Clinical Outcomes of Metal-Ceramic versus Metal-Acrylic Resin Implant-Supported Fixed Complete Dental Prostheses: A Systematic Review and Meta-analysis

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ABSTRACT

Purpose: To compare the clinical outcomes of metal-ceramic vs metal–acrylic resin implant-supported fixed complete denture prostheses (IFCDPs). Materials and Methods: An electronic literature database search was conducted in the CINAHL, EMBASE, PubMed, and Web of Science databases. Additionally, a manual search of the literature was performed. Studies conducted in edentulous human subjects comparing clinical outcomes of metal-acrylic resin IFCDPs to those of metal-ceramic IFCDPs were included if quantitative outcomes for the following variables were reported: implant failure, prosthetic failure, incidence of peri-implantitis, incidence of peri-implant mucositis, incidence of peri-implant mucosal recession, prosthetic complications, and any patient-centered outcomes. Data from included studies were pooled to estimate effect size. Results: Five studies met the inclusion criteria. A quantitative analysis was possible for risk of implant failure, prosthesis failure, and incidence of peri-implantitis. Meta-analysis showed no statistically
significant differences in the risk of implant or prosthesis failure between the two groups. However, meta-analysis showed a significantly greater risk of developing peri-implantitis at the implant level in the metal-acrylic group when compared to the metal-ceramic group (risk difference = 0.069; 95% CI = 0.028 to 0.06; \( P = .001 \); fixed-effects model). Furthermore, descriptive analysis of the literature indicated a higher incidence of other biologic complications such as peri-implant mucositis and peri-implant mucosal recession, as well as prosthetic complications such as abrasion and veneer fracture, in metal-acrylic resin IFCDPs compared to metal-ceramic IFCDPs. **Conclusion:** The available evidence suggests that a higher incidence of biologic and prosthetic complications, including a higher risk of peri-implantitis, are present with metal–acrylic resin IFCDPs compared to metal-ceramic IFCDPs. *Int J Prosthodont 2022. doi: 10.11607/ijp.7592*

**INTRODUCTION**

Previously complete tooth loss has been called “the dental equivalent of mortality.”(1) Over 10 million people suffer from edentulism in the U.S. alone.(2) Patients who are edentulous tend to avoid certain foods and have an increased risk of malnutrition.(3) There is also a direct relationship between the loss of teeth and a lower oral health-related quality of life (OHRQoL).(4) Therefore, there continues to be a demand for replacing teeth in an edentulous patient. While complete removable dentures have been the traditional method for restoring edentulous arches, they are no longer the standard of care.(5, 6) Implant-supported restorations have become predictable therapeutic approaches to restore the function and esthetics of edentulous patients.(7) Long-term success of implant-supported restorations has been well documented under a variety of conditions.(8-12) Dental implants can be used in edentulous patients to provide additional support and retention of dental prostheses.(7)
There are different therapeutic approaches using dental implants for rehabilitation of edentulous patients. Implant-supported prostheses can be removable, such as an implant overdenture, or they can be fixed. (13) Implant-supported fixed complete dental prostheses (IFCDPs) have become commonly utilized in dental practices. (14, 15) Two main designs for IFCDPs include the metal-acrylic resin IFCDP and the metal-ceramic IFCDP (Figure 1). Metal-acrylic resin IFCDPs are single unit prostheses that consist of a metal-based framework, acrylic resin base, and denture teeth that are screw-retained directly or with an abutment in between to the dental implants. (16) Metal-ceramic IFCDPs consist of a ceramic layer bonded to a metal-based framework that are either screw-retained or cement-retained directly or with an abutment in between to the dental implants. (16)

It has been shown that dental implants restored using both types of IFCDPs have high survival rates. (17) (18) However, in contemporary implant dentistry, survival of the implant is no longer considered a success. (19) Instead, treatment success depends on a variety of factors that affect the implant-prosthetic complex. These factors include the health and stability of peri-implant soft and hard tissues, prosthetic level factors, and patient satisfaction. (19) While IFCDPs have a high implant survival rate, there are biological and technical complications that arise with both the prosthesis and the implants.

Biological complications are those affecting peri-implant soft and hard tissues such as peri-implantitis, peri-implant mucositis, and peri-implant mucosal recession. (20, 21) Peri-implantitis is a major biological complication that is currently the leading cause of implant failure after osseointegration. (22) Although dental implants have become a routine procedure in restoring lost teeth, the prevalence of peri-implantitis is increasing. (22, 23) Peri-implantitis was recently defined at the 2017 AAP world workshop as a plaque-associated pathologic condition occurring in the
tissue around dental implants, characterized by inflammation in the peri-implant mucosa and subsequent progressive loss of supporting bone. (24) It is currently believed that peri-implantitis is preceded by peri-implant mucositis. (25) A meta-analysis by Derks et al. estimated the prevalence of peri-implant mucositis and peri-implantitis at 42.9% and 21.7%, respectively. (26) Peri-implantitis can eventually result in the loss of dental implants, which in an IFCDP may result in a complete prosthetic failure. (18, 20) This prosthetic failure may require advanced surgical and prosthetic intervention and become a costly inconvenience for a patient. (20)

Technical complications include mechanical damage to the implant, implant components and prostheses including abutment screw loosening or fracture, prosthesis fracture, and implant fracture. (21) These technical complications result in an increased number of repairs and maintenance visits, which will not only lead to increased chair time and maintenance cost, (27) but also can affect the patient’s satisfaction.

