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Original Article

Clinical outcome of metal- and all-ceramic resin-bonded fixed dental prostheses

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Abstract

Purpose: The aim of this retrospective cohort study was to investigate the long-term outcome of metal- and all-ceramic resin-bonded fixed dental prosthesis (RBFDP) up to 17 years, and to evaluate potential factors influencing the risk for complications.

Methods: Patients who were treated with RBFDP to replace teeth in the anterior or first premolar region in an university setting were identified from electronic records. Data collection comprised dental and periodontal parameters, periapical radiographs, and assessment of the RBFDP. Patient-reported satisfaction was evaluated on visual analog scales (VAS), and 5-year cumulative survival and success rates were calculated. Cox regression models were used to compare metal- versus all-ceramic RBFDPs.

Results: Seventy-one patients with RBFDP replacing 65 anterior teeth and 6 premolars were included with a mean observation period of 56.1 (± 42.7) months. RBFDP cumulative survival rate was 86.7% and cumulative success rate 71.7% after 5 years, with no significant difference between metal- and all-ceramic RBFDPs. The risk for RBFDP failure was significantly higher with more than one pontic (OR 6.1; $p=0.033$), or negative pulp vitality testing of abutments (OR 7.3; $p=0.042$), while complications tended to be increased with two-wings compared to one-wing RBFDP (OR 5.4; $p=0.054$).

Conclusions: Metal- and all-ceramic RBFDPs facilitated good long-term results, particularly with one-wing, one-cantilever, and vital abutment teeth.

Keywords: Resin-bonded fixed dental prosthesis (RBFDP), All-ceramic, Metal-ceramic, Survival, Success

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1. Introduction

Resin-bonded fixed dental prosthesis (RBFDP) is an established, minimally invasive treatment option for replacing missing anterior teeth [1]. While early metal frameworks were designed with perforated lingual retainers to facilitate a mechanical lock to etched enamel through resin luting agents [2], better retention is achieved with modern resin cements that bond to metallic oxides after air-particle abrasion. Furthermore, applying a retentive preparation with lateral guiding grooves and a palatal pin offers mechanical retention [3–6]. Advancements in resin bonding enabled the introduction of all-ceramic restorations which require larger connector dimensions and retainer thickness [6, 7]. Fixation relies solely on the adhesion of the resin cement to the enamel since replication of thin pins is not feasible. Due to the limited flexural strength and fracture toughness of etchable lithium disilicate ceramics, a connector cross-section of 16 mm² and a palatal clearance of 1.0 mm is required for the retainer. For zirconia RBFDP, a connector surface of 12 mm² with 0.7–1.0 mm retainer thickness and surface treatment with air-abrasion has been recommended [8]. The fact that metal, particularly non-precious

alloys, can be designed with thinner layers of 0.3–0.5 mm thickness with connector dimensions of 6–9 mm², and that replication of thin grooves or pins is feasible when waxed on investment models, has led to distinct indications for metal- and all-ceramic frameworks for RBFDP. All-ceramic frameworks offer the opportunity of a minimally invasive preparation of one abutment tooth when sound enamel structure is present, framework dimensions are achievable, adhesive cementation techniques are applicable, and functional contacts at the cantilever are avoidable. Alternatively, metal-ceramics are indicated if the enamel structure is compromised (leading to reduced bonding which necessitates retentive preparation for additional mechanical retention), if interocclusal clearance is limited, splinting is needed (e.g., after orthodontic treatment), or if two or more teeth are being replaced [6].

A recent review investigated the outcome of single-retainer (one-wing) cantilever RBFDPs compared with two-retainer (two-wing) fixed-fixed RBFDPs, and included two studies that used all-ceramic RBFDPs and three studies applying metal-ceramics [1]. No influence of the framework design on metal restorations was observed, while higher failure rates were found with two-wing restorations for all-ceramic RBFDPs [1]. A review restricted to all-ceramic restorations confirmed that the cantilever design was superior to the two-retainer RBFDP in the anterior and also that the functional occlusion was deemed responsible for these differences [9]. Limited data are available from comparative studies investigating metal- and all-ceramic RBFDPs with one or two retainers. Cantilevered glass-infiltrated alumina had lower success (75%) compared to cobalt-chromium-ceramics (100%) as a result of fracture or debonding [10].

