

Review

Shortened dental arch and prosthetic effect on oral health-related quality of life: a systematic review and meta-analysis

K. FUEKI*  & K. BABA†  *Removable Partial Prosthodontics, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University (TMDU), Tokyo, and †Department of Prosthodontics, Showa University, Tokyo, Japan

SUMMARY This systematic review aimed to compare oral health-related quality of life (OHRQoL) between two tooth replacement strategies – the shortened dental arch (SDA) concept and conventional treatment with removable partial dental prosthesis (RPDP) or implant-supported fixed partial dental prosthesis (IFPDP) – for distal extension of edentulous space in the posterior area. We retrieved eligible randomised controlled trials (RCTs) and non-RCTs published between 1980 and November 2016 retrieved from MEDLINE and the Cochrane Central Register of Controlled Trials. The primary outcome was OHRQoL evaluated using validated questionnaires. Two reviewers independently screened and selected the articles, evaluated the risk of bias and determined the standardised weighted mean difference (SWMD) in OHRQoL scores between the two strategies using a random effects model. Two RCTs and one non-RCT involving 516 participants were included in this review. All studies employed the oral health impact profile (OHIP) for

evaluation of OHRQoL. There was no statistically significant difference in OHIP summary scores between SDA and RPDP at 6 (SWMD = 0.24) or 12 (SWMD = 0.40) months post-treatment. Only one non-RCT had reported higher OHRQoL with IFPDP than with SDA; however, because of the small sample size, there was no significant difference in OHIP summary scores between the two strategies at 6 (SWMD = –0.59) or 12 (SWMD = –0.67) months post-treatment. In terms of OHRQoL in partially dentate patients, the SDA concept appears to be as feasible as RPDP restoration. Further clinical trials are required to clarify the effect of IFPDP restoration on OHRQoL.

KEYWORDS: oral health-related quality of life, shortened dental arch, removable partial denture, implant-supported fixed partial denture, systematic review, meta-analysis

Accepted for publication 26 March 2017

Introduction

It is becoming increasingly recognised that the impact of disease and treatment on quality of life (QoL) – and its consequences – should be taken into account during assessment of health status and treatment outcomes; clinical indicators should be supplemented by patient perception, especially in case of chronic debilitating disorders (1, 2). In dentistry, the association between objective measures of dental disease and patient-based opinions of oral status had been

reported to be weak, with objective measures failing to accurately reflect patient perceptions; this suggested the need for development of a paradigm that encompassed the multidimensional nature of health, and all of its possible outcomes (3). The impact of oral disorders and interventions on patient-perceived oral health status, evaluated as oral health-related (OHR) QoL, is now regarded as an important component of oral health (3), and its importance in planning oral-healthcare programmes and advocating oral health practices has been acknowledged (3).

An important question in prosthodontic treatment is the extent to which tooth loss actually affects OHRQoL, the knowledge of which would aid clinical decision-making and provision of appropriate oral health care. Systematic reviews published hitherto have concluded that, regardless of the OHRQoL instrument and context of the included sample, there is fairly strong evidence that tooth loss is associated with impairment of OHRQoL (4, 5). Moreover, not only the number, but also the location and distribution of missing teeth affect the severity of OHRQoL impairment (4, 5). One of the reviews suggested that patients with shortened dental arches (SDAs) with complete anterior dentition and at least four occlusal units (OUs; a pair of occluding premolars and molars corresponding to one and two units, respectively) (6) maintain an acceptable level of OHRQoL (5). This indicates that, in the absence of significant OHRQoL impairment, it is likely that there will be a lower demand for treatment from patients with SDA, and prosthodontic treatments would have to be aimed at establishing fixed premolar contacts. On the other hand, a few Japanese studies have reported significant impairment of OHRQoL (7) and the tendency to seek prosthodontic treatment (8) among patients without molar contacts, which leaves some room for debate on the SDA concept.

Another clinically important question is whether extensive prosthodontic treatments, such as removable partial dental prosthesis (RPDP) and implant-supported fixed partial dental prosthesis (IFPDP), might improve OHRQoL status in patients with SDA. Treatment outcomes of restoration of partially edentulous arches with RPDPs or IFPDPs up to molars – evaluated by OHRQoL – should be compared with those of fixed restoration of partially edentulous arches up to premolars (SDA) or SDA without restoration (non-Tx SDA), ideally by randomised clinical trials (RCTs). Conclusions drawn from such studies will provide strong evidence for reference in clinical decision-making in prosthodontics.

Although several systematic reviews have focused on the effects of prosthetic intervention on OHRQoL in patients with SDA, availability of only a limited number of relevant RCTs forced these reviews to include studies of different designs and lower strength (9–11). They, consequently, failed to provide strong evidence that could potentially impact clinical decision-making (5, 9–12). In 2012, the Cochrane Library published a systematic review including only RCTs (13). However, because only one relevant RCT with respect to

OHRQoL could be identified at the time of literature search, this review did not involve meta-analysis.

For these reasons, we performed an exclusive meta-analysis of RCTs and summarised the results of non-RCTs selected based on predetermined criteria. This review was designed to answer the following clinical questions (CQs) based on existing evidence.

CQ#1: Does prosthetic restoration with RPDP up to molars in partially dentate patients provide better OHRQoL than SDA or non-Tx SDA?

CQ#2: Does prosthetic restoration with IFPDP up to molars in partially dentate patients provide better OHRQoL than SDA or non-Tx SDA?

Materials and methods

The protocol for systematic review was developed according to the Cochrane Handbook for Systematic Review of Interventions version 5.1.0 (14). The only deviation in protocol from that described in the handbook was that we included unpublished data in the meta-analysis. The results have been reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guideline (15).