Patient satisfaction is an integral component of health care. Occurrences of biological and technical complications may affect patient satisfaction with the overall treatment. (28) Additionally, patients may not fully realize the long-term maintenance costs associated with their fixed dental prostheses. (28, 29) Therefore, evaluating patient-centered outcomes such as short-term and long-term satisfaction of patients with the treatment are crucial in aiding clinicians to provide patient-centered care.

To the best of the authors’ knowledge, there are currently no systematic reviews and meta-analyses directly comparing clinical outcomes of metal-ceramic IFCDPs with metal-acrylic resin IFCDPs. As both treatment options become more frequently utilized in daily practice, it is vital to compare metal-ceramic IFCDPs with metal-acrylic resin IFCDPs in terms of clinical outcomes including, but not limited to, implant failure, prosthetic failure, incidence of biological complication such as
peri-implant mucosal recession, peri-implant mucositis, peri-implantitis, and incidence of mechanical complications. In addition, there are only limited data available comparing patient-centered outcomes in subjects receiving these treatment modalities. Therefore, the aim of this systematic review and meta-analysis was to compare clinical outcomes and patient-centered outcomes of metal-acrylic resin IFCDPs with metal-ceramic IFCDPs. The null hypothesis was that there are no differences in the clinical and patient-centered outcomes between metal-acrylic resin and metal-ceramic IFCDPs.

MATERIALS AND METHODS

This systematic review and meta-analysis was executed following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines. The study protocol was registered in PROSPERO database (# CRD42019124614).

Research Question

The following is our defined research question: “Is there a difference in clinical outcomes or patient-centered outcomes among patients who have had edentulous arches restored with metal-acrylic resin IFCDPs as compared with metal-ceramic IFCDPs.”

Inclusion/Exclusion Criteria

The Population, Intervention, Comparison, and Outcome (PICO) framework was applied to guide the inclusion and exclusion of studies using these approach elements: (1) Population: studies conducted in adult human subjects with edentulous arches restored with IFCDPs; (2) Intervention: all included studies had a test group consisting of patients with at least one edentulous arch restored with a metal-acrylic resin IFCDP. In terms of definition, metal-acrylic resin IFCDPs are single unit (one piece, cross-arched) prostheses that consist of a metal-based framework, acrylic resin base, and denture teeth that are screw-retained to the dental implants; (3) Comparison: all

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included studies had a comparison group consisting of patients with at least one edentulous arch restored with a metal-ceramic IFCDP. In terms of definition, metal-ceramic IFCDPs consist of a ceramic layer bonded to a metal-based framework that are either screw-retained or cement-retained to the dental implants;(16) (4) Outcome: all included studies provided quantitative outcomes for at least one of the following categories: (a) implant failure, (b) prosthetic failure, (c) incidence of peri-implantitis, (d) incidence of peri-implant mucositis, (e) peri-implant mucosal recession, (f) prosthetic complications, or (g) any patient-centered outcomes. Study designs that had a control or a comparison group were considered for inclusion in the present study including randomized controlled trials (RCTs), non-randomized controlled trials, prospective cohort studies, and retrospective cohort studies. Studies were excluded for any one of the following: (1) did not fulfill the above-mentioned definitions for the PICO framework; (2) did not fulfill the above-mentioned intervention of a metal-acrylic resin IFCDPs; (3) did not have the above-mentioned comparison group of a metal-ceramic IFCDP; (4) did not clearly describe the experimental methodology or outcome parameters; (5) implants that were not placed in the maxillary or mandibular alveolar ridges such as zygomatic implants or sub-periosteal implants; (6) in vitro studies, animal studies, editorials, reviews, case reports, and non-English citations.

**Literature Search**

CINAHL, EMBASE, PubMed, and Web of Science are the electronic databases that were searched from the start of the database through January 2019. Details of the electronic search strategy are outlined in the Appendix. To supplement the searches, reference lists of relevant reviews and all included articles were also screened.

**Selection of Studies**
The results of the systematic literature search were reviewed by two investigators independently (N.E. and K.N.). Titles and abstracts were excluded if they are unmistakably irrelevant to the topic. Remaining articles were read fully to ensure they met all criteria for inclusion. Disagreements between the two investigators regarding the inclusion and exclusion of the studies were resolved through discussion and consensus with consultation of a third author (S.B.).

**Data Extraction**

Two reviewers (N.E. and K.N.) extracted data independently from the included studies using a predetermined data extraction table. Any discrepancies were resolved by discussion and consensus with consultation of a third author (S.B.). When needed, corresponding authors were contacted for missing data relevant to the research question. Details of data extraction methodology are presented in the Appendix.

**Quality Assessment**

Quality assessment was done using Newcastle-Ottawa Quality Assessment Scale for Cohort studies.(31) This tool assesses the methodological quality of the studies according to three categories of Selection (4 items), Comparability (1 item), and Outcome (3 items). Each study can be given a maximum of one star for each item within the Selection and Outcome categories, and two stars for the Comparability category. Accordingly, each citation could be given a maximum of nine stars. Assessment of the risk of bias was performed independently by two reviewers (N.E. and K.N.). Any discrepancies between the two reviewers in the ratings were resolved by discussion and consensus, and if needed, consultation by a third author (S.B.).

**Meta Analyses, Assessment of Heterogeneity, and Publication Bias**

Quantitative analyses were performed to compare metal-acrylic resin with metal-ceramic IFCDPs. Meta-analyses were prepared for all outcome variables if there were studies with parallel
comparisons reporting the same outcome measures. Data from the included studies were pooled to estimate the effect size. This was expressed as risk ratio for dichotomous outcomes and as mean differences for continuous outcomes.

