Predictability of resin bonded bridges – a systematic review

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In brief

- In spite of problems, such as debonds, resin bonded bridges (RBBs) can be considered as minimally invasive, reversible, aesthetic and predictable restorations for fixed replacement of missing teeth in a general dental setup.
- Recommendations from literature about favourable prognostic factors should be understood and applied when planning RBBs.
- RBBs can be ideal restorations for fixed replacement of teeth if good survival rates can be achieved.
- Careful patient selection, treatment planning and meticulous attention to all the factors discussed will help to achieve successful restorations with long survival rates.

Objective The objective of this systematic review is to evaluate the survival rate of resin bonded bridges (RBBs) and understand the relationship between various prognostic factors and survival rate. **Methods** An electronic medline and hand search were carried out to identify prospective studies on RBBs. Critical appraisal of the studies was done and data was extracted from selected studies. Survival rate was estimated with random effect Poissons regression using R software. Influence of location and luting cements was estimated using odds ratio and forest plots using CMA software. **Results** The predicted survival rate for 5 and 10 years are 83.6% and 64.9%, respectively. Functional survival after rebonding has not been considered in this study. It is expected that functional survival will be higher than event free survival. Debonding of the restoration (78%) is the most common type of failure followed by porcelain fracture (13%). Bridges cemented with Panavia showed the highest survival rate (67%) among the luting cements analysed for 5 years. Retentive tooth preparation, preparation confined to enamel, silicoating, supra gingival margins, Ni-Cr or Co-Cr alloys and no occlusion on pontic in lateral excursions have been reported to be associated with better survival rates. Anterior RBBs were found to be more retentive than posterior RBBs. Pooled odds for retention of RBB in anterior segment when compared to posterior is 1.915 (95%CI – 0.847–4.329). RBBs placed in maxilla were found to be more retentive than bridges placed in mandible. Pooled odds for retention of RBB in maxilla when compared to mandible is 1.774 (95%CI – 0.803–3.917). **Conclusion and recommendations** Replacement of missing teeth with resin-bonded fixed partial dentures is a conservative alternative to conventional fixed partial dentures and should be included as a treatment option wherever possible. There are numerous factors that influence the longevity of RBBs. To achieve successful long-term survival, careful case selection and consideration of various variables is crucial. There is a clear and urgent need for well controlled studies to better understand the effects of these prognostic factors.

Introduction

Resin bonded bridges (RBBs) were first described in 1970s and as seen in the present form have evolved from several significant developments.

In 1973, Rochette pioneered the use of a lingual perforated cast alloy framework with acid etch composite for periodontal splinting of anterior teeth.[1] In 1977, Howe and Denehy described a technique for the fabrication and attachment of an anterior fixed partial denture (FPD) (without tooth preparation) to the lingual surface of abutment teeth using composite resin and acid-etch enamel.[2] Thompson and Livaditis recommended preparation of guide planes on inter-proximal and lingual surfaces and rests on occlusal surface to enhance retention and resistance of posterior RBBs.[3] They also reported enhanced retention of etched solid casting acid etch composite bonded posterior bridges. Since then there has been tremendous development in surface treatments, enamel- and dentine-bonding agents and resin cements, thus increasing the overall survival of RBBs.

The main advantage of RBBs is the possibility of fixed replacement of missing teeth with conservative preparation of abutment teeth. This reduces risk of endodontic complications in abutment teeth. There are numerous studies that evaluate the survival of RBBs and prognostic factors that influence their longevity. Due to tremendous development in aspects like preparation designs, bonding techniques etc, the results of recent and earlier studies vary in numerous ways. There is little evidence on the long-term survival of RBBs. This has increased the need for literature and systematic reviews to gather robust evidence about survival characteristics of RBBs.

