader inclusion criteria

3. Porcelain-fused-to-metal crowns versus all-ceramic crowns: a review of the clinical and cost-effectiveness [Internet]. Ottawa: CADTH; 2015 May 29. [cited 2016 Mar 23]. (Rapid response report: summary with critical appraisal). Available from: https://www.cadth.ca/sites/default/files/pdf/htis/may-2015/RC0657%20PFM%20vs%20Ceramic%20Crowns%20Final.pdf