Clinical Oral Investigations
https://doi.org/10.1007/s00784-018-2522-y

REVIEW

Biological complications of removable dental prostheses in the moderately reduced dentition: a systematic literature review

Ovidiu Moldovan[1,2] · Heike Rudolph[1] · Ralph G. Luthardt[1]

Received: 3 May 2017 / Accepted: 11 June 2018

Abstract

Objectives The aim of the present study was a systematic review and subsequent meta-analysis on biological complications of removable prostheses in the moderately reduced dentition.

Materials and methods A systematic literature search in established medical databases (MEDLINE, EMBASE, BIOSIS, SciSearch, Cochrane, FIZ Technik Web) and a hand search of relevant dental journals was conducted. The search terms were relevant MeSH terms, free search terms, and combinations of the two. The search included randomized controlled trials, prospective and retrospective studies with data on biological complications of removable dental prostheses in the moderately reduced dentition with at least 15 participants, an observation period of at least 2 years, and a drop-out rate of less than 25%. The selection of relevant publications was carried out at the title, abstract, and full-text level by at least two of the authors involved. The publications included were tabulated and analyzed.

Results Of the original 12,994 matches, 1923 were analyzed by title, 650 by abstract, and 111 according to the full text. A total of 42 publications were ultimately included. The following parameters were evaluated.

Tooth loss Results varied, depending on the observation period, between 0 and 18.1% for clasp-retained removable dental prostheses (RDPs), between 5.5 and 29% for attachment-retained RDPs, and between 5.5 and 51.7% for double crown-retained RDPs.

Caries Results varied, depending on the observation period, between 0 and 32.7% for clasp-retained RDPs, between 1.8 and 29% for attachment-retained RDPs, and between 1.8 and 16.4% for double crown-retained RDPs.

Endodontic treatment Results varied, depending on the observation period, between 3.5 and 19.2% for clasp-retained RDPs, between 6.9 and 16.4% for attachment-retained RDPs, and between 0.6 and 13.9% for double crown-retained RDPs.

Tooth fracture Results varied, depending on the observation period, between 1.7 and 5.3% for clasp-retained RDPs, between 12.7 and 40% for attachment-retained RDPs, and between 0.4 and 4.4% for double crown-retained RDPs.

Tooth mobility There were no changes or improvements for clasp-retained RDPs. The better the pre-treatment and supportive care is, the smaller the differences are. For double crown-retained RDPs, a slight increase was found in one study. The results for the parameters probing depth and radiological bone loss were inconclusive.

Gingival recession Gingival recession seemed to be favored by a mandibular sublingual bar. Compared to fixed restorations, removable restorations seemed to be associated with a more pronounced need for dental treatment. Stringent pre-treatment and supportive care reduced the complication rates.

Conclusions Heterogeneous study designs and data analyses rendered a meta-analysis impossible, so that an evaluation at the highest level of evidence could not be performed.

Clinical relevance Within the limitations of this study, it would be correct to state that removable dental prostheses require intensive maintenance. Suitable pre-treatment and supportive care can lower the complication rates, in the absence of which they constitute trigger factors for (additional) biological complications.

✉ Ovidiu Moldovan

[1] Department of Prosthetic Dentistry, Center of Dentistry, University of Ulm, Albert-Einstein-Allee 11, 89081 Ulm, Germany

[2] Augsburg, Germany

Published online: 29 June 2018

Keywords RDP · Removable dental prosthesis · Removable partial denture · Biological complications · Systematic review · Meta-analysis

Introduction

Removable dental prostheses (RDPs) are still the most common form of treatment of the reduced, seriously compromised dentition. One treatment goal, in addition to restoring the patient's function and esthetics, is to prevent further damage to the masticatory system. However, scientific publications on this topic provide conflicting results.

Numerous studies attest to common biological complications of RDP or a faster deterioration of the patient's health compared to rehabilitation with fixed dental prostheses (FDPs) or even to non-treatment. High abutment loss rates [1–5], high caries rates [2, 6], higher plaque and gingival indices [2, 7], more pronounced attachment loss [8], stomatitis [9], or an exacerbation of TMD symptoms [2] have been reported.

Other authors, however, saw no differences or reported improvements. Walter [10] found no significant differences in abutment loss rates between attachment-retained FDP and the shortened dental arch. Kapur [11, 12] detected no difference in the development of periodontal parameters. Bergman [13] did not see any changes in periodontal parameters at 25 years in a group of clasp-retained RDP wearers, either. Akaltan [14] even reported a significant reduction in attachment loss at 2.5 years in two patient groups with RDPs designed with lingual plates or with bars.

The frequent reports of complications related to RDPs have resulted in a more restrictive indication from a scientific perspective. Fixed restorations are currently considered the treatment of choice for the partially edentulous jaw, and the range of indications for this treatment has been considerably expanded through the use of dental implants. Nevertheless, removable prostheses are still frequently provided, especially if cost or general medical reasons do not allow the use of fixed restorations. The primary underlying reasons of tooth loss and their modulatory effect on any type of therapy are often analyzed insufficiently.

The aim of the present article was to evaluate the biological complications associated with removable prostheses in the moderately reduced dentition based on a systematic literature review. A meta-analysis was planned to be performed wherever possible, based on the PRISMA checklist [15].

Material and methods

Eligibility criteria

The search strategy has already been described in detail in a previous publication [16]. The present review included single- or multi-arm longitudinal studies on treatment options for the moderately reduced dentition with one or more groups of removable restorations and an observation period of at least 2 years. Another requirement was a residual dentition with at least three teeth. All retentive elements were taken into account. The selected publications were classified according to their level of evidence. Randomized controlled trials (RCTs) and prospective and retrospective controlled clinical trials were considered.

While the above publication included only studies of the survival rates of removable prostheses, the central inclusion criterion for the present article was the presence of data on time-related biological failure or complication rates. Both articles with data on restorative survival rates and biological complications and articles with information on biological complications but without survival rates were considered.

Exclusion criteria were as follows:

- Number of cases less than 15
- Observation period less than 2 years
- Drop-out rate higher than 25%; retrospective studies that examined only part of an initially defined population were not excluded
- Studies on full-arch restorations, overdentures (telescopic complete dentures/resilient telescopic dentures), simple acrylic dentures (interim dentures), and implant-supported prostheses
- Case reports
- Pilot studies
- Abstract publications
- Studies without an adequate definition of their inclusion or failure criteria.