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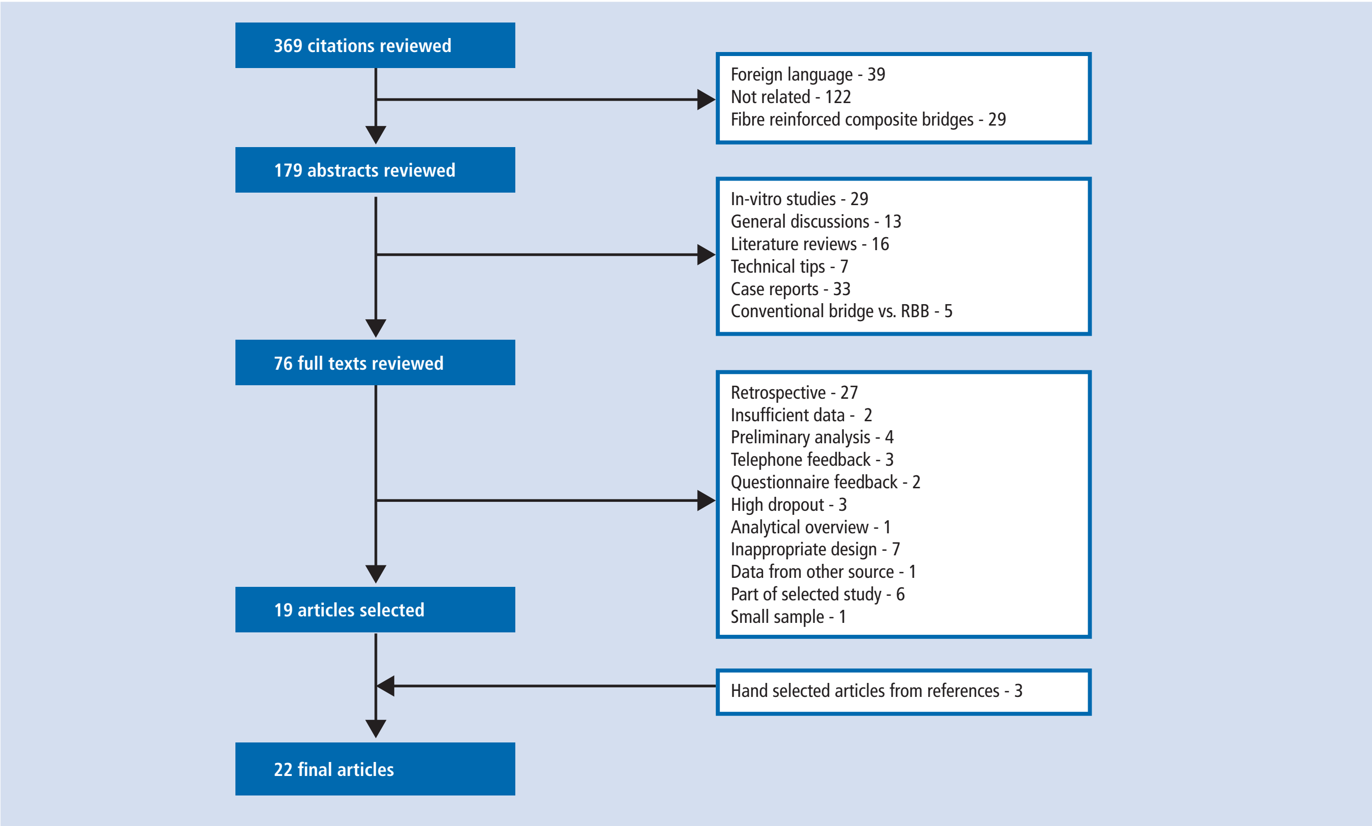
Fig. 1 Flow of reviewed study selection



Literature reviews

Literature reviews have helped in understanding the prognostic factors on the survival rate of RBBs to an extent.

Creugers and Vanthof carried out a meta-analysis to assess the overall survival ratio of RBBs and explore the relationship between potential success factors and survival times.[4] A weighted multiple regression analysis revealed no significant effect of type of retention and location on the survival rate.

A literature review by Mowafy and Rubo concluded that preparation design, cement type, casting alloy and surface treatment are the most important factors that affect the longevity of resin bonded fixed dentures (RBFDs).[5]

Aims

The aim of this study is to carry out a systematic review of the literature to assess survival rate of RBBs and understand relationship between the prognostic factors and survival rate.

Methods

Data sources and searches

An electronic search with an Ovid interface to Medline and Cochrane was conducted from 1946 to February 2014 to identify relevant published articles on RBBs that discussed survival rate, failure rate and variables that affect their predictability. Manual searches of reference lists from selected studies were performed to identify studies that may have been missed in the electronic search.

Study selection

Potentially relevant articles were selected by reviewing the title followed by the abstract and full text. The inclusion criteria for the studies were as follows:

1. The studies should be prospective cohort studies or RCTs that evaluated RBBs
2. The minimum follow-up period should be at least 1 year
3. The study should provide information about patients and patient selection to exclude extreme samples like all children or high risk patients
4. Studies that analysed survival rate and failure rate of RBBs
5. Studies that assessed various variables that could potentially influence survival of RBBs.

The exclusion criteria for the studies are as follows:

1. Foreign language articles were excluded
2. Studies based on patients' records, questionnaires and interviews only were not included
3. *In vitro* studies were excluded as results from *in vitro* studies may be inappropriate indicators of the clinical behaviour of RBB
4. Retrospective studies were excluded as there are increased chances of inaccurate information about the recruitment of samples and treatment carried out. Important confounding factors and materials used may be missed
5. Interim/preliminary follow-up studies were not included as results from interim studies may be different from the final study
6. Studies with inappropriate design, insufficient primary data, large drop outs and small samples were excluded
7. Studies that used natural pontics were excluded.

