

Title	Tooth replacement options for partially dentate older adults: a survival analysis
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Publication date	2020-12-06
Original Citation	McKenna, G., Tada, S., McLister, C., DaMata, C., Hayes, M., Cronin, M., Moore, C. and Allen, F. (2020) 'Tooth replacement options for partially dentate older adults: A survival analysis', Journal of Dentistry, 103, 103468 (6pp). doi: 10.1016/j.jdent.2020.103468
Type of publication	Article (peer-reviewed)
Link to publisher's version	10.1016/j.jdent.2020.103468
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Download date	2026-09-13 03:18:57
Item downloaded from	https://hdl.handle.net/10468/14710

1 **Abstract (250/250 words)**

2 **Tooth replacement options for partially dentate older adults: a survival analysis**

3 **Objectives:** To compare the success of two different tooth replacement strategies for
4 partially dentate older adults; namely resin bonded bridgework (RBB) provided to
5 restore patients according to the principles of the shortened dental arch concept (SDA)
6 and conventional full-arch rehabilitation with removable dental prostheses (RDPs).

7 **Methods:** A randomised controlled clinical trial (RCT) was conducted with partially
8 dentate adults aged 65 years or older. Each patient from the RDP group had all missing
9 natural teeth replaced with cobalt–chromium framework RDPs. Each patient from the
10 SDA group was restored to 10 occluding pairs of natural and replacement teeth using
11 RBB. Patients were followed-up at 6, 12, 24, 36 months. Success rates were generated
12 according to defined success criteria. Log-rank tests and Cox's proportional hazard
13 models were used to compare the success of the two treatment strategies.

14 **Results:** After 36 months, 89 patients completed the RCT; n=45 in the RDP group and
15 n=44 in the SDA group. The overall success rate of the SDA treatment was 90.4%
16 compared to 73.0% for RDPs (p=0.005). In the upper arch SDA treatment was 100%
17 successful compared to 86.4% for RDPs (p=0.019). In the lower arch, lower success
18 rates were reported for both the SDA treatment (80.0%) and RDPs (60.0%) (p=0.054).

19 Further analyses with cox's proportional hazard models demonstrated that SDA
20 treatment was significantly more successful than RDPs (Hazard Ratio: 2.47, p=0.04).

21 **Conclusions:** After 36 months SDA treatment using RBB was significantly more
22 successful than RDPs used for conventional full-arch rehabilitation in partially dentate
23 older adults.

24 **Clinical significance: (37/ 50 words)** Functionally orientated treatment according to
25 the principles of the SDA is a feasible alternative to RDPs for partially dentate older

- 1 patients. SDA treatment using RBB can achieve higher success rates compared to RDPs
- 2 in this patient group.
- 3

1 Introduction

2 Global population projections indicate that the proportion of people over 65 years of age is
3 increasing and will continue to do for the foreseeable future. Oral health professionals have
4 observed that in addition to simply an ageing population, there have been significant
5 changes in the oral health of older adults in recent years^{1,2}. As the numbers of edentulous
6 older adults has declined, there has been a significant increase in the number of partially
7 dentate elderly. Changing attitudes, improved access to dental care and more effective
8 preventative programmes have meant that large numbers of patients are now retaining
9 natural teeth into old age. However, despite these improvements to dental health, many of
10 these partially dentate older patients still require treatment to replace missing teeth.

11
12 As older patients retain natural teeth for longer the dental profession is charged with
13 controlling chronic dental diseases in an increasingly challenging oral environment. Many
14 older patients suffer from a variety of conditions which make mechanical tooth cleaning and
15 denture cleansing very difficult. By their nature, older patients also suffer most from chronic
16 systemic diseases. Loss of manual dexterity due to conditions such as Parkinson's Disease or
17 Arthritis can make keeping teeth and dentures clean almost impossible. In addition, many
18 older patients consume food rich in complex carbohydrates which can promote the
19 development of coronal and root caries^{3,4}. As these patients get older, their mouths and
20 teeth undergo a number of age related changes. One of the most marked changes is a
21 reduction in the amount of saliva in their mouths with large numbers complaining of
22 xerostomia. Physiological changes can contribute to xerostomia but dry mouth is a common
23 side effect of many drugs taken by to control systemic medical conditions. A lack of saliva
24 can have a devastating effect on the remaining dentition, directly contributing to an
25 increased risk of caries, periodontal disease and subsequent tooth loss⁵. Removable dental
26 prostheses (RDPs) can themselves present a significant maintenance challenge for

1 patients^{6,7}. This can have further negative effects on dental disease progression and
2 subsequent tooth loss.