Study selection and data collection process

The initial selection of articles found was performed out generously ("if in doubt, leave it in") on a title and abstract level by at least two independent authors (reviewers) independently, based on the eligibility criteria. The full text of all potentially relevant publications was retrieved and analyzed, also by at least two authors independently. The final decision about the inclusion or exclusion of an article was made in consensus sessions. The included publications were tabulated by one of the authors (OM), analyzed and checked by the co-authors.

The following biological parameters were evaluated:

- Tooth loss
- Caries
- Endodontic treatment
- Tooth fracture
- Tooth mobility
- Probing depth
- Radiological bone loss
- Gingival recession
- Other parameters or biological complications such as oral hygiene (plaque index), inflammatory conditions (gingival index), and temporomandibular disorders
- Information on pre-treatment and supportive care was also included (Table 1).

Results

Study selection

The electronic search yielded 12,994 matches, of which 7543 remained after removing duplicates either automatically or manually. The manual search found 368 results, of which 158 remained after removing duplicates. Of the 7701 matches, 1923 were included by title and analyzed at the abstract level. Of these, 650 were retrieved as full-text versions. After excluding publications that were obviously not pertinent, 111 were analyzed in the context of several consensus sessions. Of these, 42 met the inclusion criteria (Fig. 1).

Study characteristics

Study design

The included trials were 10 randomized controlled trials (of which 5 multicenter) as well as 9 prospective and 23 retrospective trials, published in English (38) or German (4). In the case of randomized controlled trials, blinding was not possible for the treatment being performed. The observation periods in the studies varied between 2 and 25 years. The treatments were performed mainly at universities but also in military hospitals, both by dentists and by dental students under supervision.

Several studies were multiple publications following the same group of patients over several years. This was the case for the working groups of Bergman [8, 13, 17, 18], Bergman [19, 20], Budtz-Jørgensen and Isidor [2, 9, 21, 22], Jepson and Thomason [1, 6], and Walter [10, 23]. Or different parameters were analyzed for the same patient group: Budtz-Jørgensen and Isidor [2, 9, 21, 22], Jepson and Thomason [1, 6], Walter and Wolfart [10, 24], Witter [25, 26], and Wöstmann and Rehmann [27, 28].

Participants

All study participants had partially edentulous jaws requiring restorative treatment. Especially where the study design provided comparisons with fixed restorations or a shortened dental arch or where attachment RDPs were investigated, a unilaterally or bilaterally shortened dental arch was usually present. Exclusion criteria were defined only in seven instances and were meant to reduce the surgical risk in the studies involving implant therapy or to safeguard adequate compliance (general health, diet, no mental illness, no substance abuse, etc.).

Prosthetic treatment

The study designs varied greatly. Some studies examined individual types of prostheses, sometimes with different designs, while others compared groups of differently retained restorations (clasps, double crowns, attachments). Others compared removable prostheses with different types of retention with fixed restorations or with the concept of the shortened dental arch (Table 2).

Parameters examined

The parameters analyzed depend on the publication and were not uniformly defined (Table 1). The same is true for any information on pre-treatment or supportive care. For this reason, a meta-analysis is not feasible. Rather, time-related complications of certain therapies are often not apparent from the precarious data or are based on only a few publications with different levels of evidence. The individual parameters are therefore descriptively summarized below as stated by the authors.

Evaluation of individual parameters

Tooth loss

RDP/clasps

One tooth (3.8%) was lost with clasp-retained RDPs at 2 years, compared to no tooth for FDPs, in the study by Budtz-Jørgensen [9].

Table 1 Biological complications

	Biological complications						
	Abutment loss	Tooth loss	Tooth loss in the restored jaw	Caries	Endodontic treatment	Tooth fracture	Tooth mobility
2 years							
RDP/clasps		1 (3.8%) (Budtz-Jørgensen, 1987)		2 (7.1%) for CoCr RDPs (Au, 2000); 51 (32.7%) (Jepson, 2001); primary and secondary dental caries 22 (84%) (Budtz-Jørgensen, 1987)	2 (7.7%) (Budtz-Jørgensen, 1987)	1 (5.3%) for Ti RDPs (Au, 2000); 3 (1.9%) (Jepson, 2001)	Significantly higher in RDPs with lingual bar than lingual plate; significant reduction at 2.5 years (Akaltan, 2005); significant decrease in the RDP group compared to control (Bergman, 1971); slight decrease (Isidor, 1987)
RDP/attachments	3 (5.5%) (Heydecke, 2003)			1 (1.8%) (Heydecke, 2003)	9 (16.4%) (Heydecke, 2003)	7 (12.7%) (Heydecke, 2003)	
RDP/double crowns (conical)							
RDP/double crowns (telescopic)							
RDP/double crowns (electroplated)							
FDP/shortened arch		0 (Budtz-Jørgensen, 1987)		6.6% (Jepson, 2001); primary and secondary dental caries 2 (7.4%) (Budtz-Jørgensen, 1987)	1 (3.7%) (Budtz-Jørgensen, 1987)	0.6% (Jepson, 2001)	
3 years							
RDP/clasps	5.8% (Rehmann, 2013)	5 (2.4%) (Bergman, 1989)		31 of 436 intact surfaces (7.1%), 0.9 surfaces per patient over 3 years, more surfaces in contact to RDP but not significant; 26 of 422 (6.2%) restored surfaces, 0.8 surfaces per patient over 3 years, more surfaces in contact to RDP but not significant (Bergman, 1986)			Slightly better results for the 14 patients with regular check-ups; differences are small, probably because of good initial instructions, and might increase with time (Bergman, 1989)
RDP/attachments		13 (17%) (Walter, 2010)	5 (6.5%) (Walter, 2010)				
RDP/double crowns (conical)	3 (2,7%) (Stober, 2012); 3 (3%) (Ericson, 1990)			6.2% of surfaces (Ericson, 1990)	3 (2.7%) (Stober, 2012)		Small increase (Ericson, 1990)

Table 1 (continued)