Eligibility criteria

In this review, SDA was defined as a partially dentate arch with premolar occlusion, without any molars in at least one quadrant, and with all anterior teeth intact or restored with fixed prosthesis. This systematic review and meta-analysis only included RCTs and non-RCTs. Case-control, cross-sectional and cohort studies, case series and reports, and analytical and narrative reviews were excluded. Participants included in this review were partially edentulous adult male and female subjects ≥ 20 years of age. Studies that comparatively evaluated OHRQoL between RPDPs or IFPDPs for restoration of partially edentulous arches up to molars and SDA or non-Tx SDA using validated instruments were included.

Search methods and study selection

Online electronic databases, including the MEDLINE database and the Cochrane Central Register of Controlled Trials, were searched by a reviewer (KF)

without any language filters for articles published between 1980 and 1 November 2016. The search terms included shortened dental arch, SDA, quality of life and OHRQoL. For example, the search strategy in MEDLINE was “shortened dental arch”[All Fields] OR “shortened dental arches”[All Fields] OR SDA [All Fields] OR SDAs [All Fields] AND (“quality of life”[All Fields] OR OHRQoL [All Fields]). Additionally, reference lists of relevant articles were manually searched to identify eligible studies. The two authors (KF and KB) independently screened the titles and abstracts of the retrieved articles to identify studies that fulfilled the predetermined eligibility criteria and then reviewed the full texts of the shortlisted articles to arrive at the final selection of studies for inclusion in this meta-analysis. Multiple publications from the same study were considered as amounting to a single study.

Data synthesis and assessment of risk of bias

Data regarding study design, setting, follow-up period and frequency, number of participants, eligibility criteria, OHRQoL instrument, sex distribution, type of prosthetic treatment, and mean and standard deviation (SD) of OHRQoL scores were retrieved from the selected articles and checked by the other reviewer (KB) for completeness. In case of studies with incomplete data, the corresponding authors were contacted for the additional information. Data synthesis was performed by one reviewer (KF) using Review Manager 5 (<http://community.cochrane.org/tools/review-production-tools/revman-5>). Two reviewers (KF and KB) independently assessed the risk of bias of the included studies using the Cochrane risk of bias tool. In case of heterogeneity in data among the included studies, standardised weighted mean differences (SWMDs) and 95% confidence intervals (CIs) for pooled data were calculated using the random effects model and presented using forest plots. Three additional meta-analyses were conducted including only RCTs, subgroups without elderly subjects and studies using clasp-retained RPDPs. A *P*-value <0.05 was considered statistically significant.

Results

Screening and selection

Figure 1 presents the flow diagram of study screening and selection. Electronic search yielded 45 relevant

articles, and manual search identified one more article. After exclusion of six duplicate articles, the 39 remaining articles were screened based on the title and abstract. After exclusion of 29 ineligible articles, the remaining 10 were subject to full-text review, upon which, seven articles were excluded either because the study design did not meet the eligibility criteria (8, 16–20) or because the studies reported on the pilot phase of a large RCT (21). Finally, one RCT each from Germany (22) and the United Kingdom (UK) (23) and one non-RCT from Japan (24) were included in the qualitative and meta-analysis. Our manual search yielded an RCT conducted by another research group in the UK (25–28). However, this RCT was not designed for OHRQoL assessment and was, therefore, not included in our review. Upon our request, the authors of the German study (22) provided the mean value and SD of OHRQoL scores of each group at each centre. For the Japanese study (24), we supplied unpublished data related to OHRQoL scores of a subgroup of participants with intact premolars but missing first and second molars in at least one quadrant of the dental arch – a condition referred to as SDA type II in a previous paper (9) – in order to match the dental conditions evaluated in the German and UK studies.

Characteristics of the included studies

Table 1 presents the characteristics of the included studies (22–24). All three studies employed the oral health impact profile (OHIP) questionnaire, either the full (29) or abbreviated (OHIP-14) (30) form, for evaluation of OHRQoL. All three studies recruited participants from multiple hospitals. While participants in the German and UK studies were sex-matched, the Japanese study had a higher proportion of female than male subjects. Although the mean participant ages at enrolment in the German and Japanese studies were comparable, participants enrolled at one of the centres in the UK study were older compared to those enrolled at the other centres. The follow-up period of the German study (60 months) was longer compared to those of the UK and Japanese studies (12 months); therefore, meta-analysis was conducted at the two common time points (6 and 12 months). In the SDA group, patients in the German study had received cantilever FPDPs, while those in the UK study had received resin-bonded bridges for restoration up to second premolars. In the prosthetic