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The aim of this retrospective cohort study was to investigate the long-term outcome of metal- and all-ceramic RBFDPs, hypothesizing that no difference exists between the framework materials, and to evaluate potential factors influencing the risk for complications or failures.

2. Materials and methods

All patients treated with RBFDP at the University Center of Dental Medicine, University of Basel, Switzerland, from 2002 to 2019 were recruited for this retrospective cohort study. Patients who underwent an RBFDP (dental tariff position 4715 and 4.7140) that was inserted on natural abutment teeth in the postgraduate and specialized clinic were identified from electronic records. Inclusion criteria were a minimal duration of 6 months with the restorations in function and a clinical recall examination between January and December 2019. The study protocol was approved by the local ethics committee (EKNZ BASEC 2018-01972). Among 80 retrieved patients, two died, six had moved and were no longer available, and one reported to have the RBFDP replaced by an implant upon his own initiative; the remaining 71 patients agreed to participate in the study, provided written informed consent, and attended the study examination free of charge.

2.1. Treatment protocol

Throughout the entire study period the decisive parameters for selecting metal- or all-ceramic RBFDPs were the intermaxillary space, the enamel surface, and the potential need for additional retention from a preparation with parallel grooves.

For metal-ceramic restorations, a diagnostic preparation with an intraoral parallelometer (Parallel-A-Prep, Dentatus) was performed on the diagnostic cast and the selected path of insertion transferred to the intraoral situation (Fig. 1a, b). Parallel walls were established to eliminate undercuts, to use the entire enamel surface, and to house the parallel guiding grooves. Proximal and palatal pins facilitated retention and resistance against buccolingual forces (Fig. 1c, d). All-ceramic RBFDPs were fabricated out of either lithium disilicate or zirconia. For the preparation, undercuts were removed and a slight proximal wraparound was prepared to create a clear marginal demarcation line on the palatal surface (Fig. 2a, b). Additionally, a shallow groove located at the cingulum enabled exact positioning during the cementation procedure [11]. A palatal clearance of 0.7 mm was required if zirconia was used, whereas a retainer thickness of at least 1 mm was required if lithium disilicate was used. A minimally invasive preparation of the remaining oral surface was performed to ensure sufficient palatal clearance and to avoid removing the entire enamel layer, which comprises on average an oral thickness of 0.5 mm [12]. Occlusal and functional contacts on the pontic or cantilever were avoided whenever possible. Resin cements were used for cementation (Table 1, Fig. 1e, f & Fig. 2c) which were opaque in case of metal-ceramics to avoid discoloration and gray shine-through. After try-in, the enamel surface was etched with phosphoric acid (37%, 30 seconds) with rubber dam or relative dryness. Lithium disilicate was etched with hydrofluoric acid (5%, 20 seconds) and zirconia and metal-alloys were treated with tribochemical silica-coating (30 µm silica-coated aluminum oxide particles; chairside CoJet; 3M ESPE) [13]. The restoration surface was cleaned in an ultrasonic bath with isopropanol (99%) and dried with air. The respective ceramic primer or silane coupling agent was applied to the restoration and a bonding agent was used on the tooth surface. Single tooth periapical radiographs of the abutment teeth were taken after cementation of the RBFDP and then every 2–3 years or as required. Patients were included in a maintenance program at the university clinics according to their needs (recall intervals every 6–12 months). If patients cancelled appointments or failed to attend, they were motivated to return (Fig. 1g, h). In addition to regular personal hygiene with toothbrush and interproximal cleaning

Fig. 1. Illustration of metal-ceramic RBFDP. a) Diagnostic preparation for two-wing RBFDP using the Parallel-A-Prep system. b) Transfer with intraoral parallelometer. c) Cast model with prepared abutment teeth 12 and 22. d) Metal-ceramic RBFDP with chrome-cobalt framework. e) Clinical situation after cementation with resin cement (occlusal view). f) Clinical situation after cementation (frontal view). g) Clinical situation at the 5-year recall (61 months). h) Periapical radiograph at the 5-year recall (61 months).