	Biological complications						
	Abutment loss	Tooth loss	Tooth loss in the restored jaw	Caries	Endodontic treatment	Tooth fracture	Tooth mobility
RDP/double crowns (telescopic)	7 % (Mock, 2005); 4% for RDPs, 13% for coverdentures (Mock, 2005)						
RDP/double crowns (electroplated)	4 (3.8%) (Stober, 2012)				3 (2.8%) (Stober, 2012)		
FDP/shortened arch		9 (14%) (Walter, 2010)	5 (7.8%) (Walter, 2010)	3 (1.2%) for resin-bonded FDPs (Besimo, 1997)			Decrease in mobility of abutments and neighboring teeth (Besimo, 1997)
5 years							
RDP/clasps	5 (0.87%) (Kapur, 1994); 7 (30%) (Budtz-Jørgensen, 1990); 5 (5.1%) (Kapur, 1989); 13.7% (Tada, 2013)	7 of 30 (23%) remakes necessary due to tooth loss, 8 of 30 prostheses were not worn (26.6%) (Thomason, 2007); 1.04% for non-abutment teeth (Kapur, 1994); 11 (5.9%) (Budtz-Jørgensen, 1990); 11 (5.9%) (Isidor, 1990); 4.4% loss of non-abutment teeth (Tada, 2013)		No significant increase in tooth decay for two RDP/clasp designs (Kapur, 1994); significantly higher caries rates in the RDP group (234%) compared to the FDP group (37%) (Budtz-Jørgensen, 1990)	5 (19.2%) (Budtz-Jørgensen, 1990)	3 abutment teeth, 2 non-abutment teeth (19.2% of RDPs) (Budtz-Jørgensen, 1990)	No change over 5 years (Kapur, 1994): slight yet statistically significant decrease (Isidor, 1990)
RDP/attachments		46 (26%) (Walter, 2013)	18 (12%) (Walter, 2013)	2 (10%) in bilateral RDP group (Schmitt, 2011)		4 (20% of RDPs) of non-splinted abutment teeth in bilateral RDP group and 1 (12,5% of RDPs) in unilateral RDP group (Schmitt, 2011)	
RDP/double crowns (conical)	30 (6,7%) (18 vital, 12 non-vital) (Piwowarczyk, 2007); 49%, significantly fewer molars lost than other tooth types (endodontically treated with posts) (Wegner, 2006)				3 (0,6%) (Piwowarczyk, 2007)		Increase of 0.15 units per year (Piwowarczyk, 2007)
RDP/double crowns (telescopic)	66 (3.8%) higher risk of loss in patients with no follow-up and fewer teeth (Wöstmann, 2007); 6% (Wenz, 2001); 66 of 1758 (3.8%) (Rehmann, 2006); at 43 (5%) significantly more losses in the maxilla (Nickenig, 1995)			1.2% (Nickenig, 1995)	6% (Wenz, 2001); 3.3% (Nickenig, 1995)	4.4%, with no differences related to root fillings, for all double crowns (Dittmann, 2008); 0.4% (Nickenig, 1995)	
RDP/double crowns							

Table 1 (continued)

	Biological complications						
	Abutment loss	Tooth loss	Tooth loss in the restored jaw	Caries	Endodontic treatment	Tooth fracture	Tooth mobility
(electroplated)							
FDP/shortened arch	0 teeth and 19 blade implants (17.3%) (Kapur, 1989); 1 (3.7%) (Budtz-Jørgensen, 1990)	28 (26%) (Walter, 2013)	12 (16%) (Walter, 2013)	Significantly higher caries rates in the RDP group (234%) compared to the FDP group (37%) (Budtz-Jørgensen, 1990)	2 (7.7%) (Budtz-Jørgensen, 1990)	2 (7.7%) abutment teeth (Budtz-Jørgensen, 1990)	
6 years							
RDP/clasps				Of 21 caries lesions, 11 were in contact with the RDP surface, 10 were not (21 patients with no caries, 7 patients with 21 caries lesions) (25% of patients) (Bergmann, 1977)	1 (3.5%) (Bergman, 1977)		Slight decrease (Bergman, 1977)
RDP/attachments	18 (Studer, 1998)	73 (Studer, 1998)		21 with caries (Studer, 1998)	5 (Studer, 1998)	29 (Studer, 1998)	
RDP/double crowns (conical)	7 (8.9%) (Bergman, 1996)	34 (8.8%), 20% of root-filled teeth and 5.7% of the vital teeth, posterior, 13.6% and anterior, 5.3% for all double crowns (Dittmann, 2008)		56 of 312 surfaces (18%); 2.5%–3% per year (Bergman, 1996)	1 (1.3%) (Bergman, 1996)	3 (3.8%) (Bergman, 1996)	Increase (Bergman, 1996)
RDP/double crowns (telescopic)							
RDP/double crowns (electroplated)							
FDP/shortened arch							
10 years							
RDP/clasps	1 (0.5%) (Bergman, 1982)	3 (1.5%) (Bergman, 1982)		45 (5.6%) secondary caries in abutment teeth; 55 of 369 surfaces (15%) renewed because of secondary caries (Bergman, 1982)	7 (3.5%) (Bergman, 1982)		No changes evident (Bergman, 1982)
RDP/attachments	24 (29%) (Müller, 2013)						
RDP/double crowns (conical)	16 (41%) (Wagner, 2000); 15 (51.7%) when combined with clasp-retained RDPs;			16.4% for zinc-oxide cement and 13.5% for glass-ionomer cement (of all prostheses);	81.6% for zinc oxide dement and		

Table 1 (continued)

	Biological complications						
	Abutment loss	Tooth loss	Tooth loss in the restored jaw	Caries	Endodontic treatment	Tooth fracture	Tooth mobility
	prostheses designed with one supporting point lost significantly more abutment teeth (Wagner, 2000)			non-significant differences for all double crowns (Behr, 2009); 2 (11.1%) (Wagner, 2000); 7 (63%) when combined with clasp-retained RDPs; abutment teeth lost twice as often as non-abutment teeth (Wagner, 2000)	87.2% for glass--ionomer cement (of all prostheses), non--significant differences for all double crowns (Behr, 2009)		
RDP/double crowns (telescopic)	18% (Wenz, 2001); 33 (32%) (Müller, 2013)				8% (Wenz, 2001)		
RDP/double crowns (electroplated)							
FDP/shortened arch	13 (12%) (Müller, 2013)						
25 years							
RDP/clasps	3 (2.5%) (Bergman, 1995)	5 (4.2%) (Bergman, 1995)			8 (6.7%) (Bergman, 1995)	2 (1.7%) (Bergman, 1995)	No changes evident over 25 years (Bergman, 1995)