3

4 Future dental practitioners will spend an increasing proportion of their time providing
5 treatment for older patient¹. With increasingly available sources of information and a more
6 dentally aware population, clinicians will be tasked with replacing teeth in a conservative,
7 cost effective and patient centred approach. Despite the large numbers of RDPs produced
8 there are alternative treatments available to replace missing teeth. These include fixed
9 prosthodontic options attached to natural teeth or dental implants. Less complex,
10 functionally orientated treatment solutions are very applicable to partially dentally older
11 patients. One of these is the Shortened Dental Arch (SDA) concept which aims to provide
12 patients with a functional dentition of 10 occluding pairs of teeth without the need for a
13 RDP⁸. By preserving mainly anterior teeth the SDA concept can offer patients an aesthetic
14 result which they can easily maintain. Studies have shown that by providing 10 occluding
15 pairs of teeth patients have suboptimal but acceptable levels of function for older patients⁹.
16 Although the SDA concept has been shown to be acceptable to both patients and clinicians
17 there is also evidence to suggest that it is currently an underutilised treatment approach¹⁰.
18 Whilst a small number of patients will retain the 20 natural teeth necessary to achieve a
19 natural SDA, a more realistic situation is that patients can be restored to a SDA. This can be
20 done using a variety of fixed prosthodontic options including fibre reinforced composite
21 resin, conventional bridgework and adhesive resin bonded bridgework (RBB). RBB has been
22 shown to be an effective and simple way of replacing missing teeth to provide patients with
23 a SDA¹¹.

24

25 The aim of this study was to compare the success of two different tooth replacement
26 strategies for partially dentate older patients. These strategies were conventional full-arch

1 rehabilitation with RDPs and functionally orientated treatment according to the principles of
2 the SDA with RBB used to replace missing teeth.

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1 **Material and Methods**

2 As illustrated in Figure 1, a randomised controlled clinical trial (RCT) was conducted
3 (Trial registration: ISRCTN26302774). The in-depth methodology of the RCT has been
4 described in a number of previous publications and so a short summary is provided
5 here¹². Partially dentate patients aged 65 years and older were recruited from two
6 centres: Cork University Dental Hospital and St Finbarr's Geriatric Day Hospital in Cork,
7 Ireland. Those patients in St Finbarr's Geriatric Day Hospital represented a more
8 systemically unwell and older cohort as they attended the Day Hospital to receive a
9 range of medical treatments.

10
11 Patients were included in the study if they were 65 years or older and seeking
12 replacement of missing natural teeth. Participants had a minimum of six remaining
13 natural teeth in both arches of good prognosis, could accept routine dental care in a
14 dental chair, could communicate in English and had no medical conditions which
15 precluded routine dental treatment. Full ethical approval was granted for the study (ref:
16 ECM 5 (9) 05/02/08). Each patient was provided with written information detailing the
17 proposed treatment involved and each patient completed a written consent form prior
18 to treatment. A power calculation was made based on summary OHIP-14 score data
19 from the United Kingdom Adult Dental Health Survey¹³. The calculation was based on an
20 equivalence study. The power calculation indicated that 44 patients per group was
21 required to give power of 80% with a one sided 5% level of significance. The attrition
22 rate was set at 30% to allow for drop outs during the study, so the targeted baseline
23 recruitment was 130 participants. Patients were recruited and treated in both a dental
24 hospital and a geriatric day hospital with a mobile dental unit.

25
26 Randomisation was performed using a computer generated schedule in SAS®. All
27 patients were randomly allocated to two different treatment groups: the RDP group and

1 the SDA group. Randomisation was conducted in blocks of varying length and was
2 stratified according to age and gender with separate randomisation sequences in the
3 two recruitment centres. There was no difference in randomisation according to dental
4 status or number of missing teeth. Patient randomisation was conducted by a research
5 assistant and the allocation was concealed from the clinical operator. Initially, all
6 patients received standardised dental care to render them dentally fit including
7 extraction of hopeless teeth, restoration of caries and non surgical management of
8 periodontal disease.