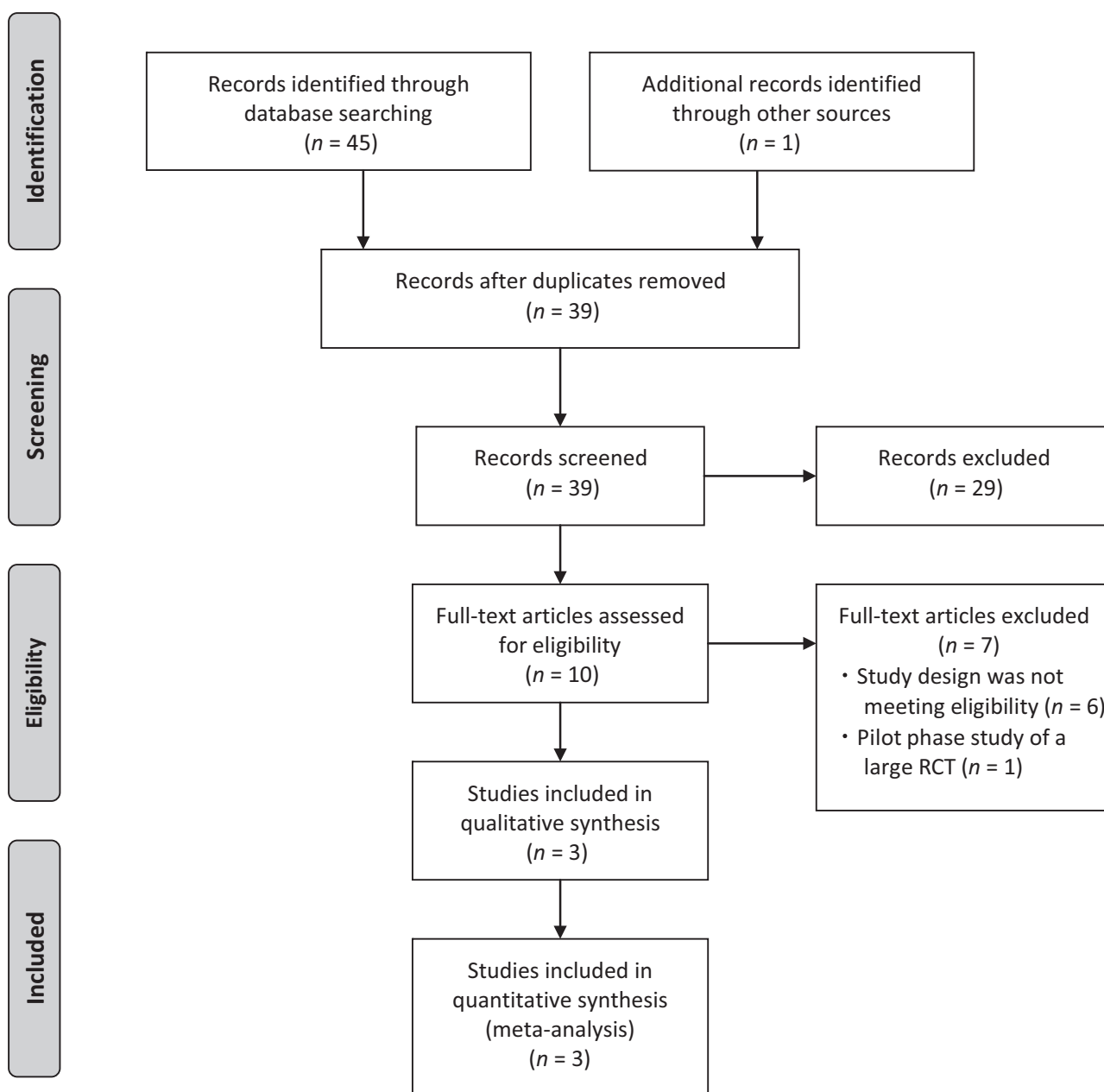


Fig. 1. Flowchart of the study process.

treatment group with restored molars, patients in the German study had received precision attachment-retained RPDPs and those in the UK study received clasp-retained RPDPs, while those in the Japanese study had received clasp-retained RPDPs or IFPDPs.

OHRQoL

The German study recruited participants from 14 university-based hospitals (22); statistical analysis of

pooled data revealed no statistically significant differences in OHIP-49 summary scores or any other subscale scores between the SDA and RPDP groups at any time point during the 5-year follow-up period (22). The UK study recruited participants from a university-based hospital (Cork University Dental Hospital: CUDH) and a residential hospital (St Finbarr's Geriatric Day Hospital in Cork: SFDH) representing an older population (23). As statistical analysis indicated significant interactions at the group, time point and

Table 1. Characteristics of included studies

	Country	Study design	Setting (number of centres)	Follow-up period (month)	Follow-up rate
Wolfart <i>et al.</i> (22)	Germany	RCT	University-based hospital (14)	60	92% (138/150)
McKenna <i>et al.</i> (23)	United Kingdom	RCT	University-based hospital (1) Residential hospital (1)	12	69% (89/130)
Fueki <i>et al.</i> (24)	Japan	Non-RCT	University-based hospital (7)	12	71% (89/125)

OHRQoL instrument	Inclusion criteria of participants	SDA group	Prosthetic treatment group
OHIP-49 (German version)	Missing all molars in at least one jaw At least canine and one premolar present on each side Age >35 years	Cantilever FPDP or no-treatment	Precision attachment-retained RPDP
OHIP-14	Minimum of six remaining natural teeth in both arches Age >65 years	Resin-bonded bridgework	Clasp-retained RPDP
OHIP-54 (Japanese version)	Missing 2–12 occlusal units All anterior teeth intact or restored with fixed prostheses Age >20 years	No-treatment	Clasp-retained RPDP (metal framework or acrylic resin base) IFPDP

Number of patients (SDA/RPDP/IFPDP) at entry	Mean age at entry (years)	Sex (male) (%)	Number of patients completed intervention		
			SDA	RPDP	IFPDP
215 (109/106/—)	59.4	50.2	81	69	—
132 (66/64/—)	70.2	43.9	64	66	—
169 (70/69/30)	63.6	25.0	53	53	19

centre levels, intergroup comparison of OHIP-14 summary scores was performed separately for each centre. In CUDH, while the two groups exhibited comparable OHIP summary scores at 1 and 6 months post-treatment, the SDA group exhibited a significantly lower score than the RPDP group at 12 months. In SFDH, the SDA group exhibited significantly lower OHIP scores at all time points post-treatment (1, 6 and 12 months). The Japanese study recruited participants from seven university-based hospitals (24). Participants were allocated to the SDA, RPDP or IFPDP groups primarily according to patient preference (8). Table 2 presents the changes in OHIP summary scores

in a subgroup of patients with SDA type II restoration. The RPDP group exhibited slightly greater pre- and post-treatment OHIP summary scores than the SDA group. In comparison with the SDA group, the IFPDP group exhibited equivalent OHIP scores before and 3 months after treatment, but substantially lower scores at 6 and 12 months post-treatment. However, because of the low statistical power (0.193 and 0.220 at 6 and 12 months, respectively), intergroup comparison of OHIP scores by one-way analysis of covariance after controlling for age, sex and number of missing OUs revealed no significant intergroup differences at any time point ($P > 0.05$).