Fig. 2. Illustration of zirconia RBFDP. a) Cast model with preparation for one-wing RBFDP. b) All-ceramic RBFDP with zirconia framework. c) Clinical situation after cementation with resin cement. d) Clinical situation at 40 months with a ceramic chipping fracture at the incisal edge after an additional trauma. e) Occlusal view displaying a small step formation between cantilever and adjacent tooth. f) Periapical radiograph at 40 months.

measures, patients were advised to clean the pontic surface at least every second day (e.g. with Super Floss, Oral-B, Procter & Gamble).

2.2. Data collection

The restoration's location was grouped as anterior or posterior (first premolar region) in the upper or lower jaw. The design was categorized as one-wing cantilevered to the mesial or distal, or two-wing with mesial and distal wings. Information about the indication for RBFDP, the restoration's material, and cement material used were retrieved from patients' records. Examination of the RBFDP comprised dental and periodontal parameters and periapical radiographs. Probing pocket depth (PPD) was measured at six sites per tooth and the highest value was recorded and grouped as 1–3 mm, 4–5 mm, or ≥ 6 mm. Bleeding on probing per tooth was recorded 20 seconds after probing, and the presence of plaque in the marginal region was recorded per abutment tooth. Marginal integrity of the restoration retainers and conditions of the abutment teeth (including tooth mobility, caries lesions, pulp vitality testing, and periapical lesions) were investigated. The presence of chipping or veneering fracture in the pontic region was recorded.

The mucosal contact was analyzed using Super Floss (Oral-B) and described as complete, loose, or visible gap; the occlusal contact was categorized as none, only occlusal, only functional, or occlusal and functional contacts. The restoration's position within the arch circumference was investigated and classified as harmonious or with step formation (< 1 mm or ≥ 1 mm). Patients were asked to fill out a questionnaire to collect data about smoking (including pack years), personal oral hygiene (frequency and measures), and recall frequency. Patients' satisfaction related to the RBFDP was evaluated on visual analog scales (VAS) (marks between 0% for poorest and 100% for best situation) and specified by chewing ability, esthetics, and cleanability. RBFDPs were regarded as "successful" if they were still in situ at the time of examination and did not display any biological or technical complication such as PPD ≥ 6 mm, carious lesion or repair filling, periapical lesion on the radiograph, and/or debonding (loss of retention) of the RBFDP with or without re-cementation. RBFDPs were considered as "survival" if they were still in situ during the recall exam, irrespective of any complications. Time in situ was calculated in months from the date of insertion until the first event (complication or failure) or until the date of the study examination if no failure or complication had occurred. Patients' records were studied to analyze any previous complication or failure during the observation period.

2.3. Statistical analysis

Descriptive statistics included means and standard deviations (SD) for metric variables and counts and percentages for categorical variables. Differences between metal- and all-ceramic RBFDP were analyzed using the Wilcoxon rank sum test. Due to the skew of the VAS values, medians and inter-quartile range (IQR) were compared. Kaplan-Meier figures were presented for failures and complications derived from survival analysis of censored data [14]. Assuming proportional hazard ratios, Cox regression models were performed to compare the time course of events between metal- versus all-ceramic RBFDPs. Logistic regression models adjusted for age and gender were performed to calculate odds ratios (OR) for the various comparisons between chosen parameters. In addition, corresponding 95% confidence interval (95%CI) and p-values (Wald's test) were calculated. The level of significance was set at $\alpha=0.05$. Because of the descriptive nature of the study, adjustment of the significance level for multiple comparisons was omitted. Calculations were performed using the statistical software R (version 3.5.1).