Heterogeneity across studies were assessed using Cochran-Q statistic and I² statistic tests. (32) Fixed effect model was employed if no significant heterogeneity was found. In the case of significant heterogeneity, a random effect model was used to perform the meta-analyses. The effects of arch (maxilla vs. mandible) on the outcomes of treatment was assessed. Potential publication bias for each outcome variable was assessed by funnel plots and Egger’s Test. Statistical analyses were performed by the Comprehensive Meta-Analysis software (Version 3, Biostat Inc., Englewood, NJ, USA).

RESULTS

Study Selection

A flow diagram of the literature search results is displayed in Figure 2. The electronic and manual literature search identified a total of 2,432 unique citations. 1,616 articles were excluded after initial screening of titles and abstracts. The full-text of the remaining 816 articles were reviewed. Only five articles met the inclusion criteria (Tables 1 and 2). The list of excluded articles and the reason for their exclusion is presented in the Appendix.

Study Characteristics

Table 1 and Table 2 present characteristics of the included studies. One study was a prospective study(33), and four studies were retrospective studies.(34-37) None of the studies were randomized clinical trials. Two studies were conducted in the United States(34, 37), and three studies were conducted in Europe.(33, 35, 36) One study was in an academic setting(37), one study
was conducted in two specialist centers associated with Swedish Dental Care setting,(36) and three studies were in private practice settings.(33-35) Majority of the funding sources were non-industrial funding,(35-37) and the other studies did not report funding sources.(33, 34) Two studies did not report smoking status of the patients.(34, 37)

Two studies included only mandibular IFCDPs,(33, 34) while one study only included maxillary IFCDPs.(36) The other two studies included IFCDPs for both arches.(34, 37) Types of opposing dentition were reported in three studies.(33, 35, 36)

Four studies reported the number of implants per arch, which ranged from 4 to 8 implants.(33, 35-37) Two studies used tapered implant systems,(33, 35) one study used a parallel implant system(36), and two other studies did not report the type of implant system utilized.(34, 37) Two studies reported surgical flap techniques(33, 35), and the other three studies did not report surgical techniques.(34, 36, 37)

Immediate functional loading was reported in two studies,(33, 35) one study reported a delayed loading protocol(36), and the other two studies did not report loading protocols.(34, 37) The time of prosthetic loading for the immediate functional loading group ranged from 6 hours to 48 hours.(33, 35) Delayed prosthesis loading ranged from 3 to 6 months.(36)

Only one study reported a maintenance protocol and compliance with the maintenance protocol,(35) where 29 subjects had a good compliance while 27 subjects had poor compliance with maintenance protocol.(35)

**Quality Assessment**

Quality assessment was done using Newcastle-Ottawa Quality Assessment Scale for Cohort studies.(31) The results of the quality assessment for included studies are presented in Table 3. The total score for included studies ranged between 6-9 stars. Variability between studies was
found in the Comparability category. There was additional variability between studies in item 3 of the outcome category (adequacy of follow-up in the included studies). One study received the maximum score of 9 stars, (33) one study received 7 stars, (34) and the remaining three studies received six stars.

**Outcome Variables**

**A) Risk of Implant Failure:**

The total number of implants and number of failed implants in each group were reported in four studies. (33, 34, 36, 37) Overall, 1,934 implants were loaded with metal-acrylic resin IFCDPs and 532 implants were loaded with metal-ceramic IFCDPs. The number of failed implants was 53 for metal-acrylic resin IFCDPs within the tested observation period, resulting in an implant survival rate of 97.26% (1,881/1,934). The overall survival rate was 98.68% (525/532) for metal-ceramic IFCDPs with only seven reported implant failures. Meta-analysis demonstrated no statistically significant difference in the risk of implant failure between the two groups (Figure 3; Risk difference = 0.007; 95%CI = -0.01, 0.023; \( p = 0.443 \); heterogeneity \( I^2 = 40.69\% \); heterogeneity \( p = 0.15 \); \( \tau = 0.016 \); Fixed-effect model).

Sub-group analysis was not possible to evaluate the effect of maxillary vs mandibular arch on the risk of implant failure. Two studies included only mandibular IFCDPs (33, 34), one study was completed only on the maxilla (36), and one study included both mandibular and maxillary arches (37). Balshi et al. only included mandibular IFCDPs and their results favored metal-ceramic IFCDPs.(34) The other three studies did not find any significant difference between the two groups for the risk of implant failures.

**B) Risk of Prosthesis Failure:**
Prosthesis failure was reported in four studies. In total, 121 metal-acrylic resin IFCDPs and 129 metal-ceramic IFCDPs were compared in these studies. Five IFCDPs failed in the metal-acrylic resin group and one failed in the metal-ceramic. Hence, the overall prosthesis survival rate was 95.87% (116/121) and 99.23 (128/129) for metal-acrylic resin and metal-ceramic IFCDPs, respectively. No significant differences were found between the two groups in the risk of prosthetic failure (Figure 4; Risk difference = 0.013; 95%CI = -0.035, 0.06; p = 0.603; heterogeneity $I^2 = 33.64$%; heterogeneity $p = 0.197$; $\tau = 0.047$; Fixed-effect model).

It was not possible to preform sub-group analysis to evaluate the effect of maxillary vs mandibular arch on the risk of prosthetic failure. One study was executed only on mandibular arches, (33) one study was executed only on maxillary arches, (36) and two studies included both maxillary and mandibular arches. (35, 37) Papaspyridakos et al. showed results that favored metal-ceramic IFCDPs as a lower risk of prosthetic failure. (37) The other studies did not show any significant differences between the two groups.