Table 2. Change in mean OHIP-J 49 summary score in the Japanese study (24)

	Pre-treatment			3 months			6 months			12 months		
	<i>n</i>	Mean	SD	<i>n</i>	Mean	SD	<i>n</i>	Mean	SD	<i>n</i>	Mean	SD
SDA group*	24	31.1	24.9	23	32.9	22.2	22	23.7	16.2	21	31.4	25.7
RPDP group*	24	43.6	22.8	24	38.1	24.6	18	31.1	24.9	15	36.6	24.9
IFPDP group*	13	31.7	24.8	7	30.7	21.8	6	13.8	17.2	7	15.1	14.8

*Subjects were limited to those who missed all molars for at least one quadrant from participants in the study (9).

Risk of bias

The German and UK studies reported adequate random sequence generation and allocation concealment (Table 3). The Japanese study did not employ random allocation or propensity analysis and, consequently, presented a high risk of sampling bias. None of the studies could blind dentists or patients to treatment allocation. As the OHIP questionnaire is self-administered by patients, the risk of bias due to blinding of outcome assessment appeared to be low. As all studies were registered in clinical trial registries, and all outcome measures were described in the study protocols (31) or published papers (8, 23), the risk of selective reporting bias appeared to be low. The follow-up rate of the German study was very high. Although nearly 30% of the participants dropped out from the UK and Japanese studies, there were no systemic differences between these subjects and those who reached study completion in either study. The German and UK studies employed intention-to-treat analysis, which lowered the risk of overestimation of treatment effect.

Meta-analysis

Meta-analysis was performed for comparison of OHIP summary scores between the SDA and RPDP groups at 6 and 12 months evaluations. A total of 270 participants at 6 months and 266 participants at 12 months were pooled for data synthesis. As the included studies had employed either the full-scale or the short form of the OHIP questionnaire, the mean difference in OHIP summary scores between the two groups was standardised (effect size). Because of significant heterogeneity in the 12-month follow-up data

($P < 0.05$), data synthesis was performed using the random effects model. The RPDP group exhibited slightly, but not significantly, higher integrated OHIP summary scores (greater OHRQoL impairment) than the SDA group (6 and 12 months post-treatment: SWMD, 0.24 and 0.40; 95% CI, -0.17 to 0.66 and -0.21 to 1.01 , respectively; $P > 0.05$; Fig. 2). Sub-group meta-analysis including only the two RCTs (22, 23) revealed similar results at 6 and 12 months post-treatment (SWMD, 0.24 and 0.50; 95% CI, -0.30 to 0.78 and -0.32 to 1.32 , respectively; $P > 0.05$), as did that excluding older participants at the SFDH (23) (SWMD, 0.03, both; 95% CI, -0.22 to 0.28 and -0.22 to 0.28 , respectively; $P > 0.05$).

In studies that administered clasp-retained RPDPs (23, 24), the RPDP group exhibited moderately, but not significantly, higher OHIP scores than the SDA group at 6 and 12 months post-treatment (SWMD, 0.42 and 0.65; 95% CI, -0.12 to 0.97 and -0.16 to 1.46 , respectively; $P > 0.05$). The possibility of publication bias was not assessed on a funnel plot, because the number of included studies was <10 (14). In the Japanese non-RCT (24), the IFPDP group exhibited moderately, but not significantly, lower OHIP scores than the SDA group (6 and 12 months post-treatment: SWMD, -0.59 and -0.67 ; 95% CI, -1.50 to 0.33 and -1.55 to 0.21 ; $P > 0.05$).

Discussion

To answer the first clinical question (CQ#1), this systematic review identified two RCTs and one non-RCT on comparison of OHRQoL between SDA and RPDP restorations. Narrative appraisal and meta-analysis of these studies did not reveal RPDP restoration of missing molars as being superior to SDAs with intact premolar occlusion in terms of OHRQoL, which corresponds with the conclusions of previous reviews (5, 9–13) that supported clinical application of the SDA concept (6). Considering that perceived need for dental treatment is associated with OHRQoL impairment (4), the conclusions drawn from these systematic reviews justify the concept that patients with SDA do not need additional prosthodontic treatment. As cost is an important determinant in clinical decision-making, another important issue is the cost-effectiveness of each treatment strategy, including post-treatment maintenance. In the UK study, RPDP restoration was found to be 1.84 times more expensive than treatment for SDA, considering a

Table 3. Risk of bias in included studies assessed by reviewers

	Wolfart <i>et al.</i> (35)	McKenna <i>et al.</i> (23)	Fueki <i>et al.</i> (24)
Study design	RCT	RCT	Non-RCT
Random sequence generation	Low risk	Low risk	High risk
Allocation concealment	Low risk	Low risk	High risk
Blinding of participants and personnel	High risk	High risk	High risk
Blinding of outcome assessment	Low risk	Low risk	Low risk
Incomplete outcome data	Low risk	Low risk	High risk
Selective reporting	Low risk	Low risk	Low risk
Other bias	Low risk	Low risk	Low risk