10 Patients from each treatment group received standardised care according to a treatment
11 protocol. Each patient from the RDP group had all missing natural teeth replaced with
12 RDPs fabricated with cobalt–chromium frameworks. Each patient from the SDA group
13 was restored to a premolar occlusion of 10 occluding pairs of natural and replacement
14 teeth using RBB throughout the arch. The number and position of RBBs provided was
15 tailored to the clinical needs of each patient. Posterior teeth distal to the SDA were left
16 unopposed. The RBB was provided using a standardised protocol in each case with each
17 unit of bridgework designed with a nickel chromium wing which was sand blasted
18 chairside prior to cementation using a resin cement. Cantilever designs were utilised for
19 each item of RBB. Each item of fixed and removable prosthodontics was constructed by
20 the same dental laboratory. All operative treatment was conducted by a single operator
21 with postgraduate training in clinical prosthodontics during a 24 month period.

22 Patients were followed up for 36 months with review appointments at 6, 12, 24 and 36
23 months. In addition, patients attended without appointments if they required further
24 treatment associated with either tooth replacement strategy. At each appointment both
25 the SDA and the RDP patients were assessed for success according to the criteria in
26 Table 1.

1 The success of tooth replacement (RDP or SDA) in each arch was measured from the
2 entry-point into the study, defined as the date of treatment provision (RDP or SDA),
3 until the end-point, defined as the date when decementation, the need for repair, or non
4 usage were observed. The observation period was censored when 36 months had
5 passed since the date of treatment provision. A Kaplan–Meier survival analysis was
6 performed to illustrate the success probability of the two treatments and the
7 distribution was compared with a log-rank test. Further survival analysis was
8 undertaken using a Cox proportional hazards model with age, gender, arch (upper vs
9 lower) and pattern of tooth loss (Kennedy Classification) used as covariates. To compare
10 the characteristics of the two treatment groups, Mann-Whitney U and Chi-squared tests
11 were used. P-values of less than 0.05 were considered to be statistically significant and
12 data were analyzed using IBM SPSS Statistics 24 (IBM Company, Tokyo, Japan).

1 **Results**

2 After 36 months, 89 participants completed the RCT. As part of the study a total of 89
3 RDPs were constructed and 73 arches were restored to SDAs using RBBs. For the arches
4 restored to a SDA, 66 (90.4%) were judged as successful with a further 7 (9.5%) having
5 survived after one episode of recementing. In comparison, 65 RDPs were judged to
6 have been successful (73.0%) with a further 10 (11.2%) having survived. A total of 14
7 RDPs (15.7%) were no longer in use and were considered as unsuccessful (Table 1).

8

9 The profiles of the patients treated as part of the trial are summarised in Table 2. Forty
10 patients did not complete the trial (30.3%), 15 from Cork University Dental Hospital and
11 25 from St Finbarr's Geriatric Day Hospital. The high dropout rate in St Finbarr's
12 Geriatric Day Hospital was due to a variety of reasons including death (10 patients) and
13 admission to long - term care facilities due to illness (eight patients), which represented
14 this older and more systemically unwell group. During the trial, 20 patients (30.8%)
15 were lost from the RDP group and 20 were lost from the SDA group (29.9%). This
16 indicated that patients did not leave the study simply because they were randomly
17 allocated to the more experimental treatment group (SDA group). Analysis of the non-
18 responders did not indicate any systemic differences between them and those who
19 completed the trial.

20

21 The success rates for the treatment groups according to pattern of tooth loss (Kennedy
22 classification) and arch is illustrated in Table 3. This data illustrates that the majority of
23 cases treated in the upper arch for both groups were Kennedy Class III: RDP Group
24 n=17, SDA Group n=23; and Kennedy Class I in the lower arch: RDP Group n=23, SDA

1 Group n=14. This data illustrates the high success rates for SDA treatment in the upper
2 arch (100%) across all Kennedy Classifications but low success rates for RDPs placed in
3 Kennedy Class I cases (34.8%).

4 Kaplan-Meier survival curves for the two treatment groups are illustrated in Figure 2
5 with the data broken down by arch in Figures 3 and 4. A log-rank test demonstrated
6 that the overall success rate for the SDA Group was significantly better than the RDP
7 Group ($p=0.005$). This finding was consistent when the upper ($p=0.019$) and lower
8 ($p=0.054$) arches were analysed separately (Table 4). Further survival analysis for the
9 two treatment groups using a Cox proportional hazards model with age, gender, arch
10 and Kennedy Classification as covariates is illustrated in Table 5. This analysis
11 demonstrated that SDA treatment was almost 2.5 times more successful than RDP
12 treatment (HR 2.47; $p=0.04$). Treatment provided in the upper arch was also
13 significantly more successful than the lower arch (HR: 3.9, $p<0.05$).