Data extraction

The following data was extracted from selected studies: characteristics and size of the study cohort, age range and mean age of patients, preparation of abutments, alloy material, luting cement, location of the bridge, surface treatment, number of units, number of retainers, retainer design and occlusal characteristics of the bridge. In addition, the

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Table 1 Survival data of RBBs from selected studies

Study	Years	Sample size	Survival rate
Mohl, 1988[6]	2	33	85%
Aboush, 2001[7]	2	57	86%
Clyde , 1988[8]	2.5	122	89%
Wahad, 2004[9]	3	21	90%
Rashid, 2003[10]	3	70	94%
Isidor, 1992[11]	4	20	100%
Al-Shammery, 1989[12]	4	36	72%
Sun, 2013[13]	4	35	100%
Cruegers, 1992[14]	5	189	75%
Stockholm, 1996[15]	5	51	96%
Kanter, 1998[16]	5	201	53%
Sasse, 2012[17]	5	30	89%
Cotert, 1997[18]	5	60	58%
Rammelberg, 1993[19]	6	141	83%
Deniz, 2013[20]	7.5	41	76%
Hansson, 1996[21]	8.5	29	50%
Corrente, 2000[22]	10	61	79%
Probster, 1997[23]	11	325	60%
Priest, 1995[24]	11	77	61%

Poissons regression was done using 'R' language to estimate survival rate

Table 2 Outcome of predicated survival rate using Poissons regression in 'R'

		Confidence Interval		Credibility interval	
	Predicted survival rate	Lower bound	Upper bound	Lower bound	Upper bound
5 year	83.60%	77.00%	88.60%	51.30%	96.10%
10 year	64.90%	47.80%	78.90%	25.80%	90.80%

number of bridges retained and debonded, survival rate, failure rate and types of failures were noted from the selected studies.

Functional survival rates after rebonding has not been considered in this study. Only complete survival rate without complications has been considered. When survival rates are available for multiple years within the duration of the study, the longer duration survival rate was used for analysis.

Results

Literature search

The electronic search yielded 329 potentially relevant articles published between January 1946 and February 2014. After initial review, 179 titles met the study inclusion criteria. The abstracts were reviewed. One hundred and three articles were excluded and 76 articles were selected for full text review. Fifty-seven studies were excluded after full text review. The remaining 19 studies satisfied the inclusion and exclusion criteria. The reference list of all the selected studies was assessed and three articles were selected. This yielded a total of 22 articles (Fig. S1, available in the online supplementary information).

Study characteristics

Characteristics of the included studies are included in Appendix 1 (available in the online supplementary information). Twenty-two studies were identified, with a total of 1,603 bridges, assessing the impact of various prognostic variables on their survival.

Overall survival

Among the selected 22 studies, 19 studies evaluated overall survival rate of RBBs with varying follow up. Details of data extracted from these studies are presented in Table 1.

The predicted survival rate for 5 years and 10 years are 83.6% and 64.9% respectively (Table 2). Confidence and credibility intervals have also been obtained through the Poissons regression analysis using 'R'.

Complications in RBBs

Among the selected 22 studies, 16 assessed the types of complications in RBBs. The most common failure was restoration debond. Details of number and types of complications extracted from the studies are summarised in Table 3.

Debond and porcelain fracture percentages have been calculated for each study (Table 3). Using CMA software, pooled debond percentages have been calculated along with forest plots (Figs S2 and S3, available in the online supplementary information). Based on the pooled estimate, 77% of the complications are due to debond of RBBs and 13% are due to porcelain fracture.

Other complications reported are caries, framework fracture, root resorption, retainer cusp fracture, loss of abutment due to periodontitis and minor rotation. Deniz *et al.* evaluated posterior RBBs with composite veneering over retainer wings and reported composite fracture as a major complication.[20]

Association between various prognostic factors and survival of RBBs

Tooth preparation

Among the selected 22 studies, three studies evaluated the effect of abutment teeth preparation on RBB survival. Due to dissimilar primary data type and outcome measure, statistical analysis has not been possible and therefore the results are summarised.

A 10-year study concluded that location and surface conditioning had no effect on survival rate and that survival time was determined mainly by preparation technique.[27] The mean of the survival time was calculated to be 9.1 ± 0.2 years (95% CI: 8.7/9.4) for RBBs with retentive preparation and 6.0 ± 0.9 years (95% CI: 4.1/7.8) for RBBs without retentive preparation (Table 4).

It was concluded that retentive preparation made a 95% survival rate possible after 10 years (Kaplan-Meier estimation). Without retentive preparation, the risk of failure increased by a factor of 3.7.

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Table 3 Debond rate and other complications

Study	Failures	Debond	debond %	Porcelain fracture	Porcelain fracture %	Caries	Framework fracture	Composite fracture	Root resorption	Retainer cusp fracture	Loss of abutment due to periodontitis	Minor rotation
Stockholm, 1996[15]	7	1	14%	4	57%	1	0	0	1	1	0	0
Aboush, 200[17]	9	8	89%	1	11%	0	0	0	0	0	0	0
Clyde , 1988[8]	13	11	85%	2	15%	0	0	0	0	0	0	0
Wahad, 2004[9]	2	2	100%	0	0%	0	0	0	0	0	0	0
Rashid, 2003[10]	4	4	100%	0	0%	0	0	0	0	0	0	0
Cotert, 1997[18]	18	16	89%	0	0%	2	0	0	0	0	0	0
Boening, 1996[25]	10	8	80%	2	20%	0	0	0	0	0	0	0
Bessimo, 19972[6]	9	6	67%	1	11%	2	0	0	0	0	0	0
Sasse, 2012[17]	4	2	50%	0	0%	1	0	0	0	0	0	1
Cruegers, 1992[14]	77	47	61%	30	39%	0	0	0	0	0	0	0
Mohl, 1988[6]	5	5	100%	1	20%	0	0	0	0	0	0	0
Hansson, 1996[21]	5	5	100%	0	0%	0	0	0	0	0	0	0
Deniz, 20132[0]	10	1	10%	0	0%	0	1	8	0	0	0	0
Corrente, 2000[22]	13	12	92%	0	0%	0	1	0	0	0	0	0
Behr, 1998[27]	23	20	87%	2	9%	0	1	0	0	0	0	0
Priest, 1995[24]	30	28	93%	1	3%	0	0	0	0	0	1	0