	Biological complications					
	Probing depth	Radiological bone loss	Gingival recession	Other	Pre-treatment	Supportive therapy
2 years						
RDP/clasps	Significant reduction after 2.5 years, no difference by RDP design (Akaltan, 2005); no significant difference at 2 years (Bergman, 1971); no changes (Isidor, 1987)	Significant attachment loss distal of the abutment teeth (Bergman, 1971); no attachment level loss (Isidor, 1987)	1 for Ti RDPs (5.3%) and 1 for CoCr RDPs (3.6%) (Au, 2000); significantly higher in RDPs with lingual bars than in RDPs with lingual plates (Akaltan, 2005)	Caries rates in the FDP group: 14% for non-abutment and 9% for abutment teeth, and in the RDP group, 14% and 60%, mostly root caries (Jepson, 2001); significantly higher gingival index in RDPs with lingual plates than in RDPs with lingual bars and significant reduction of attachment loss at 2.5 years in	Oral hygiene instructions (Au, 2000); oral hygiene instruction, conservative and periodontal pre-treatment (Jepson, 2001); periodontal pre-treatment (Akaltan, 2005); restoration of caries lesions, endo and perio treatment (Budtz-Jørgensen, 1987; Isidor, 1987)	1, 6, 12, 24 months (Au, 2000); yearly (Jepson, 2001); every 6 months (Akaltan, 2005); 1–2 months after baseline, then after 6, 12, 18, 24 months (Budtz-Jørgensen, 1987; Isidor, 1987) 1, 6, 12, 24 months (Au, 2000); yearly (Jepson, 2001); every 6 months (Akaltan, 2005); 1–2 months after baseline, then

Table 1 (continued)

	Biological complications					
	Probing depth	Radiological bone loss	Gingival recession	Other	Pre-treatment	Supportive therapy
				both RDP design groups (Akaltan, 2005); denture-induced stomatitis in 18 cases (69%), denture ulcers in 19.2%, irritation from sublingual bars in 8 (30%); TMD significantly aggravated and gingival indices and caries higher and oral mucosa lesions more frequent in the RDP than in the FDP group; need for dental treatment more pronounced in the RDP than in the FDP group (Budtz-Jørgensen, 1987); plaque index significantly higher in the RDP than in the FDP group, especially on proximal surfaces in contact with RDP (Isidor, 1987)		after 6, 12, 18, 24 months (Budtz-Jørgensen, 1987; Isidor, 1987) 1, 6, 12, 24 months (Au, 2000); yearly (Jepson, 2001); every 6 months (Akaltan, 2005); 1–2 months after baseline, then after 6, 12, 18, 24 months (Budtz-Jørgensen, 1987; Isidor, 1987)
RDP/attachments	Increase in 2 teeth (3.6%) (Heydecke, 2003)			Tooth migration 2 (3.6%) (Heydecke, 2003)	Oral hygiene instructions (Besimo, 1997); comprehensive pre-treatment (Heydecke, 2003)	Recall every 6 months (Besimo, 1997); clinical examinations at 6, 12, 24, 60 months (Heydecke, 2003)
RDP/double crowns (conical)						
RDP/double crowns (telescopic)						
RDP/double crowns (electroplated)						
FDP/shortened arch				Caries in FDP group, 14% for non-abutment and 9% for abutment teeth, in the RDP group, 14% and 60%, respectively, mostly root caries (Jepson, 2001); denture-induced stomatitis, 15 (55%); denture ulcers, 2 (7.4%) (Budtz-Jørgensen, 1987)	Oral hygiene instructions, conservative and periodontal pre-treatment (Jepson, 2001)	Yearly (Jepson, 2001)
3 years						
RDP/clasps	Slightly better results for the 14 patients with regular check-ups; differences are small, probably because of good initial instructions, and might increase with time (Bergman, 1989)			Slightly better results for gingiva and plaque indices for the 14 patients with regular check-ups; differences are small, probably because of good initial instructions, and might increase with time (Bergman, 1989);	Instructions for and control of oral hygiene (Bergman, 1989)	Yearly appointments recommended, less than 50% compliance (Bergman, 1989); recalls offered, less than 50% accepted (Rehmann, 2013)

Table 1 (continued)

	Biological complications					
	Probing depth	Radiological bone loss	Gingival recession	Other	Pre-treatment	Supportive therapy
				Lactobacilli, S. mutans, saliva flow rate, and buffer alone did not correlate with the number of caries lesions; when combined, tendency to correlate with number of caries lesions (Bergman, 1986); no significant difference for combined sites between survival of bounded edentulous spaces in untreated and RDP groups; significant difference between untreated and RDP compared to FDP groups (Shugars, 1998); mandibular RDPs have significantly better survival rates than maxillary RDPs (Rehmann, 2013)		
RDP/attachments					yes, pockets ≤ 4 mm, BOP < 25% (Walter, 2010) yes, pockets ≤ 4 mm, BOP < 25% (Walter, 2010) yes, pockets ≤ 4 mm, BOP < 25% (Walter, 2010)	No data; control after 1, 2, 6 months, 1, 2, 3 years (Walter, 2010) No data; control after 1, 2, 6 months, 1, 2, 3 years (Walter, 2010) No data; control after 1, 2, 6 months, 1, 2, 3 years (Walter, 2010)
RDP/double crowns (conical)				50% minor inflammation of the mucosa; improvement of PI and GI, small attachment loss, 50% improvement of chewing ability (Ericson, 1990)	Pre-treatment with special regard to periodontal care and caries control (Ericson, 1990)	Necessary treatments and repeated information (Ericson, 1990) Necessary treatments and repeated information (Ericson, 1990) Necessary treatments and repeated information (Ericson, 1990)
RDP/double crowns (telescopic)	Increase in probing depths (from 2.0 to 2.7 mm) (Mock, 2005)			Increase in sulcular bleeding index, 8 (8.7%) prosthesis-induced stomatitis (Mock, 2005)		
RDP/double crowns (electroplated)				Risk of loss of non-vital abutments increased 6.7-fold, highest risk for premolars and molars, followed by anterior teeth (Stober, 2012)		
FDP/shortened arch					yes, pockets ≤ 4 mm, BOP < 25% (Walter, 2010); oral hygiene instructions (Besimo, 1997) yes, pockets ≤ 4 mm, BOP < 25% (Walter, 2010); oral hygiene instructions (Besimo, 1997) yes, pockets ≤ 4 mm, BOP < 25% (Walter, 2010); oral hygiene instructions (Besimo, 1997)	n.d.; control after 1, 2, 6 months, 1, 2, 3 years (Walter, 2010); recall every 6 months (Besimo, 1997) n.d.; control after 1, 2, 6 months, 1, 2, 3 years (Walter, 2010); recall every 6 months (Besimo, 1997) n.d.; control after 1, 2, 6 months, 1, 2, 3 years (Walter, 2010); recall every 6 months (Besimo, 1997)
5 years						