C) Risk of Developing Peri-implantitis:

The risk of developing peri-implantitis was assessed at implant level and prosthetic level. (35-37) Peri-implantitis was referred as the peri-implant bone loss of more than 2.5 mm in one study,(36) and implants with bleeding and/or suppuration on probing and with bone loss of more than 1.5 mm(35) or 2 mm(37) in the other studies. (35, 37)

Two studies with three comparison arms compared the incidence of peri-implantitis after five years of function at the implant level between metal-acrylic resin and metal-ceramic IFCDPs. (36, 37) The total numbers of implants in this comparison were 487 for the metal-acrylic resin group and 448 for the metal-ceramic group. 52 implants were diagnosed with peri-implantitis in the metal-acrylic resin group, resulting in an implant-level peri-implantitis incidence of 10.68% for metal-
acrylic resin IFCDPs. In the metal-ceramic group, 32 implants were diagnosed with peri-
implantitis, resulting in a peri-implantitis incidence of 7.14%. Our meta-analysis showed that
implants in the metal-acrylic resin group had a significantly greater risk of developing peri-
implantitis compared to those in the metal-ceramic group. The risk difference was 6.9%, favoring
metal-ceramic IFCDPs (Figure 5A; Risk difference = 0.069; 95%CI = 0.028, 0.06; p = 0.001;
heterogeneity $I^2 < 0.001\%$; heterogeneity $p = 0.465$; $\tau < 0.001$; Fixed-effect model).

Three studies with four comparison arms reported the data on incidence of peri-implantitis at the
prosthetic level. (35-37) This comparison included 107 metal-acrylic resin IFCDPs and 115 metal-
ceramic IFCDPs. In the metal-acrylic resin group, 39 IFCDPs had one or more implants with peri-
implantitis. Therefore, the incidence of peri-implantitis was found to be 36.45% at a prosthetic
level for metal-acrylic resin IFCDPs. In the metal-ceramic group, peri-implantitis was reported for
33 IFCDPs, resulting in a prosthetic level peri-implantitis incidence of 28.70%. The quantitative
analysis found 12.1% increase in the risk of developing peri-implantitis for metal-acrylic resin
IFCDPs compared to metal-ceramic IFCDPs. However, this difference was not statistically
significant (Figure 5B; Risk difference = 0.121; 95%CI = -0.016, 0.257; p = 0.083; heterogeneity
$I^2 = 29.26\%$; heterogeneity $p = 0.237$; $\tau =0.091$; Fixed-effect model).

Sub-group analysis was not possible to evaluate the effect of maxillary vs mandibular arch on the
risk of peri-implantitis at the implant level and prosthetic level. At the implant level, two studies
were included. (36, 37) One study included only maxillary arches (36), while the other study
included both maxillary and mandibular arches (37). Both studies showed results that favored
metal-ceramic IFCDPs as a lower risk of developing peri-implantitis. (36, 37) At the prosthetic
level, three studies were included. (35, 36, 37) Two studies included both maxillary and
mandibular arches (35, 37), and one study included only maxillary arches. (36) The difference
between the two IFCDPs designs for risk of developing peri-implantitis at prosthetic level was not statistically significant in these studies (35).

D) Incidence of Peri-implant Mucositis:
Data for peri-implant mucositis was presented in three studies. (33, 36, 37) The incidence of peri-implant mucositis was reported at the implant-level in two studies (33, 37) and at the prosthetic level in two studies. (36, 37) A meta-analysis was not possible for this variable due to heterogeneity in the reporting the data.

In the study by Ayna and colleagues, in which all IFCDPs were done on mandibular arches, peri-implant mucositis was recorded as implants that presented with bleeding on probing (BOP) after at least five years in function. (33) In this study, BOP was recorded for each implant region and varied from a total of 7.14% to 40.74%. They reported a general increase in BOP from 1-5 years. After 5 years of loading, out of 56 total implants, 33.93% of implants in the metal-acrylic group presented with BOP. In the metal-ceramic group, out of a total of 52 implants, only 19.23% presented with BOP. The study by Papaspyridakos and colleagues, which included both maxillary and mandibular IFCDPs, reported a total incidence of peri-implant mucositis presented as a 6.3% annual rate affecting 138 total implants and 21 total prostheses. (37) After five years in function, out of 98 total implants in the metal-acrylic group, 45.91% (45/98) presented with peri-implant mucositis. Out of 359 implants for the metal-ceramic group, only 25.9% (93/359) presented with peri-implant mucositis after five years of loading. The incidence of peri-implant mucositis at the prosthetic level was 43.75% for metal-acrylic resin IFCDPs and 25.45% for metal-ceramic IFCDPs after five years in function. (37) Another study by Hjalmarssson and colleagues, which only included maxillary IFCDPs, reported the incidence of peri-implant mucositis in metal-acrylic resin IFCDPs and metal-ceramic IFCDPs after five years of loading. In this study two groups of metal-
acrylic resin IFCDPs made at the implant level and at the abutment level were investigated. The incidence of prosthetic level peri-implant mucositis in these two groups after five years of loading were 44% (11 out of 25 IFCDPs) and 25% (11 out of 25 IFCDPs). The incidence of prosthetic level peri-implant mucositis for metal-ceramic IFCDPs was 33.33% (5 out of 15 IFCDPs) during the same timeframe. (36)

E) Peri-implant Mucosal Recession:
Only one study, which included both maxillary and mandibular IFCDPs, compared the incidence of peri-implant mucosal recession between metal-acrylic resin IFCDPs and metal-ceramic IFCDPs. (37) Papaspyridakos and colleagues reported that the peri-implant mucosal recession was the most frequently observed minor complication for IFCDPs after 5 years of loading in this study. (37) They found a higher incidence of peri-implant mucosal recession for metal-acrylic resin IFCDPs compared to metal-ceramic IFCDPs. Out of 98 implants in the metal-acrylic group, 49 implants (50%) presented with recession. The metal-ceramic group consisted of 359 implants in which 118 implants (32.8%) presented with peri-implant mucosal recession.