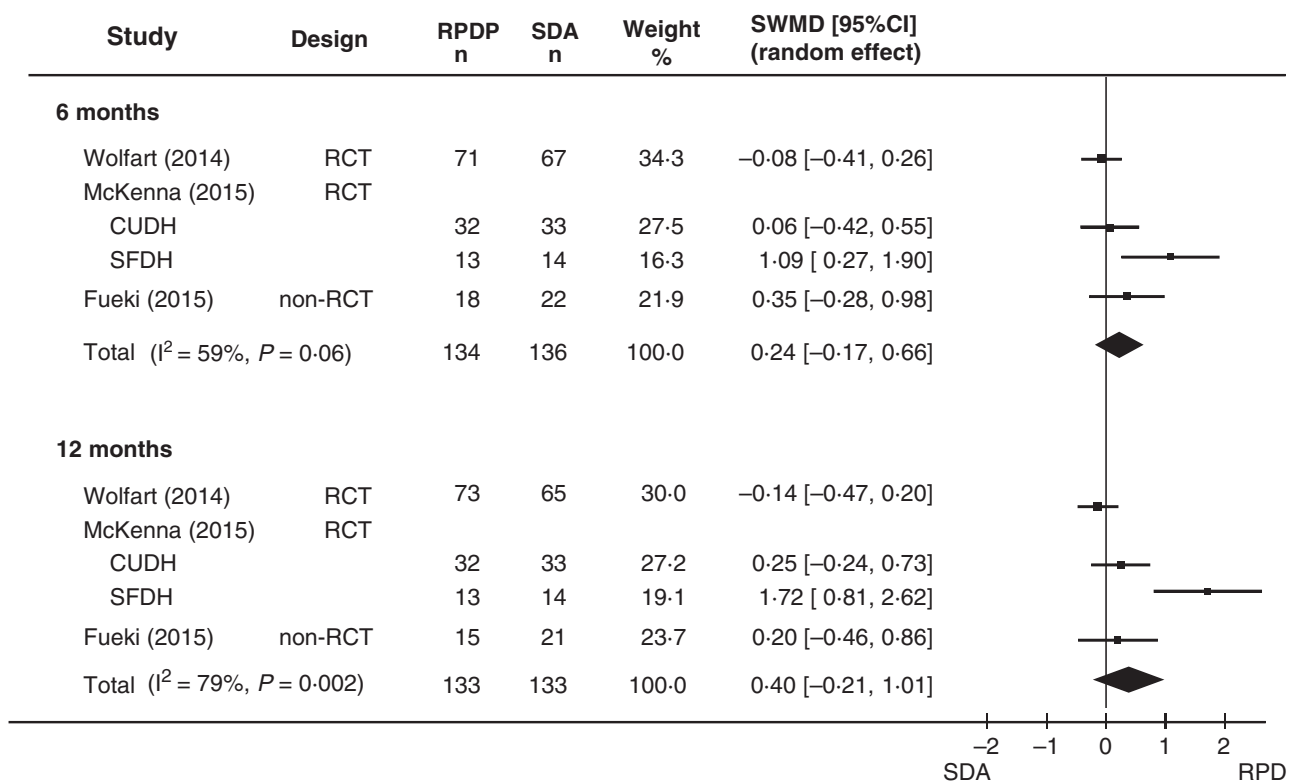


Fig. 2. Forest plots for comparison of OHIP summary scores between the RPDP and SDA groups included in this systematic review (22–24). The SWMD with 95% CI in each study and the overall effect are presented at 6 and 12 months of follow-up. Positive SWMD indicates higher OHIP summary scores (impaired OHRQoL) in the RPDP group in comparison with the SDA group. As the 12-month data exhibited significant heterogeneity ($P < 0.05$), SWMD was computed using the random effects model. OHIP, oral health impact profile; RPDP, removable partial dental prosthesis; SDA, shortened dental arch; SWMD, standardised weighted mean difference; CI, confidence interval; OHRQoL, oral health-related quality of life; CUDH, Cork University Dental Hospital; SFDH, St Finbarr's Geriatric Day Hospital.

12-month follow-up period (32). This result, together with the conclusion of this systematic review, indicates the feasibility of the SDA concept as a potential treatment option. This might particularly true among the elderly population, because elderly patients in the SDA group in the UK study exhibited significantly better OHRQoL than those in the RPDP group. The elderly population is rapidly increasing in developed countries, and the number of partially dentate individuals is expected to increase in the future. Therefore, it is important to focus on the elderly population in future studies on SDA.

With regard to the second clinical question (CQ#2), the one non-RCT included in this review reported that patients with IFPDP restoration exhibited better OHRQoL than those with non-Tx SDA, although the difference was not statistically significant. A prospective study, not included in this systematic review, reported significantly improved OHRQoL after IFPDP

treatment in patients with Kennedy Class II partially edentulous mandibles (33); and a case-control study reported significantly higher OHRQoL in patients with Kennedy Class II IFPDPs than in patients with SDA (16). Additionally, a cross-sectional study reported partially dentate patients with IFPDPs as exhibiting better OHRQoL than those with RPDPs (34). Although more evidence from well-planned clinical trials is required to reach a definitive conclusion regarding CQ#2, IFPDP restoration might benefit patients with SDA in terms of OHRQoL. However, no study till date has compared the cost-effectiveness of IFPDP and SDA, which is particularly important because IFPDP is generally associated with relatively high expenditure and surgical invasiveness; therefore, this issue should be considered in future studies.