Table 1 (continued)

	Biological complications					
	Probing depth	Radiological bone loss	Gingival recession	Other	Pre-treatment	Supportive therapy
RDP/clasps	No progression of periodontal disease around abutment teeth (Budtz-Jørgensen, 1990); no changes (Isidor, 1990)	No changes in bone height (Kapur, 1994)	Slight but significant increased incidence of lingual recessions (Kapur, 1994)	No significant changes in oral hygiene, gingival inflammation, or bone progression (Kapur, 1994); significantly more TMD symptoms in the RDP group at 1 year, significant deterioration in occlusal stability, higher plaque indices in the RDP than in the FDP group (Budtz-Jørgensen, 1990); slight and not significant deterioration in periodontal parameters in both groups over 5 years (Kapur, 1989); plaque index higher in the RDP group, but only the first 2 years were statistically significant, significantly higher plaque index on proximal surfaces in contact with RDPs, gingival index higher in the RDP group, small and non-significant attachment loss (Isidor, 1990); multivariate analysis showed higher hazard ratios regarding abutment survival for: crown-root ratio <1.0/1.0–1.5/> 1.5 3.13; root-canal treatment, 2.93; pocket probing depth, 2.51; abutment type, 2.19; occlusal support, 1.9 (Tada, 2013)	Oral hygiene instructions, conservative and periodontal pre-treatment (Thomason, 2007;) standardized plaque control instructions at three visits (Kapur, 1994); no information (Budtz-Jørgensen, 1990); no information except endo treatment with extraradicular posts and conical double crowns in RDP (Wegner, 2006); caries, endo and perio treatment (Isidor, 1990)	Reviews 3 months and 1 year after insertion, then yearly, additional maintenance appointments as clinically required (Thomason, 2007); dental check-up and oral prophylaxis every 6 months (Kapur, 1994); yearly review (Budtz-Jørgensen, 1990); every 6 months (Wegner, 2006); 1-2 months after treatment as "baseline", then recalls at 6, 12, 18, 24 months (Isidor, 1990)
RDP/attach-ments	No increase in abutment teeth (Schmitt, 2011)			Plaque index and sulcus bleeding index decreased significantly (Schmitt, 2011); no significant difference between tooth loss in RDP and shortened arch groups (Walter, 2013)	No information (Schmitt, 2011); probing depth ≤ 4 mm, bleeding on probing < 25% (Wolfart, 2012; Walter, 2013)	Annual follow-ups (Schmitt, 2011); follow-ups at 6 months, then yearly (Wolfart, 2012; Walter, 2013)
RDP/double crowns (conical)	No significant changes (Piwowarczyk, 2007)	Increase of 0,02 units per year (Piwowarczyk, 2007)		Significantly lower survival rates for teeth with posts with RDPs than FDPs; direct post-and-core restorations (84.5%) had significantly better survival rates than restorations with posts and cast cores (43.4%); significant better prognoses for teeth with ISO 90 than ISO 50 or ISO 110 posts and for posts luted adhesively (Panavia) compared to zinc oxide and glass-ionomer	No information (Piwowarczyk, 2007)	No information (Piwowarczyk, 2007)

Table 1 (continued)

	Biological complications					
	Probing depth	Radiological bone loss	Gingival recession	Other	Pre-treatment	Supportive therapy
				cement; and significant better survival rates of vital compared to non-vital teeth in RDPs and no difference in FDPs (Wegner, 2006)		
RDP/double crowns (telescopic)				90% survival probability for the abutment teeth was 6.9 years (Rehmann, 2006); 25% needed periodontal therapy (Nickenig, 1995)	No information (Wenz, 2001; Dittmann, 2008); oral hygiene program (Wöstmann, 2007)	No information (Wenz, 2001; Dittmann, 2008); recall every 12 months; 5.3% higher risk for RDPs to cease function in patients not in follow-up (97.3% and 81.7% RDP survival with and without follow-up, respectively) (Wöstmann, 2007); half of the patients once a year, the other half irregularly (Nickenig, 1995)
RDP/double crowns (electroplated)						
FDP/shortened arch				Slight but non-significant deterioration of periodontal parameters in both groups over 5 years (Kapur, 1989); non-significant difference between tooth loss rates in RDP and shortened-arch groups (Walter, 2013)	No information (Budtz-Jørgensen, 1990): pocket depths ≤ 4 mm, bleeding on probing < 25% (Wolfart, 2012; Walter, 2013)	Yearly recalls (Budtz-Jørgensen, 1990) follow-up at 6 months, then yearly (Wolfart, 2012; Walter, 2013)
6 years						
RDP/clasps	Unchanged (Bergman, 1977)	Relative increase in height mesially and distally of 3% and 2%, respectively, in abutment teeth, compared to 3% and 5% in controls (Bergman, 1977)		Absence of molar support is not a risk factor for TMD, free-end RDPs (in the lower jaw) in the shortened arch did not prevent signs and symptoms of TMD, the shortened arch (3–5 occlusal units) provided sufficient oral comfort for a long-term period, free-end RDP (in the lower jaw) in the shortened arch did not improve oral comfort and were a frequent cause for re-treatment (Witter, 1994); decrease in gingival index while plaque index remained unchanged (Bergman, 1977); the shortened arch provided long-term occlusal stability, free-end RDPs did not contribute to occlusal stability in	Instruction, motivation, and control of oral hygiene procedures, complete conservative and surgical pre-treatment (Bergman, 1977)	2 weeks after the end of treatment (baseline), 3 months later to check oral hygiene, then yearly (Bergman, 1977)