F) Prosthetic Complications:
Three articles reported data on prosthetic complications. (33, 35, 36) A Meta-analysis was not possible for this variable due to heterogeneity in the reporting of the data. Ayna and colleagues reported mechanical complications of abrasion, veneer fractures, and screw loosening for mandibular IFCDPs after 5 years in function. (33) They found that all metal-acrylic resin IFCDPs included in the study (n=14) presented with abrasion, while the abrasion was not present in any of the metal-ceramic IFCDPs (n=14). In addition, four veneer fractures were reported for the metal-acrylic group, while none were reported for the metal-ceramic group. Out of those four veneer fracture cases, three were able to be fixed chair-side while one affected the
substructure and the prostheses required to be repaired in a laboratory. There was only one report of screw loosening which was in the metal-ceramic group. (33) Hjalmarsson and colleagues reported mechanical complications in maxillary IFCDPs, after five years of loading, including loose prostheses, veneer fractures, loss of screw site filling, wear, redesigned occlusal table, necessary occlusal adjustments, phonetic complications, lip biting, implant component fracture, and framework fracture. Out of 80 included IFCDPs, only one loose prosthesis was reported, which belonged to metal-acrylic resin IFCDPs made at the implant level. Veneer fractures were reported in 17.5% of IFCDPs (14 out 80). Out of 25 metal-acrylic resin IFCDPs made at the implant level, 6 presented with veneer fractures (24%) and out of 40 metal-acrylic resin IFCDPs made at the abutment level, only 4 presented with veneer fractures (10%). Veneer fractures were reported in 4 out 15 (26.67%) metal-ceramic IFCDPs. Loss of screw site fillings were reported only in three metal-acrylic resin IFCDPs made at the implant level. None were reported in the other groups. Wear of prosthetic material was reported in 9 out of 80 (11.25%) included IFCDPs. It was reported that 8 out of 9 IFCDPs with wear belonged to the metal-acrylic groups. Occlusal tables were re-designed in four metal-acrylic IFCDPs, while none of metal-ceramic IFCDPs required redesigning of the occlusal table. In addition, an occlusal adjustment was needed for one metal- acrylic IFCDP and one metal-ceramic IFCDP. Phonetic complications were reported for three patients in the metal-acrylic groups and two patients in the metal-ceramic group. Only one patient with a metal-acrylic resin IFCDP made at the implant level presented with lip-biting. No IFCDPs in any group presented with implant component or framework fractures. Another study published by Cercadillo-Ibarguren compared 26 metal-acrylic resin IFCDPs and 46 metal-ceramic IFCDPs after an average of 50 months in function. Both maxillary and mandibular arches were included in this study. They reported no major mechanical complications, such as
framework fracture and mobility of the prosthesis for any of evaluated IFCDPs. It should be noted that minor mechanical complications such as ceramic or resin fractures, initial cracks, tooth wear and prosthetic retention screw fractures were not recorded in this study.

G) Patient-centered Outcomes:

Patient-centered outcomes were reported only in one study. (33) Ayna and colleagues compared the oral health-related quality of life of 14 patients who received metal-acrylic resin IFCDPs and 13 patients who received metal-ceramic IFCDPs in mandibular arches only. An Oral Health Impact Profile (OHIP) questionnaire was used for this purpose in the study. Authors reported substantial improvements in the OHIP score of both groups when compared to baseline values. However, no significant differences were found between metal-acrylic resin and metal-ceramic groups.

Publication Bias

The analysis of publication bias was performed for the following outcome variables: risk of implant failure, risk of prosthetic failure, and risk of developing peri-implantitis at the implant and prosthetic levels. No obvious asymmetry was found in the funnel plots for these variables (Figure 6). Furthermore, no evidence of publication bias was found by the Egger test for the risk of implant failure \( (p = 0.219, \ 95\% CI = -6.63, 2.29) \), risk of prosthetic failure \( (p = 0.323, \ 95\% CI = -2.18, 4.74) \), risk of developing peri-implantitis at the implant level \( (p = 0.762, \ 95\% CI = -106.08, 112.85) \), and risk of developing peri-implantitis at the prosthetic level (Egger test: \( p = 0.125, \ 95\% CI = -4.91, 19.29) \).
DISCUSSION

The results of this systematic review and meta-analysis showed that there was no statistically significant difference between the risk of implant failure or prosthesis failure between metal-ceramic IFCDPs and metal-acrylic resin IFCDPs. However, a higher incidence of biological complications and technical complications was found for the metal-acrylic IFCDPs compared with metal-ceramic IFCDPs.

The results of the present systematic review suggest an increased incidence of peri-implantitis, peri-implant mucositis, and peri-implant mucosal recession for metal-acrylic resin IFCDPs when compared with metal-ceramic IFCDPs. The metal-acrylic resin group had a statistically significant greater risk of developing peri-implantitis than the metal-ceramic group. The risk difference was 6.9% in favor of the metal-ceramic IFCDPs. Although a meta-analysis for peri-implant mucositis was not possible due to heterogeneity between the studies, all three studies reported data on the higher incidence of peri-implant mucositis in the metal-acrylic resin groups.(33, 36, 37) Only one study reported peri-implant mucosal recession between the two groups.(37) Papaspyridakos reported that there was a higher incidence of recession for metal-acrylic resin IFCDPs (11.0% annual complication rate) than metal-ceramic IFCDPs (6.9% annual complication rate).(37)

One explanation for the observed higher incidence of biological complications in metal-acrylic resin IFCDPs could be that the acrylic resin has a higher surface roughness than the ceramic which could lead to an increase in biofilm accumulation on the suprastructure,(38, 39) which is a precursor to plaque associated peri-implant mucositis and peri-implantitis.(24, 25) Additionally, most of the IFCDPs in the study presented with the intaglio surface in close contact to the ridge.(37) A ridge-lap prosthesis in close contact to the intaglio surface may have an adverse effect on the cleansability of the prosthesis.(37, 40) Therefore, it is crucial for the clinician to take into
consideration during treatment planning the design of the prosthesis which has an impact on the
cleansability of the IFCDP.