A 5-year RCT to evaluate different designs of posterior RBBs compared conventional preparation (minor preparation like path of insertion and occlusal stops) and modified preparation (approximal grooves, guiding planes and occlusal stops). A significant difference in complete survival was found in modified abutment preparation (62% vs. 42%) (Table 5).[16]

It was concluded that abutment tooth preparation including proximal grooves is recommended for posterior bridges.

In a 6-year study to evaluate 141 RBBs placed under controlled conditions, minimal preparation bridges showed 38% survival and modified preparation bridges showed 96% survival (Table 6).[19]

It was concluded that tooth preparation that included parallel channels and grooves had a substantially reduced risk of failure.

Tooth preparation depth

Among the selected 22 studies, one study evaluated the effect of preparation depth on survival of RBBs. Cotert and Ozturk evaluated 60 posterior AFPDs retained by resin bonded cast metal inlays under controlled conditions for 6 years.[18] Preparation depth was found to have no effect on complete or functional survival. The statistics are summarised in Table 7.

The term 'unexposed' represents abutments which were prepared in the enamel level and extra coronal/Maryland type restorations. The term 'exposed' included abutments which were prepared in dentine level.

Table 4 Association between tooth preparation and survival[27]

Preparation type	No of bridges	Mean survival time	95% CI
Retentive preparation	91	9.1+/-0.2	8.7/9.4 years
Non-retentive preparation	29	6+/-0.9	4.1/7.8 years

Table 5 Association between tooth preparation and survival[16]

Preparation type	Complete SR% 5 yrs	Relative Risk	95% CI	p value
Conventional – Modified	46 – 62	0.6	0.4 –1.0	0.04

Table 6 Association between tooth preparation and survival[19]

Preparation type	Total	Retained	Dislodged	Survival rate in 6 years
Minimal preparation	32	12	20	38%
Modified preparation	109	105	4	96%

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Table 7 Association between preparation depth and survival[18]

Preparation depth	No of bridges	Survival rate (%) 3 yrs	Survival rate (%) 5 yrs	Survival time median	95% CI	Univariate p-value	Multivariate p-value
Both retainers in unexposed dentine	17	84.7	70.6	59	49-70	0.24	0.62
Both retainers in exposed dentine	18	66.2	44.1	50	31-69		
Exposed and unexposed	25	75.3	62.7	50	40-61		

Occlusion

Among the selected 22 studies, two studies evaluated the effect of occlusion on survival of RBBs. Due to dissimilar primary data type and outcome measure, statistical analysis has not been possible and therefore the results are summarised.

In a clinical trial, 203 RBBs were evaluated for a period of 7.5 years and effect of occlusion on survival was studied.[28] Occlusion was studied under two headings: initial occlusion (before insertion of RBB) and occlusion on retention wings. Results reported that initial occlusion, occlusion on pontic and occlusion on retention wings had no significant effect on the survival of the bridges. Full data on retention rate and p-value have not been published.

A 45-month longitudinal study to evaluate 46 RBBs concluded that a pontic directly involved in protrusive and laterotrusive contacts had no significant effect on longevity of RBBs ($p = 0.56$).[25] The probability of survival was 82% and 80% after 2 and 3 years.

Table 8 Association between surface treatment and survival[15]

Surface treatment	Total	Retained	Dislodged	Survival rate % in 5 years
Silicoated	24	24	0	100%
Lost sugar crystal method	13	13	0	100%
Tin plating	14	12	2	86%

Table 9 Association between surface treatment and survival[19]

Surface treatment	Total	Retained	Dislodged	Survival rate % in 5 years
Sand blasted	52	29	23	56%
Acid etched	33	30	3	91%
Silicoated	30	30	0	100%
Rocatec	26	26	0	100%

Table 10 Association between retainer type and survival - Cotert and Ozturk (1997)[18]

Retainer design	Total made	Survival rate % 5 yrs
Approximal inlay and approximal inlay	33	49%
Approximal inlay and MOD inlay	10	68%
Approximal inlay and extra coronal retainer	17	66%

Table 11 Association between retainer type and survival[24]

Retainer design	Total made	Retained	Debond	Survival rate (%) 5 yrs
Perforated	3	0	3	0%
Duralingual pattern	1	0	1	0%
Electrolytically etched	27	10	17	37%
Chemically etched	46	37	9	80%

Surface treatment of retainer

Among the selected 22 studies, three evaluated the effect of surface treatment of retainers on survival of RBBs.[15,16,19] Due to dissimilar primary data and outcome measure, statistical analysis has not been possible and therefore the results are summarised.