3. Results

The 71 included patients were restored with 74 RBFDPs replacing one to four missing teeth. Three patients had two RBFDPs each, presenting symmetrical situations in the jaw (missing premolar or incisor replacement). As these RBFDPs had identical records related to materials, observation time, and clinical measures, only one randomly assigned restoration per patient was considered for the statistical analysis. Data from patients' records, RBFDP specifications, and results of the clinical examination and questionnaires are summarized in Table 1. The mean observation period was longer for metal- than for ceramic RBFDP ($p=0.02$, Table 1). In addition to congenitally missing teeth, tooth loss due to trauma, root fracture, or periodontal disease were the most common indications for RBFDP (Table 2). Two-thirds (66.7%) of the all-ceramic restorations were designed with one wing, while the majority (63.4%) of metal-ceramic RBFDPs had two wings. Restorations with more than one pontic were designed as two-wing RBFDPs and were made with a non-alloy framework, except for two lithium disilicate RBFDPs replacing the two lower central incisors.

Among the 71 included RBFDPs, 66 were in situ for examination after a mean observation period of 56.1 (± 42.7) months (range 6 to 205 months); 20 metal- and 10 all-ceramic RBFDP were followed for at least 60 months. Seven RBFDPs were rated as failures and

Fig. 3. Distribution of RBFDP with proportions (and numbers) of success, failures, and complications for different reasons.

complications were documented for an additional 10 RBFDPs (Fig. 3). The cumulative survival rate was 86.7% and the cumulative success rate was 71.7% after 5 years. There was no significant difference between the 5-year time-course of metal- and all-ceramic RBFDPs for cumulative survival (90.6% and 79.6%, respectively; $p=0.23$), and success (69.4% and 75.7%, respectively; $p=0.51$; Fig. 4a, b). All seven failures occurred in the anterior region, with two of these resulting from a new trauma with restoration fracture (a one-wing zirconia RBFDP after 25 months and a one-wing lithium disilicate RBFDP after 33 months). Three failures with non-precious alloy frameworks were caused by irreversible debonding and affected two RBFDPs replacing the four lower incisors after 29 and 56 months, and one restoration with two pontics (upper central and lateral incisor) after 21 months. Two 2-wing lithium disilicate RBFDPs showed fractures at one of the two retainers after 13 months (one pontic) and after 14 months (two pontics). Failure distribution within the different material groups amounted to 8.1% of the non-precious alloys, 0% of noble frameworks, 17.7% of lithium disilicate, and 7.7% of zirconia restorations ($p=0.717$). The failure rate of metal-ceramics (7.3%) and all-ceramics (13.3%) was not significantly different ($p=0.446$). Re-treatment was feasible in each of the failing restorations with either metal-ceramic RBFDP ($n=2$), conventional fixed dental prostheses (FDP) ($n=2$), or implant treatment ($n=3$).

Complications affected 5.7% of the one-wing restorations and 22.2% of the two-wing restorations ($p=0.027$). One out of 107 abutment teeth developed signs of pulp necrosis during the observation period and was root canal treated after 110 months. The most frequent complication was re-cementation after loss of retention, which affected four metal-ceramic RBFDPs and one zirconia restoration. Considering complications (with re-cementation) and failure from debonding, no effect of the cement material was found ($p=0.54$), but an effect of the design was conceivable with two complications with cantilever RBFDPs (zirconia and metal), while two-wing restorations experienced three complications and three failures each (OR 4.63; 95%CI 0.77, 27.83; $p=0.094$). Increased abutment tooth mobility or location in the anterior or premolar region had no effect on failures and complications. During the clinical examination of two maxillary one-wing RBFDPs, a small step formation (< 1 mm) was observed from the occlusal view due to a buccal position of the replaced tooth in relation to the adjacent tooth despite tight approximal contacts and periodontal health. These patients were 18 and 21 years of age at the time of RBFDP placement and were examined after 40 and 36 months, respectively (Fig. 2d, e).