The present systematic review demonstrated that the incidence of developing peri-implantitis at
the implant level after 5 years in function was 10.68% for implants of metal-acrylic IFCDPs and
7.14% for implants of metal-ceramic IFCDPs. This incidence rate is lower than that reported by
Derks et al. who assessed the prevalence of peri-implantitis in a Swedish general population and
reported a prevalence of peri-implantitis in 45% of the population.(41) It should be noted that they
defined peri-implantitis as having bleeding on probing/suppuration with bone loss greater than
0.5mm.(41) However, for moderate/severe peri-implantitis (having bleeding on probing/suppuration with bone loss greater than 2mm), they recorded an alarming 14.5%
prevalence rate.(41) The lower incidence of peri-implantitis found in this systematic review could
be due to the fact that the included studies were performed in controlled research settings where
included patients met specific inclusion and exclusion criteria. Hence, the prevalence of peri-
implantitis for implants supporting metal-ceramic or meta-acrylic IFCDPs may be greater in the
general population.

It was also found that metal-acrylic IFCDPs displayed an increase in prosthetic complications
when compared with metal-ceramic IFCDPs. Two studies by Ayna et. al (33) and Hjarlmarsson et
al. (36) reported higher incidences of wear/abrasion and veneer fracturing with the acrylic resin
IFCDPs. These results are in line with those reported by Johansson et al. who found 22% of
patients experienced fracturing of teeth in acrylic-resin prostheses.(42) It has been suggested that
utilizing ceramic materials in IFCDPs might be a longer lasting material than acrylic resin.(20)
Therefore, for patients with bruxism or excessive occlusal forces, metal-ceramic may be a more
suitable treatment option than metal-acrylic resin restorations.
To the best of the authors’ knowledge, the present study is the first systematic analysis of the literature including a meta-analysis that directly compared the outcomes of metal acrylic-resin with metal-ceramic IFCDPs. However, other systematic reviews and meta-analyses have assessed outcomes of IFCDPs in general.\textsuperscript{(16, 20, 43, 44, 45)} A systematic review by Papaspyridakos and colleagues included 281 IFCDPs over a 5-year and 10-year follow-up.\textsuperscript{(20)} They reported 5-year and 10-year cumulative complication rates of 20.1\% and 40.3\%, respectively.\textsuperscript{(20)} However, the complication rates between metal-ceramic and metal-acrylic resin IFCDPs were not compared. A systematic review and meta-analysis published by Bagegni and colleagues evaluated the effect of various restorative materials on implant survival rate and prosthetic survival rates of IFCDPs. They reported implant and prosthetic survival rates of 97\% and 95\% for the metal-ceramic group, and 97\% and 97\% for the metal-resin group, respectively. It should be noted that studies without control group were included in Bagegni’s study, and the metal-ceramic and metal-resin IFCDPs were not compared directly.\textsuperscript{(45)} Three other systematic review only evaluated long-term or short-term outcomes of metal-acrylic resin IFCDPs.\textsuperscript{(16, 43, 44)}

It is important to highlight that no randomized clinical trials that directly compare the outcomes of metal-ceramic and metal-acrylic resin IFCDPs were found. It may not be feasible or ethical to perform randomized clinical studies to compare different materials for full arch implant-supported prostheses. One reason may be that since acrylic veneer fractures have long been reported, it may be inappropriate to choose this type of material in patients where a risk of fracturing or occlusal wear may be anticipated.\textsuperscript{(36)} However, all studies with a control and comparison group were included. In addition, it was not possible to perform sub-group analysis to assess the effect of arch (maxilla vs. mandible) on the outcome of the therapy. This variable may have a cofounding effect since metal-acrylic resin IFCDPs are more common for mandible and metal-ceramic IFCDPs are
more common for maxilla. Therefore, future clinical studies are needed to compare these two IFCDPs design solely in mandible or maxilla to eliminate the effect of this confounding variable. Furthermore, only studies published in the English language were included in this study and a search of gray literature was not performed which is considered a limitation of the present study. It should be also mentioned that several clinical parameters such as number of implants per jaw, systemic risk factors, type of implant, implant length and diameter, history of site-development procedures, surgical technique, and width of keratinized tissue around implants, design and cleansability of the prosthesis, and retention type (cementation type or screw-retained) may affect the outcome of therapy. Well-designed large clinical trials are needed in the future to directly compare the effects of these clinical variables on the outcomes of full arch implant-supported rehabilitation. Furthermore, it should also be emphasized that patient-centered outcomes were only reported in one study which reported no significant differences between the two groups.(33) Hence, future clinical trials are needed to further evaluate the patient-centered outcomes of metal-ceramic and metal-acrylic resin IFCDPs.
CONCLUSION

The present systematic review and meta-analysis found greater biological and technical complications, including a higher risk of peri-implantitis, with metal-acrylic resin IFCDPs when compared with metal-ceramic IFCDPs. Considering a high complication rate associated with IFCDPs, it is important to consider the choice of material when planning these full-arch cases. Future clinical trials are needed to assess the effects of arch (maxilla vs. mandible), various surgical and prosthetic variables on outcomes of IFCDPs.