Recently, implant-assisted RPDP (IARPDP) restoration has emerged as a potential alternative for patients with SDA. Some prospective studies have shown that

the placement of a minimum number of implants (one or two) under existing free-end RPDPs results in additional improvement of OHRQoL, with minimal expense and surgical intervention (35–39) (Fig. 3). Future RCTs on comparison of OHRQoL between IARPDP and SDA are required to justify the clinical application of IARPDPs in patients with SDA.

Overall, the results of the present systematic review on OHRQoL status of two different tooth replacement strategies for distal extension of edentulous areas in the posterior region could serve as a reference for clinical decision-making. However, treatment decision should also consider the situation of individual patients and expertise of the dentist.

There are several limitations to this study. First, only three studies met the predetermined eligibility criteria for this review, and subgroup analysis further limited the sample size, which resulted in low statistical power. Second, differences in study design, age and sex distribution, type of RPDP retainer (clasp/precision attachment), and OHIP questionnaire version among the three studies might have led to heterogeneity and imprecise estimation of overall effect size. For this reason, we performed subgroup analyses

including only RCTs and study populations excluding older participants, which yielded consistent results. However, subgroup analysis of studies that provided clasp-retained RPDPs revealed better OHRQoL in patients with SDA than in patients with clasp-retained RPDPs. In one of the RCTs, patients with precision attachment-retained RPDPs exhibited significantly better OHRQoL than those with clasp-retained RPDPs (41), which suggests that precision attachment dentures, which lack metal clasps, provide better aesthetics and OHRQoL than clasp-retained RPDPs. Third, the meta-analysis only included data gathered over as short a follow-up period as 12 months, because only one study had presented longer follow-up data. Follow-up data acquired over longer durations should be assessed to determine the effectiveness of the SDA concept. Fourth, differences in sociocultural background and medical insurance systems among the countries in the included studies might have influenced treatment outcomes, especially in the non-RCT. In fact, a clinical trial on mandibular implant-supported overdentures reported the influence of cultural differences on OHRQoL (42). Fifth, participant-recruitment centres in the included studies were

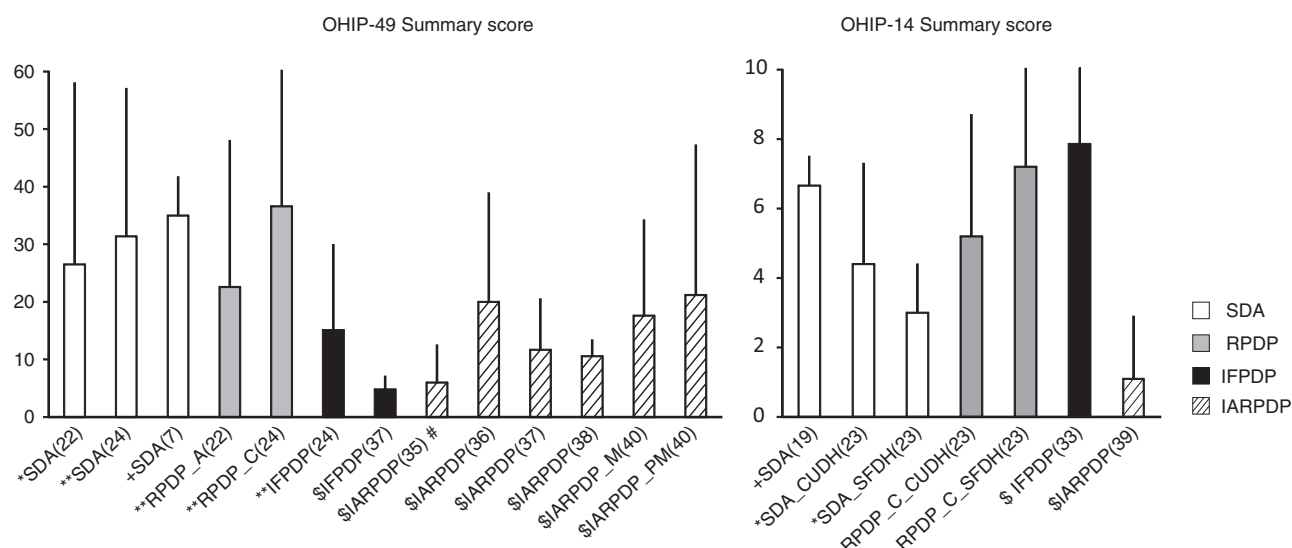


Fig. 3. OHRQoL in patients with SDA and Kennedy Class I or II partially edentulous patients with RPDP, IFPDP or IARPDP restoration up to molars (7, 19, 22–24, 33, 35–40), evaluated using the OHIP-49 or 14 questionnaire. The mean values and standard deviations of OHIP summary scores are presented. Higher scores indicate impaired OHRQoL. OHRQoL, oral health-related quality of life; OHIP, oral health impact profile; SDA, shortened dental arch; RPDP, removable partial dental prosthesis; IFPDP, implant-supported fixed partial dental prosthesis; IARPDP, implant-assisted RPDP; RPDP_C, clasp-retained RPDP; RPDP_A, precision attachment-retained RPDP; IARPDP_M, RPDP assisted by implants placed on the molar region, IARPDP_PM, RPDP assisted by implants placed on the pre-molar region; CUDH, Cork University Dental Hospital; SFDH, St Finbarr's Geriatric Day Hospital; *RCT; **non-RCT; \$prospective study; +cross-sectional study; #median and range of the 25th percentile.

mostly university-based hospitals. Population-based studies in a general-practice setting are required to establish the generalisability of the present findings. Finally, because of the small number of included studies, the possibility of publication bias was not assessed by a funnel plot.