The logistic regression analysis revealed a six-fold higher risk of failure if more than one tooth was replaced instead of one pontic (OR 6.1, 95%CI 1.2, 31.9; $p=0.033$). With negative pulp vitality testing of one or two abutment teeth, the risk for failure was increased (OR 7.3, 95%CI 1.1, 50.1; $p=0.042$). A trend towards an increased risk for

Table 1. Patients background data, oral health measures, RBFDP specification and clinical exam results

Patients background data and oral health measures					
Gender distribution (n)	39 females		32 males		
Age, mean (SD) at	insertion: 38.8 (± 20.1) years, range 13–80 years		recall: 43.5 (± 20.2) years, range 18–83 years		
RBFDP time in situ, mean (SD); median (IQR)	metal: 65.1 (± 44.1) months; 58 (36.0,73.0)		ceramics: 43.7 (± 37.9) months; 27.5 (13.2,65.7)		
Smoking status at recall	23.9% smokers; 5.8 (± 16.1) pack years		76.1% non-smokers		
Recall interval (dentist or dental hygienist)	50.7% 6 months		38.0% 12 month	11.3% > 12 month	
Frequency of brushing	14.1% 1x / day		69.0% 2x / day	16.9% 3x / day	
Oral hygiene measures general	59.2% manual tooth brush		32.4% electric tooth brush	8.5% combination	
Oral hygiene at RBFDP	26.8% SuperFloss	36.6% interdental brushes/ sticks	12.6% brushes / sticks & Floss	16.9% dental floss	7.1% not specified
Information about RBFDP design, material and cement					
RBFDP design	45.1% 1-wing mesial cantilever		4.2% 1-wing distal cantilever	50.7% 2-wing	
Number of pontics	80.3% one		12.7% two	1.4% three	5.6% four
Region of pontics	57.8% upper anterior		33.8% lower anterior	5.6% upper first premolar	2.8% lower first premolar
RBFDP material	52.1% non-precious alloy		5.6% precious alloy	23.9% lithium disilicate ceramics	18.3% zirconia
Material and design	28.2% all-ceramic 1-wing		14.1% all-ceramic 2-wing	21.1% metal 1-wing	36.6% metal 2-wing
Cement material	81.8% Panavia		8.4% Variolink	4.2% Clearfil	5.6% RelyX
Pulp vitality testing of abutment teeth at RBFDP placement	88.8% positive	1.4% negative (both abutments with RCT)	2.8% one of two abutments negative (with RCT)	1.4% both abutments negative from pulp obliteration	5.6% one of two abutments negative from pulp obliteration
Clinical parameters at recall					
Plaque present at abutments	69.2% negative		30.8% positive		
Probing pocket depth	81.3% 1–3mm		19.7% 4–5mm	0% >5mm	
Bleeding on probing	66.2% negative		30.8% positive	3.0% one out of two abutment teeth positive	
Tooth mobility	81.6% grade 0		13.8% grade I	4.6% grade II	0% grade III
Marginal adaptation	86.2% intact, harmonic contour		12.3% step formation marginal gap	1.5% slight	
Pontic base surface	80.0% tight mucosal contact		20.0% loose contact to mucosa	0% visible gap	
Position in arch circumference	97.2% harmonious		2.8% <1mm step formation	0% $\geq$ 1mm step	
Pulp vitality testing	87.7% positive		3.1% negative	9.2% positive & negative abutments	
Occlusal contacts	32.3% none		10.8% in occlusion	35.4% in function	21.5% occlusion & function

RCT: root canal treatment

Table 2. Indications for RBFDP

Reason for tooth loss	%
Trauma	32.4
Congenitally missing	18.3
Fracture	16.9
Periodontal	14.1
Endodontic	5.6
Root resorption	4.3
Caries	1.4
Unknown	7.0

complication was found for two-wing restorations compared to single retainers (OR 5.4, 95%CI 0.97, 30.0; $p=0.054$).

VAS ratings did not differ between metal- and all-ceramic RBFDPs. Median (IQR) values were 90% (82.8, 99) for chewing ability, 92.5% (90, 99) for esthetics, and 90% (80, 98) for cleanliness.

4. Discussion

This retrospective cohort study analyzed the long-term outcome of metal- and all-ceramic RBFDPs and identified a 5-year cumulative survival of 86.7% and success rate of 71.7%, with no difference between materials. Factors increasing the risk of failure were more than one pontic and negative pulp vitality testing of abutments, while complications tended to be increased with two-wing compared with one-wing RBFDPs.