REFERENCES


9. Salinas TJ, Eckert SE. In patients requiring single-tooth replacement, what are the outcomes of implant- as compared to tooth-supported restorations? The International journal of oral & maxillofacial implants 2007;22 Suppl:71-95.


FIGURE LEGENDS

Figure 1- Two main designs for implant-supported fixed complete dental prostheses (IFCDPs).
(a) A metal-acrylic resin IFCDP that consists of a metal-based framework, acrylic resin base, and denture teeth. (b) A metal-ceramic IFCDPs consisting of a ceramic layer bonded to a metal-based framework. Cases courtesy of Dr. Georgios Romanos.

Figure 2- Study selection flow diagram.

Figure 3- Forest plot for comparison of the risk of implant failure between metal-acrylic resin and metal-ceramic IFCDPs.

Figure 4- Forest plot for comparison of the risk of prosthesis failure at the implant level between metal-acrylic resin and metal-ceramic IFCDPs.

Figure 5- Forest plot for comparison of the risk of developing peri-implantitis at the implant level (a) and at the prosthetic level (b) between metal-acrylic resin and metal-ceramic IFCDPs.

Figure 6- Funnel plots assessing the potential publication bias for the risk of implant failure (a), risk of prosthetic failure (b), risk of developing peri-implantitis at the implant level (c), and risk of developing peri-implantitis at the prosthetic level (d).
Figure 1- Two main designs for implant-supported fixed complete dental prostheses (IFCDPs). (a) A metal-acrylic resin IFCDP that consists of a metal-based framework, acrylic resin base, and denture teeth. (b) A metal-ceramic IFCDPs consisting of a ceramic layer bonded to a metal-based framework. Cases courtesy of Dr. Georgios Romanos.
Figure 2- Study selection flow diagram.
**Figure 3-** Forest plot for comparison of the risk of implant failure between metal-acrylic resin and metal-ceramic IFCDPs.

<table>
<thead>
<tr>
<th>Study name</th>
<th>Statistics for each study</th>
<th>Failed Implants / Total</th>
<th>Risk difference and 95% CI</th>
<th>Relative weight</th>
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<tr>
<td></td>
<td>Risk difference</td>
<td>Lower limit</td>
<td>Upper limit</td>
<td>p-Value</td>
</tr>
<tr>
<td>Ayna et al., 2015</td>
<td>0.000</td>
<td>-0.036</td>
<td>0.036</td>
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<tr>
<td>Baleh et al., 2015</td>
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<td>Hjalmarsson et al., 2011A</td>
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<td>-0.030</td>
<td>0.030</td>
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<tr>
<td>Hjalmarsson et al., 2011B</td>
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<td>0.040</td>
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<tr>
<td>Papaspyridakos et al., 2018</td>
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<td>-0.005</td>
<td>0.075</td>
<td>0.084</td>
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<tr>
<td></td>
<td>0.007</td>
<td>-0.010</td>
<td>0.023</td>
<td>0.443</td>
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</table>

**Figure 4-** Forest plot for comparison of the risk of prosthesis failure at the implant level between metal-acrylic resin and metal-ceramic IFCDPs.

<table>
<thead>
<tr>
<th>Study name</th>
<th>Statistics for each study</th>
<th>Failed IFCDPs / Total</th>
<th>Risk difference and 95% CI</th>
<th>Relative weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Risk difference</td>
<td>Lower limit</td>
<td>Upper limit</td>
<td>p-Value</td>
</tr>
<tr>
<td>Ayna et al., 2015</td>
<td>0.000</td>
<td>-0.133</td>
<td>0.133</td>
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<tr>
<td>Cercadillo-Ibarz et al., 2017</td>
<td>0.000</td>
<td>-0.059</td>
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<tr>
<td>Hjalmarsson et al., 2011A</td>
<td>0.000</td>
<td>-0.176</td>
<td>-0.176</td>
<td>1.000</td>
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<tr>
<td>Hjalmarsson et al., 2011B</td>
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<td>-0.153</td>
<td>0.153</td>
<td>1.000</td>
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<tr>
<td>Papaspyridakos et al., 2018</td>
<td>0.294</td>
<td>0.064</td>
<td>0.524</td>
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<td></td>
<td>0.013</td>
<td>-0.035</td>
<td>0.060</td>
<td>0.603</td>
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</table>
Figure 5- Forest plot for comparison of the risk of developing peri-implantitis at the implant level (a) and at the prosthetic level (b) between metal-acrylic resin and metal-ceramic IFCDPs.
Figure 6- Funnel plots assessing the potential publication bias for the risk of implant failure (a), risk of prosthetic failure (b), risk of developing peri-implantitis at the implant level (c), and risk of developing peri-implantitis at the prosthetic level (d).
## Table 1- Characteristic of included studies: study characteristics and patient characteristics

<table>
<thead>
<tr>
<th>Study Characteristics</th>
<th>Patients characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Study and Year</strong></td>
<td><strong># of Centers</strong></td>
</tr>
<tr>
<td>Ayna et al. 2015</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Balshi et al. 2015</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Cercadillo-Ibarguren et al. 2017</td>
<td>1</td>
</tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>Hjalmarsson et al. 2011</td>
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</tr>
<tr>
<td>Papaspyridakos et al. 2018</td>
<td>Acad</td>
</tr>
<tr>
<td>---------------------------</td>
<td>------</td>
</tr>
<tr>
<td>G2</td>
<td>Co-Cr alloy</td>
</tr>
<tr>
<td>G3</td>
<td>Commercially pure titanium</td>
</tr>
</tbody>
</table>