A 5-year clinical study of 51 posterior RBBs with inlay retainers evaluated three different methods of framework retention.[15] All RBBs with silicoated frameworks and frameworks made with lost crystal method were still in function after 5 years. Two of 14 tin-plated RBBs failed and needed replacement. The results are summarised in Table 8.

In a 5-year study on posterior RBBs silica coated bridges showed higher functional survival (57%) than etched (55%) and sand-blasted (48%) bridges.[16]

In a 6-year study of 141 RBBs four different methods of conditioning were evaluated: sand-blasting, electrolytic etching and two silane coating methods – pyrolytic application of silica and mechanical silane-coating by sand-blasting (Rocatec).[19] Both silicoating methods showed 100% survival after 6 years. The results are summarised in Table 9.

All three studies concluded that silicoating the retainers showed better survival than other surface treatments.

Retainer type

Among the selected 22 studies, three evaluated the effect of retainer type on survival of RBBs.[18,28,24] Due to dissimilar primary data and outcome measures, statistical analysis has not been possible and therefore the results are summarised.

A controlled clinical evaluation of 203 RBBs to assess influence of retainer type, cementation factors and other variables on etched metal bridges and perforated metal bridges.[28] The 7.5-year survival rate for E-type bridges and P-type bridges were 78% and 63% respectively. P-type bridges had a risk of failure twice that of E bridges.

Sixty resin bonded cast metal inlays were evaluated for 6 years to assess influence of various prognostic factors.[18] The retainer

Table 12 Association between gingival finish line[18]

Gingival finish line location	Total bridges	Survival rate % – 3 yrs	Survival rate % – 5 yrs	Univariate p-value	Multivariate p-value
Both supra gingival retainers	32	81.2	81.2	0.046	0.349
Both sub gingival retainers	5	66.7	NR		
Supra gingival and sub gingival retainers	23	60.2	48.2		

Table 13 Primary data of survival rate with various luting cements in 5 years[16,18]

Study	Luting agent	No. (n)	Survival %	95% CI	
				Lower	Upper
Cotert, 1997[18]	ABC adhesive bridge cement	12	18	5	49
Kanter, 1998[16]	Clearfil	63	55	43	67
Cotert, 1997[18]	Maryland bridge adhesive cement	10	20	5	54
Kanter, 1998[16]	Microfill Pontic C	71	57	45	68
Kanter 1998, Cotert 1997	Pooled value for Panavia (Fig. 4)	105	67	29	91

Table 14 Primary data of survival rate with various luting cements in 2 years[7,17]

Study	Luting agent	No. (n)	Survival %	95% CI	
				Lower	Upper
Sasse, 2012[17]	Multilink auto mix + primer	14	93	63	99
Aboush, 200[17]	Scotchbond multipurpose plus	28	82	64	92
Aboush 2001,[7] Sasse 2012[17]	Pooled value for Panavia (Fig. 5)	45	85	71	93

designs used were approximal inlay, approximal MOD inlay or extra coronal retainer. The survival rate of the various combinations are summarised in the Table 10.

An 11-year study evaluated 77 RBBs with four different retainer types – duralingual, perforated, chemically etched and electrolytically etched.[24] The results indicate that chemically etched retainers demonstrate better retention that electrolytically etched and other types investigated (Table 11).

Gingival finish line location

Among the selected 22 studies, only one study evaluated the effect of gingival finish line location on survival of RBBs.[18] Supra gingival, sub gingival and supra and sub gingival combinations were evaluated. Bridges with both retainers having supra gingival finish lines showed a better retention rate (81.2% in 3 and 5 years). Univariate statistics showed that gingival finish line ($p = 0.046$) had a significant effect on event free survival. However, no relationship was found between gingival finish line location and long-term functional survival. The data presented in the study are summarised in Table 12.

Retainer alloy

Among the selected 22 studies, one evaluated the effect of retainer alloy on survival of RBBs. A longitudinal evaluation by Hansson and Bergstrom suggested the need for increased retention and resistance form of frameworks.[21] Bond strength between resin and high gold alloys was found to be too low to resist fatigue fractures. Prostheses made of gold alloy detached earlier (3.1–5 years) than those constructed of a Co-Cr alloy (7.4–8.3 years). It was concluded that Ni-Cr and Co-Cr alloys are preferred over gold or titanium alloys as they double the modulus of elasticity.

Luting cements

Among the selected 22 studies, four evaluated the effect of luting cements on survival.[7,16–18] Due to dissimilar primary data and outcome measures, statistical analysis has not been possible and therefore the results are summarised. Panavia has been used in all four studies.

Survival rate with various luting cements in 5 years

Five different luting cements have been evaluated for 5 years by two different studies.[16,18] The details are available in Table 13. Pooled survival rate has been calculated for Panavia using CMA software. Bridges cemented with Panavia showed the highest survival rate (67%) among the luting cements analysed for 5 years (Fig. S4, available in the online supplementary information).