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1 Discussion

2 This study represents one of a very small number of randomised clinical trials within
3 clinical prosthodontics with a long-term follow up period (3 years). This study
4 illustrates that oral rehabilitation according to the principles of the SDA utilising RBBs
5 can be a very successful form of treatment with overall success rates of 90.4%. This
6 compared very favourably to conventional full-arch rehabilitation using RDPs which had
7 an overall success rate of 73.0% ($p=0.005$). This trend continued when the upper and
8 lower arches were analysed separately. In the upper arch SDA treatment was 100%
9 successful compared to 86.4% ($p=0.019$) for RDPs. In the lower arch, lower success
10 rates were reported for both the SDA (80.0%) and the RDP (60.0%) groups ($p=0.054$).
11 When the lower arch was analysed according to Kennedy Classification it was
12 demonstrated that Class I RDPs were successful in only 34.8% of cases compared to
13 80% success for Class II, 87.5% for Class III and 100% for Class IV cases.

14

15 Given patients' dislike of removable dentures, their biological cost and high levels of
16 non-compliance, other treatment options should be considered when planning tooth
17 replacement for older, partially dentate patients¹⁴. This study provides high quality
18 evidence to advance this discussion in the form of an appropriately powered
19 randomised controlled clinical trial with a significant follow up period. Despite these
20 strengths of the study a number of limitations should be noted including the assessment
21 of the prostheses. Whilst patient randomisation and allocation was conducted by a
22 research assistant the assessment of the prostheses was undertaken by the same
23 operator who provided the initial treatment. Given the clear difference between the two
24 forms of treatment provided, blinding was impossible but an independent assessor
25 could have been used to assess survival and success criteria. One operator provided all

1 of the treatment during this study. Whilst this means that the standard of treatment
2 provided was consistent throughout, the external validity of study could be questioned
3 as the operator had postgraduate training in prosthodontics. Further research is
4 required to determine if similar results could be obtained in other centres or in primary
5 care.

6
7 The results of this study can be interpreted in relation to previous work in this area.
8 Using a similar study design, researchers from the University of Newcastle concluded
9 after a 5 year follow-up RBB used to provide patients with a SDA had similar survival
10 characteristics as RDPs¹⁵. In contrast to the results present in this paper all of the RBBs
11 placed in the previous study were in the lower arch and all were placed as distal
12 extension prostheses. Further evidence is available from another study carried out at
13 the University of Geneva. In this study, which also compared functionally orientated
14 treatment with RDPs, a 19% failure rate was reported for the fixed prostheses used¹⁶.
15 Further evidence on the long term success of the SDA concept is available from a
16 multicentre German trial which has reported results over a 5 year period¹⁷. Whilst this
17 study also reports very positive survival rates for treatment according to the principles
18 of the SDA, patients in the German study were provided with RDPs retained using
19 precision attachments and conventional fixed bridgework in the SDA group. Therefore
20 the results are not directly comparable. The low success rates reported for Kennedy
21 Class 1 dentures in the lower arch do mirror other classic studies which have shown
22 that unsuccessful partial dentures are more likely to replace posterior teeth only,
23 particularly in the lower arch¹⁸.

24
25 This study provides further evidence of the advantages of functionally orientated
26 treatment compared to conventional tooth replacement strategies such as RDPs. In
27 addition to the high success rates demonstrated in this study, previous work has

1 illustrated that functionally orientated treatment has positive impacts on oral health
2 related quality life, masticatory performance and patient satisfaction¹⁹⁻²². Especially in
3 partially reduced dentitions with (almost) sound remaining teeth RBB offers a good
4 treatment alternative to RDPs. They are relative easy to place and well accepted by the
5 patient. The biological price is low compared to conventional bridges and RDPs.
6 Evidence also suggests that maintenance of a functionally orientated dentition is more
7 achievable for the patient and ultimately more cost effective²³⁻²⁵. The combination of
8 these factors should encourage both policymakers and clinicians to utilise this
9 treatment concept more widely in appropriate cases. One criticism often levelled at the
10 use of RBBs is the reduced success rate found in primary care^{26,27}. This study illustrates
11 that high success rates can be achieved in older patients when the operative treatment
12 is undertaken in both a dental hospital and non-hospital setting.