Acad: academic setting; F: female; G: group; M: male; n: number; Non-ind: non-Industry; NR: not reported; PP: private practice setting; Prosp: prospective; Retro: retrospective; SD: standard deviation; yr: year
Table 2- Characteristic of included studies: implant related factors and prosthetic related factors

<table>
<thead>
<tr>
<th>Study and Year</th>
<th>Groups</th>
<th>Groups</th>
<th># of implants per study</th>
<th>Total # of implants per group</th>
<th>Type of implant body</th>
<th>Implant Brand</th>
<th>Surgical technique (flap vs. flapless)</th>
<th>Loading protocol</th>
<th>Timing of prosthetic loading</th>
<th>Type of temporary restoration</th>
<th>Screw-retained vs cement-retained</th>
<th>Maintenance protocol reported</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ayna et al. 2015</td>
<td>G1</td>
<td>4</td>
<td>56</td>
<td>BL Tapered Nobel Speedy</td>
<td>Flap Surgery</td>
<td>Immediate Functional</td>
<td>Within 24 hours</td>
<td>NR</td>
<td>Screw-retained</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>G2</td>
<td>4</td>
<td>52</td>
<td>BL Tapered Nobel Speedy</td>
<td>Flap Surgery</td>
<td>Immediate Functional</td>
<td>Within 24 hours</td>
<td>NR</td>
<td>Screw-retained</td>
<td>No</td>
<td></td>
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<tr>
<td>Balshi et al. 2015</td>
<td>G1</td>
<td>NR</td>
<td>1,385</td>
<td>BL NR Noble Speedy</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>Screw-retained</td>
<td>No</td>
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<tr>
<td></td>
<td>G2</td>
<td>NR</td>
<td>27</td>
<td>BL NR Noble Speedy</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>Screw-retained</td>
<td>No</td>
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<tr>
<td>Cercadillo-Ibarguren et al. 2017</td>
<td>G1</td>
<td>4-6 (Mean 5.3)</td>
<td>378 Total</td>
<td>BL Tapered Nobel Replace</td>
<td>Flap Surgery</td>
<td>Immediate Functional</td>
<td>6-48 hours after surgery for provisionals; 3 months after surgery for definitive</td>
<td>Screw retained acrylic full-arch provisional</td>
<td>Screw-retained</td>
<td>Yes</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>G2</td>
<td>BL Tapered Nobel Replace</td>
<td>Flap Surgery</td>
<td>Immediate Functional</td>
<td>6-48 hours after surgery for provisionals; 3 months after surgery for definitive</td>
<td>Screw retained acrylic full-arch provisional</td>
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<tr>
<td>Hjalmarsson et al. 2011</td>
<td>G1 Implant level</td>
<td>5-7 (Mean 6.1)</td>
<td>152</td>
<td>BL (140); TL (12)</td>
<td>Parallel</td>
<td>Astra Tech (n=131 implants, n=22 prostheses), Straumann (n=12 implants, n=2 prostheses), Biomet 3i (n=6 implants, n=1 prostheses), Branemark (n=3 implants, n=1 prostheses) (this patient had 3 Branemark, and 3 Astra tech),</td>
<td>NR</td>
<td>Delayed Loading</td>
<td>3-6 months after implant placement</td>
<td>NR</td>
<td>Screw-retained</td>
<td>No</td>
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<tr>
<td></td>
<td>G2 Implant level</td>
<td>5-8 (Mean 6.3)</td>
<td>94</td>
<td>BL (88); TL (6)</td>
<td>Parallel</td>
<td>Astra Tech (n=82 implants, n=13 prostheses), Straumann (n=6 implants, n=1 prostheses), Biomet 3i (n=6 implants, n=1 prostheses)</td>
<td>NR</td>
<td>Delayed Loading</td>
<td>3-6 months after implant placement</td>
<td>NR</td>
<td>Screw-retained</td>
<td>No</td>
</tr>
</tbody>
</table>
| Group | Abutment level | 4.8 (Mean 6.2) | BL | Parallel | Branemark System | Delayed Loading | 3-6 months after implant placement | Screw-retained | Retention
<table>
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<tbody>
<tr>
<td>G3</td>
<td>Abutment level</td>
<td>243</td>
<td>BL</td>
<td>Parallel</td>
<td>Branemark System</td>
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<td>3-6 months after implant placement</td>
<td>Screw-retained</td>
<td>Retention</td>
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<td>Papaspyridakos et al. 2018</td>
<td>G1</td>
<td>Mean 6.12</td>
<td>98</td>
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<tr>
<td>G2</td>
<td>Mean 6.53</td>
<td>359</td>
<td>NR</td>
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<td>Nobel Biocare, Biomet 3i, Straumann</td>
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<td>NR</td>
<td>NR</td>
<td>Screw-retained and cement retained</td>
</tr>
</tbody>
</table>

BL: Bone Level; G: group; NR: not reported; SD: standard deviation; TL: Tissue Level
Table 3 - Summary of the quality assessment for the included studies using Newcastle-Ottawa quality assessment scale

<table>
<thead>
<tr>
<th>Studies</th>
<th>Selection</th>
<th>Comparison</th>
<th>Outcome</th>
<th>Total (9 Max)</th>
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<td></td>
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<td>Item 3</td>
<td>Item 4</td>
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<tr>
<td></td>
<td>Item 1</td>
<td>Item 2</td>
<td>Item 3</td>
<td></td>
</tr>
<tr>
<td>Ayna et al., 2015</td>
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<td>Balshi et al., 2015</td>
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<td>Cercadillo-Ibarguren et al., 2017</td>
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