Table 1 (continued)

	Biological complications					
	Probing depth	Radiological bone loss	Gingival recession	Other	Pre-treatment	Supportive therapy
				the shortened arch, shortened arches with periodontally Involved teeth showed continuing periodontal breakdown (Witter, 1994).		
RDP/attachments					Pre-treatment including perio treatment and reevaluation (Studer, 1998)	Regular recall sessions (Studer, 1998)
RDP/double crowns (conical)				Slight increase in plaque and bleeding indices; 50% speech problems, 50% improvement in chewing ability (Bergman, 1996)	No information (Dittmann, 2008); pre-treatment with special regard to periodontal care and caries control (Bergman, 1996)	No information (Dittmann, 2008); necessary treatments and repeated information (Bergman, 1996)
RDP/double crowns (telescopic)						
RDP/double crowns (electroplated)						
FDP/shortened arch						
10 years						
RDP/clasps	No changes evident (Bergman, 1982)			First retreatment of abutment teeth in 60% at 5 years and in 80% at 10 years (Vermeulen, 1996);	Instruction, motivation, and control of oral hygiene procedures, complete conservative and surgical pre-treatment (Bergman, 1982)	Check-up every 6 months (Vermeulen, 1996); 2 weeks after the end of treatment (baseline), 3 months later to check oral hygiene, then yearly (Bergman, 1982)
RDP/attachments				First retreatment of abutment teeth in 24%–41% at 5 years and in 52%–70% at 10 years (Vermeulen, 1996); Poisson regressions identified prosthodontic treatment, age, lower socioeconomic status, diabetes mellitus, mean initial bone loss, and aggressive periodontitis as factors that significantly contributed to tooth loss in general. Highly significant correlation between abutment tooth loss and loss of the entire restoration (Müller, 2013)	No information (Vermeulen, 1996)	Check-up every six months (Vermeulen, 1996)
RDP/double crowns (conical)				Poisson regressions identified prosthodontic treatment, age, lower socioeconomic status,	No information (Wagner, 2000; Behr, 2009)	No information (Wagner, 2000; Behr, 2009)

Table 1 (continued)

	Biological complications					
	Probing depth	Radiological bone loss	Gingival recession	Other	Pre-treatment	Supportive therapy
				diabetes mellitus, mean initial bone loss, and aggressive periodontitis as factors that significantly contributed to tooth loss in general. Highly significant correlation between abutment tooth loss and loss of the entire restoration (Müller, 2013)		
RDP/double crowns (telescopic)					No information (Wenz, 2001)	No information (Wenz, 2001)
RDP/double crowns (electroplated)						
FDP/shortened arch				Poisson regressions identified prosthodontic treatment, age, lower socioeconomic status, diabetes mellitus, mean initial bone loss, and aggressive periodontitis as factors that significantly contributed to tooth loss in general. Highly significant correlation between abutment tooth loss and loss of the entire restoration (Müller, 2013)		
25 years						
RDP/clasps	No changes evident over 25 years (Bergman, 1995)	No major changes (Bergman, 1995)		No changes evident in PI and GI (Bergman, 1995)	Instruction, motivation, and control of oral hygiene procedures, complete conservative and surgical pre-treatment (Bergman, 1995)	2 weeks after the end of treatment (baseline), 3 months later to check oral hygiene, then yearly; after 10 years, patients were advised to have yearly recalls on their own initiative (Bergman, 1995)

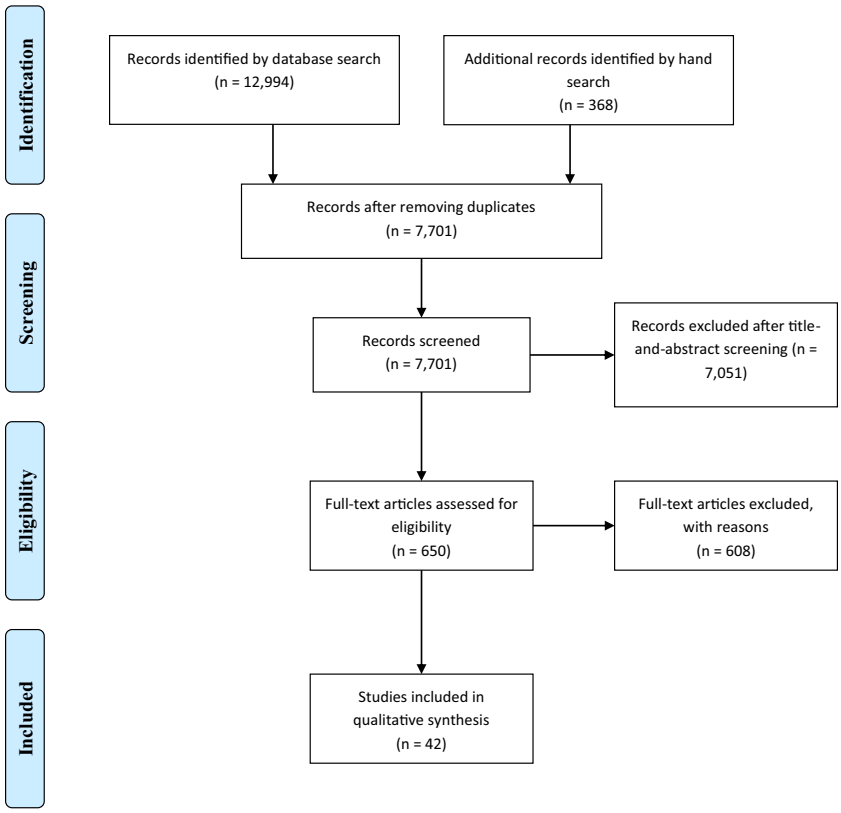


Fig. 1 Information flow

At 3 years, the number was five teeth (2.4%) in Bergman [20], and Rehmann reported a 5.8% abutment loss rate [29].