Survival rate with various luting cements in 2 years

Three types of luting cements have been evaluated for 2 years by two studies.[7,17] The details are summarised in Table 14. Panavia has been used in both studies and pooled survival rate has been calculated for Panavia using CMA software. Bridges cemented with Multilink cement showed the highest survival rate (93%) followed by Panavia (82%) (Fig. S5, available in the online supplementary information).

Location of bridge

Anterior/posterior

Among the selected 22 studies, ten studies evaluated the effect of location on survival of RBBs. The details of the studies and the primary data are summarised in Table 15.

The number of retained and debonded restorations for anterior and posterior bridges

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are available. CMA software has been used to calculate the odds ratio for retention of anterior bridges over posterior. A random effect model has been used and results are interpreted using forest plots as Figure S6, available in the online supplementary information.

Pooled odds for retention of RBB in anterior segment when compared to posterior is 1.915 (95% CI – 0.847–4.329).

Maxilla/mandible

Among the selected 22 studies, 11 studies evaluated the effect of location (maxilla/mandible) on the survival of RBBs. The details of the studies and the primary data are summarised in Table 16.

The number of retained and debonded restorations for maxillary and mandibular bridges are available. CMA software has been used to calculate the odds ratio for retention of maxillary bridges over mandibular bridges. A random effect model has been used and the results are interpreted using forest plots as Figure S7, available in the online supplementary information.

Pooled odds for retention of RBB in maxilla when compared to mandible is 1.774 (95% CI – 0.803–3.917).

Table 15 Association between anterior/posterior location and survival rate. Primary data from studies referenced

Study	Years	Retained	Debond	Retained	Debond
		Anterior		Posterior	
Mohl, 1988[6]	2	15	1	13	4
Boening, 1996[25]	2	36	5	2	3
Clyde , 1988[8]	2.5	69	9	8	2
Al-Wahadni, 2004[9]	3	14	0	5	2
Rashid, 2003[10]	3	58	2	42	2
Bessimo, 1997[26]	3.4	53	4	68	2
Al-Shammery, 1989[12]	4	20	0	6	10
Rammelberg, 1993[19]	6	65	17	52	7
Hansson, 1996[21]	8.5	16	3	8	2
Priest, 1995[24]	11	26	15	21	15

Table 16 Association between Maxilla / Mandible and survival rate. Primary data from studies referenced

Study	Years	Retained	Debond	Retained	Debond
		Maxilla		Mandible	
Mohl, 1988[6]	2	17	1	11	4
Boening, 1996[25]	2	26	2	10	6
Wahad, 2004[9]	3	15	0	4	2
Rashid, 2003[10]	3	47	3	19	1
Bessimo, 1997[26]	3.4	61	1	60	5
Al-Shammery, 1989[12]	4	21	2	5	8
Rammelberg, 1993[19]	6	71	16	46	8
Deniz, 2013[20]	7	14	7	17	3
Corrente, 2000[22]	10	23	8	26	4
Priest, 1995[24]	11	29	17	18	13
Hansson, 1996[21]	8.5	21	5	3	0

Discussion

Overall survival

Based on statistical analysis, the predicted survival rate for 5 years and 10 years are 83.6% and 64.9% respectively. Confidence and credibility intervals have also been obtained through the Poissons regression analysis using 'R'.

Meta-analysis to assess the 5-year survival rate of RBBs and incidence of technical and biological complications, indicated a good estimated survival rate of 87.7% after 5 years.[29] The authors, however, concluded that RBBs have lower survival rates than conventional FDs and implants.

Complications

Statistical analysis indicated that 77% of the complications were due to debond of RBBs and 13% were due to porcelain fracture. Pjetursson *et al.* reported that most common complication was debonding which occurred in 19.2% of RBBs over a period of 5 years.[29]

Tooth preparation

Results summarised in this review favour RBBs with tooth preparation over bridges without or minimal tooth preparation. However, the need for tooth preparation is still a subject of debate.

Earlier research followed and favoured more extensive tooth preparations.[16,27] Wyatt reported that modified tooth preparation enhanced retention and resistance form of RBBs.[30] These include creating defined path of insertion, extending the framework maximally on the lingual aspect of the abutment teeth, defined rest preparations (cingulum and occlusal) and proximal grooves on abutment teeth for posterior RBBs.

More recent studies advocate minimal preparation within enamel[31] or no preparation at all.[32,33]

Kimura *et al.* have stated that teeth with a higher concentration of fluoride could be more resistant to acid etching and can require a longer etching time.[34] Bond strengths to a group of mild to moderately fluorosed teeth demonstrated a 40% reduction in bond strength compared with normal teeth. Therefore, slight preparation or roughening the outer most layer of enamel may help in improving bond strengths.

There is a definite need for RCTs or good quality cohort studies to understand the influence of various preparation designs on RBB survival.