It might be challenging to make both patients and dentists accept the SDA concept. In Japan, the SDA concept is not always accepted by the majority of dentists (43), and its clinical application is still under debate. In the German study, a relatively high number of participants (35/106; 33%) in the SDA group dropped out before prosthetic treatment (22), which might have led to bias in terms of OHRQoL results. Therefore, the findings that were potentially affected by this high rate of dropout should be interpreted carefully.

Conclusions

Within the limited evidence obtained from hitherto published RCTs and non-RCTs, the SDA concept appears to be as feasible as RPDP restoration with respect to OHRQoL in partially dentate patients. Further clinical trials are required to clarify the effect of IFPDP restoration on OHRQoL.

Acknowledgments

Part of this systematic review paper was presented at the Journal of Oral Rehabilitation Clinical Update meeting in Beijing, China in August 2016.

We would like to express our gratitude to Drs. Stefan Wolfart (Department of Prosthodontics and Biomaterials, Medical Faculty, RWTH Aachen University), Joachim Gerst (Institute of Biostatistics and Clinical Research, University of Münster) and Chihiro Masaki and Ryuji Hosokawa (Department of Oral Reconstruction and Rehabilitation, Kyushu Dental University), who provided additional information during manuscript preparation.

Conflicts of interest

The authors have stated explicitly that there are no conflict of interests in connection with this article.

Funding

None.

References

1. Decker SD, Schultz R, Wood D. Determinants of well-being in primary caregivers of spinal cord injured persons. *Rehabil Nurs*. 1989;14:6–8.
2. Sprangers MA, Aaronson NK. The role of health care providers and significant others in evaluating the quality of life of patients. *J Clin Epidemiol*. 1992;45:743–760.
3. Allen PF. Assessment of oral health related quality of life. *Health Qual Life Outcomes*. 2003;1:40.
4. Gerritsen AE, Allen PF, Witter DJ, Bronkhorst EM, Creugers NH. Tooth loss and oral health-related quality of life: a systematic review and meta-analysis. *Health Qual Life Outcomes*. 2010;8:126.
5. Tan H, Peres KG, Peres MA. Retention of teeth and oral health-related quality of life. *J Dent Res*. 2016;95:1350–1357.
6. Käyser AF. Shortened dental arches and oral function. *J Oral Rehabil*. 1981;8:457–462.
7. Baba K, Igarashi Y, Nishiyama A, John MT, Akagawa Y, Ikebe K *et al*. Patterns of missing occlusal units and oral health-related quality of life in SDA patients. *J Oral Rehabil*. 2008;35:621–628.
8. Fueki K, Igarashi Y, Maeda Y, Baba K, Koyano K, Akagawa Y, *et al*. Factors related to prosthetic restoration in patients with shortened dental arches: a multicentre study. *J Oral Rehabil*. 2011;38:525–532.
9. Strassburger C, Kerschbaum T, Heydecke G. Influence of implant and conventional prostheses on satisfaction and quality of life: a literature review. Part 2: qualitative analysis and evaluation of the studies. *Int J Prosthodont*. 2006;19:339–348.
10. Fueki K, Yoshida E, Igarashi Y. A systematic review of prosthetic restoration in patients with shortened dental arches. *Jap Dent Sci Rev*. 2011;47:167–174.
11. Khan S, Musekiwa A, Chikte UM, Omar R. Differences in functional outcomes for adult patients with prosthodontically-treated and -untreated shortened dental arches: a systematic review. *PLoS ONE*. 2014;9:e101143.
12. Faggion CM. The shortened dental arch revisited: from evidence to recommendations by the use of the GRADE approach. *J Oral Rehabil*. 2011;38:940–949.
13. Abt E, Carr AB, Worthington HV. Interventions for replacing missing teeth: partially absent dentition. *Cochrane Database of Sys Rev*. 2012;15:CD003814.
14. Cochrane Handbook for Systematic Review of Interventions Version 5.1.0. Available at: <http://training.cochrane.org/handbook>, accessed 1 September 2016.
15. Moher D, Liberati A, Tetzlaff J, Altman DG. The PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ*. 2009;339:b2535.
16. Kuboki T, Okamoto S, Suzuki H, Kanyama M, Arakawa H, Sonoyama W *et al*. Quality of life assessment of bone-anchored fixed partial denture patients with unilateral mandibular distal-extension edentulism. *J Prosthet Dent*. 1999;82:182–187.
17. Armellini DB, Heydecke G, Witter DJ, Creugers NH. Effect of removable partial dentures on oral health-related quality