At 5 years, seven prostheses (23%) had to be replaced because of tooth loss in the study by Thomason [1]. In the study by Budtz-Jørgensen and Isidor, 11 teeth (5.6%) were lost, 7 of which were abutments [2, 22]. Kapur reported loss rates of 1.04% for non-abutment teeth and five lost abutment teeth (0.87%) [12]. Tada reported 13.7% abutment losses vs. 4.4% non-abutment losses. Multivariate analysis showed higher hazard ratios regarding abutment survival for crown-root ratio, 3.13; root canal treatment, 2.93; pocket probing depth, 2.51; abutment type, 2.19; and occlusal support, 1.9 [3].

Bergman reported three lost teeth (1.5%) and one lost abutment (0.5%) at 10 years [18].

At 25 years, the results were five lost teeth (4.2%) and three lost abutments (2.5%) in the same patient population [13].

RDP/attachments

For RDPs retained by attachments, Heydecke reported three lost abutments (5.5%) at 2 years [30].

At 3 years, 13 teeth (17%) were lost in the study by Walter, of which 5 (6.5%) in the treated jaw. By contrast, 9 teeth (14%) were lost in FDP/shortened arch group, of which 5 (7.8%) in the treated jaw [23].

At 5 years, the values were 26% lost, of which 12% in the treated jaw, for the RDP/attachments group, compared with 26%, of which 16% in the treated jaw, for the FDP/shortened arch group. There were no significant differences between the RDP and shortened arch groups [10].

Studer reported the loss of 73 teeth at 6 years, of which 29 (40%) due to fractures, 21 (29%) due to untreatable caries, 18 (25%) due to abutment extractions, and 5 (6%) due to endodontic complications [4].

Müller reported 24 lost abutments (29%) at 10 years [5].

RDP/double crowns

At 3 years, three abutment losses (2.7%) were reported for RDPs retained by conical double crowns [31], compared with 4% for telescopic [7] and 4 (3.8%) for electroplated [31] double crowns. Stober further reported a 6.7 times higher loss risk for non-vital abutments. The highest risk was found for premolars, followed by molars and anterior teeth [31].

At 5 years, 6.7% of conical telescopic abutments were lost in the study of Piwowarczyk, including 18 vital and 12 non-vital teeth [32]. For larger patient populations, abutment loss rates in telescopic double crown-retained RDPs were reported as 66 (3.8%) by Wöstmann [27] and Rehmann [28], 6% by Wenz [33], and 43 (5%) by Nickenig [34]. Wöstmann reported significantly higher loss rates in patients with fewer teeth

Table 2 Treatments investigated

Prosthodontic therapy	RDP/clasps	RDP/ attachments	RDP/double crowns (electroplated)	RDP/double crowns (conical)	RDP/double crowns (telescopic)	FDP/shortened arch
RDP/clasps	Au (2000) Akaltan (2005) Kapur (1994) Bergman (1971, 1977, 1982, 1986, 1989, 1995) Rehmann (2013) Tada (2013)					Kapur II (1989) Thomason (2007) Budtz-Jørgensen (1987, 1990) Isidor (1987, 1990) Jepson (2001) Witter (1994)
RDP/attachments	Vermeulen (1996)	Heydecke (2003) Schmitt (2011) Studer (1998)			Müller (2013)	Walter (2010, 2013) Wolfahrt (2012) Besimo (1997) Müller (2013)
RDP/double crowns (conical)			Stober (2012)	Ericson (1990) Bergman (1996) Behr (2009) Wegner (2006) Piwowarczyk (2007) Wagner (2000)		
RDP/double crowns (telescopic)					Dittmann (2008) Mock (2005) Nickenig (1995) Rehmann (2006) Behr (2009) Wenz (2001) Wöstmann (2007)	

and no follow-up, while Nickenig found significantly higher loss rates in the maxilla.

An analysis of the survival rate at 5 years of endodontically treated teeth in prostheses retained by conical double crowns showed significantly lower survival rates for teeth with endodontic posts under RDPs (51%) than under FDPs (92.7%). Direct post-and-core restorations (84.5%) exhibited significantly better survival rates than restorations with posts and cast cores (43.4%). Significant better prognoses were found for teeth with ISO 90 than ISO 50 or ISO 110 posts and for posts luted adhesively (Panavia; Kuraray, Osaka, Japan) compared to zinc-oxide cement and glass-ionomer cement. Significant better survival rates were reported for vital compared to non-vital teeth in RDPs, with no difference in FDPs [35].

Rehmann found for RDPs on telescopic double crowns that the 90% survival probability of the abutment teeth was 6.9 years [28].

At 6 years, Dittmann reported the loss of 34 teeth (8.8%) with telescopic double crown-retained RDPs. The loss rate among endodontically treated teeth was 20%, and among vital teeth, 5.7% [36].

At 10 years, 16 abutment teeth (41%) of RDPs retained strictly by conical double crowns were lost, compared to 15 (51.7%) for combination restorations that also featured clasps [37]. Abutment losses of 18% [33] and 33 (32%) [5] were reported for RDPs retained by telescopic double crowns.