Tooth preparation depth

For anterior RBBs, minimal or no preparation has been recommended to take advantage of good bond strength to enamel.[35] Bond strength to dentine is lower than in enamel and this

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might influence the retention. Retentive preparation of abutment tooth using 0.5 mm axial reduction and placement of grooves, boxes and rest seats is likely to expose dentine.[30] Dentine exposure increases risk of sensitivity and caries, if not sealed adequately during cementation, thereby increasing chances of failure. Therefore, if preparation is favoured, reliance on dentine bonding is the way forward.

Occlusion

Strong evidence on the effect of occlusion was not available and there are many gaps in our knowledge. A full articulatory system examination and detailed occlusal analysis is important before planning a RBB. Mounted casts and wax up can give valuable information about amount of inter-occlusal space available and occlusion on pontic and retainer.[35] Ideally, the pontic should not be involved in guidance during mandibular excursive movements and should not be loaded by an opposing tooth in lateral excursions.[36,37] If this is not achievable, guidance should be shared by multiple natural teeth.

Space can be gained by slight adjustments to opposite teeth through localised anterior composite build ups to attain favourable guidance pattern or cementing the bridge high and allowing the occlusion to re-establish by passive eruption.[33,35]

Parafunctional habits might increase the risk of failure of restorations. Such habits should be identified and assessed before treatment planning. If bruxism is suspected, a night guard/occlusal splint should be considered to protect the restoration.

Surface treatment of retainer

Silicoating has been reported to show better retention than other surface treatments and has also been recommended for rebonding. In etched and sandblasted bridges, a layer of the surface of the metal retainer is repeatedly removed during treatment for rebonding. In the case of silicoated bridges this loss is compensated for by the addition of a new coating with sufficient layer thickness.[38]

A literature review reported silicoating to be more retentive than electrolytic etching.[39] An 11-year longitudinal study concluded that silicoated base metal alloy RBBs had the highest survival probability.[23] Most studies concluded that silicoating improves the longevity of alloy-resin bond in resin systems. Disadvantages that have been reported with silicoating are the need for expensive equipment and decreased bond strength when bonding is delayed.

Retainer type

Retainer types used for RBBs have ranged from the perforated prototype to the chemically etched retainers that are used at present. Cotert and Ozturk reported that retainer type and approximal preparation design had no significant effect on survival of RBBs.[18] Priest reported that both chemical and electrolytically etched retentive mechanisms showed favourable long-term results when matched with the luting cement Comspan Opaque.[24]

Gingival finish line location

Numerous studies favour supra-gingival finish line.[18,40] The advantages stated are that use of supra-gingival margins will allow adequate oral hygiene thereby preventing gingivitis, periodontitis and dental caries.[30]

Retainer alloy

Alloy selection can be critical and for an alloy to be acceptable, the etched alloy/composite resin bond strength should preferably exceed the range of bond strength of etched enamel/composite resin.[41]

Hansson and Bergstrom concluded that Ni-Cr and Co-Cr alloys are preferred over gold or titanium alloys in their longitudinal study.[21] *In vitro* studies show that bond strength between resin and Co-Cr and titanium alloys are higher than that with gold alloys.[42] Wyatt reported that base metal alloys typically nickel-chromium-beryllium are preferred over gold alloys due to their enhanced bond to resin cement.[30]

Therefore, bridges made with Ni-Cr and Co-Cr alloys may have better retention rates than gold alloys. However, there is a need for well controlled clinical trials to evaluate the influence of retainer alloy material on retention rates of RBBs.

Luting cements

Based on results of this review, Panavia showed higher survival rate than other luting cements compared. Durey *et al.* report that earlier composite resins exhibit degradation and reduced bond strength with time and, in contrast, Panavia demonstrates prolonged high bond strength.[35]

In a literature review, Imbery and Eshelman reported the following about luting cements:[39]

- Studies have shown that bond strength of ABC Adhesive bridge cement was comparable with Comspan
- Several studies demonstrated comparable or greater bond strength of base metal alloys that were air abraded and cemented with Panavia compared to Comspan
- The bond strength of Panavia to dentine is low when compared to fourth generation dentine bonding agents. *In vitro* studies have reported Panavia 21 to be superior to Panavia in both physical and adhesive properties
- *In vitro* studies reported that C&B Metabond forms the strongest bond to alloy that is electrolytically etched, air abraded or silicoated
- All bond 2 bonds best to air abraded base metal and noble metal alloys
- Due to the availability of numerous luting cements for bonding resin bridges, there is an urgent need for strong RCTs to understand influence of various cements of survival of RBBs.

Location of bridge

Anterior/posterior

Results of this review state that anterior RBBs have a higher survival rate than posterior. This is similar to results of a systematic review that assessed 5-year survival rate of RBBs.[29] It concluded that the annual debonding rate for RBBs for posterior teeth (5.03%) tends to be higher than that of anterior RBBs (3.05%). However, no statistical significance was found ($p = 0.157$).

Cruegers *et al.* report that in some studies posterior RBBs were more retentive than anterior RBBs.[28] However, this deviation could be as a result of difference in tooth preparation designs for anterior and posterior bridges.