- of life in subjects with shortened dental arches: a 2-center cross-sectional study. *Int J Prosthodont*. 2008;21:524–530.
18. Baba K, Igarashi Y, Nishiyama A, John MT, Akagawa Y, Ikebe K *et al*. The relationship between missing occlusal units and oral health-related quality of life in patients with shortened dental arches. *Int J Prosthodont*. 2008;21:72–74.
 19. Tan H, Peres KG, Peres MA. Do people with shortened dental arches have worse oral health-related quality of life than those with more natural teeth? A population-based study. *Community Dent Oral Epidemiol*. 2015;43:33–46.
 20. Antunes JL, Tan H, Peres KG, Peres MA. Impact of shortened dental arches on oral health-related quality of life. *J Oral Rehabil*. 2016;43:190–197.
 21. Wolfart S, Heydecke G, Luthardt RG, Marré B, Freesmeyer WB, Stark H, *et al*. Effects of prosthetic treatment for shortened dental arches on oral health-related quality of life, self-reports of pain and jaw disability: results from the pilot-phase of a randomized multicentre trial. *J Oral Rehabil*. 2005;32:815–822.
 22. Wolfart S, Müller F, Gerß J, Heydecke G, Marré B, Böning K, *et al*. The randomized shortened dental arch study: oral health-related quality of life. *Clin Oral Investig*. 2014;18:525–533.
 23. McKenna G, Allen PF, O'Mahony D, Cronin M, DaMata C, Woods N. The impact of rehabilitation using removable partial dentures and functionally orientated treatment on oral health-related quality of life: a randomised controlled clinical trial. *J Dent*. 2015;43:66–71.
 24. Fueki K, Igarashi Y, Maeda Y, Baba K, Koyano K, Sasaki K, *et al*. Effect of prosthetic restoration on oral health-related quality of life in patients with shortened dental arches: a multicentre study. *J Oral Rehabil*. 2015;42:701–708.
 25. Moynihan PJ, Butler TJ, Thomason JM, Jepson NJ. Nutrient intake in partially dentate patients: the effect of prosthetic rehabilitation. *J Dent*. 2000;28:557–563.
 26. Jepson NJ, Moynihan PJ, Kelly PJ, Watson GW, Thomason JM. Caries incidence following restoration of shortened lower dental arches in a randomized controlled trial. *Br Dent J*. 2001;191:140–144.
 27. Jepson N, Allen F, Moynihan P, Kelly P, Thomason M. Patient satisfaction following restoration of shortened mandibular dental arches in a randomized controlled trial. *Int J Prosthodont*. 2003;16:409–414.
 28. Thomason JM, Moynihan PJ, Steen N, Jepson NJ. Time to survival for the restoration of the shortened lower dental arch. *J Dent Res*. 2007;86:646–650.
 29. Slade GD, Spencer AJ. Development and evaluation of the Oral Health Impact Profile. *Community Dent Health*. 1994;11:3–11.
 30. Slade GD. Derivation and validation of a short-form oral health impact profile. *Community Dent Oral Epidemiol*. 1997;25:284–290.
 31. Luthardt RG, Marré B, Heinecke A, Gerss J, Aggstaller H, Busche E, *et al*. The Randomized Shortened Dental Arch study (RaSDA): design and protocol. *Trials*. 2010;11:15.
 32. McKenna G, Allen F, Woods N, O'Mahony D, Cronin M, DaMata C *et al*. Cost-effectiveness of tooth replacement strategies for partially dentate elderly: a randomized controlled clinical trial. *Community Dent Oral Epidemiol*. 2014;42:366–374.
 33. Yoshida T, Masaki C, Komai H, Misumi S, Mukaibo T, Kondo Y *et al*. Changes in oral health-related quality of life during implant treatment in partially edentulous patients: a prospective study. *J Prosthodont Res*. 2016;60:258–264.
 34. Furuyama C, Takaba M, Inukai M, Mulligan R, Igarashi Y, Baba K. Oral health-related quality of life in patients treated by implant-supported fixed dentures and removable partial dentures. *Clin Oral Implants Res*. 2012;958–962.
 35. Wolfart S, Moll D, Hilgers RD, Wolfart M, Kern M. Implant placement under existing removable dental prostheses and its effect on oral health-related quality of life. *Clin Oral Implants Res*. 2013;24:1354–1359.
 36. Gates WD 3rd, Cooper LF, Sanders AE, Reside GJ, De Kok LJ. The effect of implant-supported removable partial dentures on oral health quality of life. *Clin Oral Implants Res*. 2014;25:207–213.
 37. Gonçalves TM, Campos CH, Garcia RC. Effects of implant-based prostheses on mastication, nutritional intake, and oral health-related quality of life in partially edentulous patients: a paired clinical trial. *Int J Oral Maxillofac Implants*. 2015;30:391–396.
 38. Campos CH, Gonçalves TM, Garcia RC. Implant-supported removable partial denture improves the quality of life of patients with extreme tooth loss. *Braz Dent J*. 2015;26:463–467.
 39. van Eekeren PJ, Aartman IH, Tahmaseb A, Wismeijer D. The effect of implant placement in patients with either Kennedy class II and III on oral health-related quality of life: a prospective clinical trial. *J Oral Rehabil*. 2016;43:291–296.
 40. Jensen C, Raghoebar GM, Kerdijk W, Meijer HJ, Cune MS. Implant-supported mandibular removable partial dentures; patient-based outcome measures in relation to implant position. *J Dent*. 2016;55:92–98.
 41. Peršić S, Kranjčić J, Pavičić DK, Mikić VL, Čelebić A. Treatment outcomes based on patients' self-reported measures after receiving new clasp or precision attachment-retained removable partial dentures. *J Prosthodont*. 2017;26:115–122.
 42. Awad MA, Rashid F, Feine JS. Overdenture Effectiveness Study Team Consortium. The effect of mandibular 2-implant overdentures on oral health-related quality of life: an international multicentre study. *Clin Oral Implants Res*. 2014;25:46–51.
 43. Fujimaki N, Fueki K, Igarashi Y. A questionnaire study of Japanese dentists' perceptions of risks for overeruption of molars without antagonists and attitude on prosthetic intervention. *Prosthodont Res Pract*. 2007;6:246–252.

Correspondence: Kazuyoshi Baba, Department of Prosthodontics, Showa University, 2-1-1 Kitasenzoku, Ohta-ku Tokyo, 145-8515 Tokyo, Japan.
E-mail: kazuyoshi@dent.showa-u.ac.jp