Patient data from the current study revealed that RBFDPs were inserted in all age groups and for various reasons for tooth replacement. Data from patients' records were used to retrace any complication or failure during the observation period. Including all preceding events documented in patients' records meant that the failure and complication rate was higher than if preceding events had been excluded, thus it reflects reality more accurately. A limitation of this retrospective study design was the longer observation period of metal-ceramic RBFDP and the selection bias of metal- and all-ceramic materials according to the defined indication criteria. Although metal-ceramic RBFDPs

Fig. 4. Kaplan-Meier plots for metal- and all-ceramic RBFDP over 60-months observation. a) Relative survival considering any failures. b) Relative success considering failures and complications.

were selected for challenging conditions such as limited intermaxillary space, reduced enamel substance, and for replacing several teeth, similar success and survival data were documented for both materials. A recent review reported 5-year survival rate of 91.3% for metal-ceramic RBFDPs, 95.3% for reinforced glass ceramic frameworks, and 100% for zirconia frameworks [15]. These survival rates are in accordance with the 5-year data of the present study: 90.6% for metal-ceramic RBFDPs and 79.6% for all-ceramic RBFDPs. An important aspect of this study was the feasibility of re-treatment in case of failure, which is particularly relevant in young patients with a potential need for retreatment after one or two decades due to gingival recession related to maturity (described as periodontal atrophy [16]), changes in tooth color [17], or a new trauma.

Only one abutment tooth required root canal treatment during the observation period of the current study, which emphasizes the minimal invasiveness of the preparation for RBFDP. Replacement of two or more missing teeth and negative pulp vitality testing of abutment teeth were identified as risk factors for failure. Accordingly, a recent study comparing RBFDP and FDP determined non-vital abutment teeth as risk factor for tooth extraction and reported 15-year cumulative survival rates of 66.5% for RBFDP and 61.6% for FDP. Five-year survival of the two-wing metal-ceramic RBFDP was 89.3% [18], which is similar to the 5-year cumulative survival for metal-ceramic restorations reported in the present study. A review investigating cantilever RBFDP found that debondings, particularly of zirconia ceramics, were the most frequent complication, while fracture was only associated with glass-infiltrated alumina and lithium disilicate ceramics [19]. In the present study, debondings were more frequent in two-wing restorations, which is in accordance with the findings of a previous systematic review analyzing the survival of all-ceramic RBFDP [20]. It is assumed that fractures in three-unit restorations are most likely related to shear forces between the abutments, particularly in curved RBFDP designs [21]. Recent 3D finite analysis revealed that higher stress concentrations occurred in abutment teeth and connectors of two-wing lithium disilicate RBFDPs compared to one-wing restorations during functional loading [22].

Despite periodontal healthy conditions, step formation in one-wing restorations was recorded in the present study in two young participants who experienced tooth loss after trauma. This has also been observed in patients with ankylosed teeth or single tooth implants, since such teeth / implants stay in a stable position while adjacent teeth move

downward and get trapped lingually [23]. Implant infra-positioning occurred particularly in the upper anterior region, and young women and patients with hyperdivergent growth pattern are at higher risk [23, 24]. Patients in the present study were provided with a night guard or splint when such tooth movement was observed. Whether young patients restored with a one-wing RBFDP in the anterior region would benefit from a splint guard after insertion needs to be further investigated.

Overall, a high level of satisfaction was documented in the current study for metal- and all-ceramic RBFDPs which is in line with other studies reporting patients' assessments of metal-ceramic [25], or all-ceramic [26] restorations.

5. Conclusion

RBFDP proved to be a successful minimally invasive restoration with high cumulative survival rates and success rates after 5 years. RBFDP also facilitated re-treatment if the restoration failed by leaving various treatment options open, such as dental implants or FDP at older age. While all-ceramic RBFDP should be designed preferably with one retainer and for replacing only one missing tooth, metal-ceramics offered additional retention and replacement of more than one pontic with two retainers.

Conflict of interest

The authors declare no conflict of interest.

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