Crispin has reported that anterior RBBs do not appear to need routine 180-degree-plus circumferential retainer preparation for predictable success whereas posterior RBBs do.[43]

Independent significant difference in survival rate due to anterior or posterior location may therefore be difficult to prove without evidence from robust controlled trials with otherwise similar RBBs.

Maxilla/mandible

Results of this review state that maxillary RBBs have a higher survival rate than mandibular RBBs. This is consistent with results of a systematic review conducted by Pjetursson *et al.* to assess 5-year survival rate of RBBs.[29]

Other factors

Numerous other factors that influence survival of RBBs have been discussed in various studies. Due to strict inclusion criteria some studies

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have not been selected for statistical analysis in this article. However, these factors cannot be ignored and there is a need for strong and controlled studies to understand the influence of these factors on longevity on RBBs.

Isolation

Ibbetson has stated that adhesive bridges are best fitted with rubber dam in place and anything other than this represents a compromise.[32]

Design

Median survival of fixed-fixed design (7.8 years) has been reported to be significantly shorter than cantilever design (9.8 years).[44] High failure rate of fixed-fixed design could be related to differential tooth movement and debond of one retainer. Dalen *et al.* concluded that two-unit cantilevered FPDs show better longevity than fixed-fixed design in similar situations.[45] There may be however be situations where a fixed-fixed design may be most appropriate like

- When replacing teeth in situations where periodontal splinting of abutment teeth is considered
- Large pontic spans
- Where abutment teeth are small and sufficient surface area for retention can be gained only by using one abutment t either side of the span.[35]

Abutment tooth selection

Endodontic and periodontal health of abutment tooth is critical when planning RBBs. Durey *et al.* recommend that the abutment tooth should have sufficient available enamel to favour bonding.[35] Hypodontia/microdontia, improper alignment/angulation of teeth, crowding etc can reduce the amount of tooth structure available for bonding and should be carefully assessed before treatment planning.

Abutment tooth mobility

Probster and Henrich report that restorations on immobile abutments have significantly higher survival probability than restorations on mobile abutments. Also different abutment tooth mobility can lead to a high risk of failure.[23]

Bonding area/coverage

Maximising the surface area available for bonding has been favoured by many studies. The metal framework should cover as far occluso-gingivally and circumferentially around the tooth as possible without affecting aesthetics. A wrap-around design or 180 degree extension of retainer around the axial surface of the abutment tooth is believed to improve retention of RBBs.[46]

Retainer thickness

There are not many clinical studies available for evaluating the influence of retainer thickness on the survival of RBBs. However, three-dimensional finite element analysis and Weibull analysis suggest that longevity of RBBs can be prolonged by thickening the retainers rather than using more rigid metals.[47,48]

Retainer height

In vitro study show that stress value decreased with greater retainer height at normal oral temperatures due to increased stiffness of the retainers and more bonding area to enamel.[49] Therefore, it was recommended that prosthesis retainers have as much height as possible to decrease the stress value.

Rebonding failed restorations

Rebonding of failed restoration is attempted in most cases. Rebonded restorations have been reported to be more susceptible to dislodgement than original RBBs.[14] The survival of replacement RBBs was reported to be significantly better than rebonded RBBs. Several possible reasons for low survival of rebonded restorations were stated by the authors:[14]

- Retention capacity of retainers and abutment teeth may have deteriorated
- The design (preparation or extension) may be insufficient
- Other unknown patient related factors.

Conclusion

The following conclusions are drawn from this systematic review. The predicted survival rate for 5 years and 10 years are 83.6% and 64.9% respectively. Functional survival after rebonding has not been considered in this study and it is expected that functional survival rate will be higher than event free survival. Debonding of the restoration (78%) is the most common type of failure with RRBs followed by porcelain fracture (13%). Bridges cemented with Panavia showed the highest survival rate (67%) among the luting cements analysed for 5 years. Retentive tooth preparation, preparation confined to enamel, silicoating of retainers, supra-gingival margins, Ni-Cr or Co-Cr alloys, no occlusion on pontic in lateral excursions have been reported to show better survival rates of RBBs. Anterior RBBs and bridges in maxilla were found to be more retentive than posterior RBBs and bridges in mandible respectively.

Recommendations

Replacement of missing teeth with resin bonded fixed partial dentures (RBFPDs) is a conservative alternative to conventional fixed partial dentures and should be included as a treatment option wherever possible. A systematic review to assess 5-year survival rate of RBBs concluded that despite high survival rate, technical complications like debonding are common with RBBs and there is an urgent need for studies on RBBs with a follow up of over 10 years or more to evaluate long-term outcomes.[29]

In spite of problems such as debonds, RBBs can be considered as minimally invasive, reversible, aesthetic and predictable restorations for fixed replacement of missing teeth. Recommendations from literature about favourable prognostic factors should be understood and applied when planning RBBs. These can be ideal restorations for fixed replacement of teeth if good survival rates can be achieved. Careful patient selection, treatment planning and attention to all factors will help to fabricate successful restorations with longer survival rates.

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