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14

1 **Conclusion**

2 After 36 months the cumulative survival rate for RBBs used as part of functionally
3 orientated treatment (SDA group) was significantly better than conventional full-arch
4 rehabilitation using RDPs for partially dentate older adults ($p=0.005$).

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Tables

Treatment Group	Criteria	Description	Arches Restored (n(%))
SDA			Total Number: 73
	Successful	▪ RBB all retained ▪ No episodes of decementation	66 (90.4%)
	Survived	▪ RBB recemented on one occasion	7 (9.5%)
	Unsuccessful	▪ RBB recemented on 2 or more occasions ▪ RBB remade ▪ RBB lost	0 (0%)
<u>RDP</u>			Total Number: 89
	Successful	▪ <u>RDP</u> in function	65 (73.0%)
	Survived	▪ <u>RDP</u> in function but repaired or altered	10 (11.2%)
	Unsuccessful	▪ <u>RDP</u> not in use	14 (15.7%)

Table 1 Success criteria for tooth replacement strategies

	SDA Group (n=44)	RDP Group (n=45)	p-value ¹
Age (years)	71.5 (IQR: 69.0-78.0)	74.0 (IQR: 69.0 - 78.0)	0.739
Gender	M=20, F=24	M=21, F=24	0.909
Number of residual natural teeth (n)	18.0 (IQR: 17.0-20.5)	19.0 (IQR: 17.0-20.0)	0.325
Occlusal Units (n) (baseline)	8.0 (IQR: 6.0-8.0)	7.0 (IQR: 6.0-8.0)	0.034

Table 2 Characteristics of treatment groups (¹Analyses using Mann-Whitney U and Chi-squared tests)

Kennedy Classification	<u>SDA Group</u>				<u>RDP Group</u>			
	Upper Arch (n=38)		Lower Arch (n=35)		Upper Arch (n=44)		Lower Arch (n=45)	
	n	Success Rate (%)	n	Success Rate (%)	n	Success Rate (%)	n	Success Rate (%)
I	4	100	14	85.7	4	100	23	34.8
II	1	100	1	100	15	86.7	10	80
III	23	100	11	90.9	17	76.5	8	87.5
IV	10	100	9	88.9	8	100	4	100

Table 3 Three year success rates according to treatment group, Kennedy Classification
and arch

Arch Restored	Treatment Group	Time Point (months)	Success Rate (%)	95% CI	p-value (log rank test)
Total (upper and lower arch)	SDA (n=73)	6	98.6	90.7-99.8	0.005
		12	94.5	86.1-97.9	
		24	90.4	80.9-95.3	
		36	90.4	80.9-95.3	
	<u>RDP (n=89)</u>	6	92.1	84.2 - 96.2	
		12	84.3	74.9 - 90.4	
		24	77.5	67.4 - 84.9	
		36	73.0	62.5 - 81.0	
Upper	SDA (n=38)	6	100	N/A	0.019
		12	100	N/A	
		24	100	N/A	
		36	100	N/A	
	<u>RDP (n=44)</u>	6	97.7	84.9-99.7	
		12	93.2	80.3-97.7	
		24	90.9	77.6-96.5	
		36	86.4	72.1-93.6	
Lower	SDA (n=35)	6	97.1	81.4-99.6	0.054
		12	88.6	72.4-95.5	
		24	80.0	62.6-89.9	
		36	80.0	62.6-89.9	
	<u>RDP (n=45)</u>	6	86.7	72.7-93.8	
		12	75.6	60.2-85.6	

		24	64.4	48.7-76.5
		36	60.0	44.3-72.6

Table 4 Summary of success rates for treatment groups after 3 years including
breakdown by arch

	Reference	Hazard Ratio	95% CI	P-value
Treatment Group	SDA RDP	1 2.47	1.04 – 5.86	0.040
Age	N/A	0.98	0.92 – 1.05	0.392
Gender	Female Male	1 1.36	0.67 – 2.76	0.546
Arch Restored	Upper Lower	1 3.91	1.56 – 9.83	0.004
Kennedy Classification	III & IV I & II	1 2.29	0.98 – 5.37	0.056

Table 5 Survival analysis using Cox proportional hazards model

Figure legends

Figure 1 Patient flow diagram

Figure 2 Kaplan-Meier survival analysis, RDP Group vs SDA Group

Figure 3 Kaplan-Meier survival analysis, RDP Group vs SDA Group in upper arch

Figure 4 Kaplan-Meier survival analysis, RDP Group vs SDA Group in lower arch

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