FDP/shortened arch

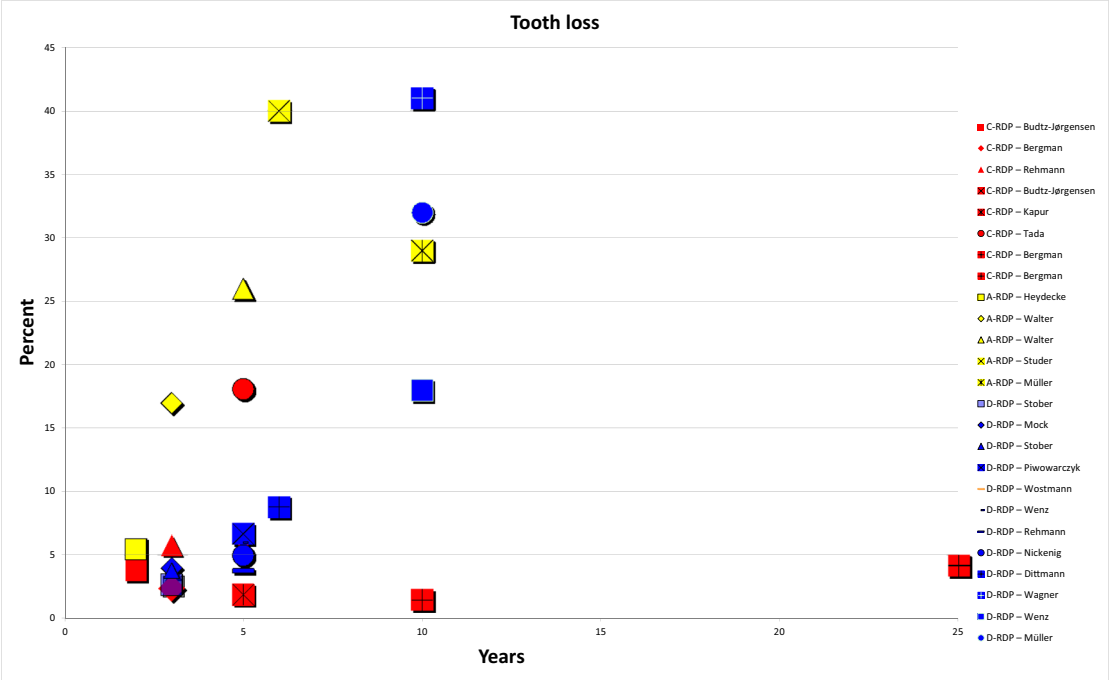
A study with an FDP/shortened arch arm used as controls reported zero loss rates at 2 years [9].

At 3 years, nine teeth (14%) were lost in the study by Walter, of which five (7.8%) in the treated jaw [23].

At 5 years, there were 28 lost teeth (26%), of which 12 (16%) in the treated jaw [10]. There were no significant differences between tooth loss rates in the RDP and shortened arch groups. Budtz-Jørgensen, by contrast, reported one lost tooth (3.7%) [2]. In the study by Kapur [11], no abutment teeth and 19 blade implants (17.3%) were lost. The introduction of rotationally symmetrical implants has led to a significant increase in healing rates, so that these values can no longer be considered representative of contemporary systems. Müller reported 13 abutment losses (12%) in the FDP group [5].

The tooth loss rates for all treatment modes have been summarized and visualized in a single graph (Table 3). For reasons of comparability, only those publications were listed where the tooth loss rates had been specified as a

Table 3 Tooth loss (dropouts not included—best-case calculation)



percentage of the total number of teeth or where that percentage could be calculated.

Caries

RDP/clasps

The results for clasp-retained RDPs varied significantly at 2 years. While Au [38] found two new caries lesions (7.1%) in the CoCrMo RDP group and none in the Ti RDP group, Jepson found 51 new lesions (32.7%) [6] and Budtz-Jørgensen 22 new lesions (11.3%) [9]. Jepson analyzes the caries by abutment and non-abutment teeth. While in the FDP group, the caries rate was 14% for non-abutment teeth and 9% for abutment teeth, in the clasp-retained RDP group, the figures were 14 and 60%, respectively, where most cases involved root caries.

Bergman counted the carious surfaces. At 3 years, there were 31 previously intact surfaces (7.1%) that had been affected by caries and 26 (6.2%) restored surfaces. The surfaces in contact with the RDP were more numerous, but this was not statistically significant. Neither *Lactobacilli* nor *S. mutans*, saliva flow rates, or buffer alone correlated with the number of caries lesions. When combined, they tended to correlate with the number of caries lesions [19].

At 5 years, Kapur found no significant increase in carious lesions in RDP/clasp groups with different designs [12]. By contrast, Budtz-Jørgensen reported a significant increase by 57 caries lesions (29.2%) in an RDP/clasp group compared to 10 lesions (5.3%) in an FDP group [2].

At 6 years, Bergman found 21 new lesions in 25% of the patients studied, 11 of which in contact and 10 not in contact with the prostheses [17].

At 10 years, there were 45 instances (5.6%) of secondary caries on abutment teeth and 55 of 369 surfaces renewed (15%) because of secondary caries [18].

RDP/attachments

In a group with attachment-retained RDP, Heydecke reported one new lesion (1.8%) at 2 years [30].

At 5 years, Schmitt found two new lesions (10%) in a group with bilateral attachment-retained prostheses and no new lesion in the unilateral group. However, 75% losses occurred in the unilateral group [39].

At 6 years, Studer observed 21 cases (29%) of new lesions [4].

RDP/double crowns

At 5 years, Nickenig found an increase in caries of 1.2% in a group of telescopic double crown-retained RDPs [34].

In conical double crown-retained prostheses, secondary caries was present at 10 years in 16.4% of patients with RDPs cemented with zinc-oxide cement and in 13.5% of patients with RDPs cemented with glass ionomer cement [40].

Wagner reported two new lesions (11.1%) in strictly double crown-retained RDPs and seven new lesions (63%) in wearers of such RDPs that also featured clasps. Abutment teeth were affected twice as frequently [37].

FDP/shortened arch

At 2 years, in the FDP groups, there were 11 new carious lesions (6.6%) in the study by Jepson [6] and 2 (7.4%) in the study by Budtz-Jørgensen [9].

At 3 years, there were three new lesions (1.2%) in the group of resin-bonded FDPs examined by Besimo [41].

At 5 years, Budtz-Jørgensen found a significantly lower caries rate (37%) in the same FDP population than in the CoCr group (234%) [2].

Endodontic treatment

RDP/clasps

At 2 years, there were two cases of endodontic treatments (7.7%) in the RDP/clasps group of Budtz-Jørgensen [9], and five cases (19.2%) at 5 years [2].

In the patient population followed by Bergman, there was one root canal treatment of an abutment tooth (0.5%) at 6 years [17], seven (4.1%) at 10 years [18], and eight (6.8%) at 25 years, of which five abutment teeth [13].

RDP/attachments

Heydecke reported nine cases (16.4%) at 2 years [30].

At 6 years, the study by Studer reported five cases (6.9%) [4].

RDP/double crowns

At 3 years, there were three cases of endodontic treatment each (2.7 and 2.8%, respectively) in the two groups of telescopic and electroplated double crown-retained RDPs observed by Stober [31].

At 5 years, the numbers were 3 (0.6%) for conical [32] and 25 (6%) [33] and 13 (3.3%), respectively, for telescopic [34].

At 10 years, endodontic treatment had been performed for 13.9% of RDPs cemented with zinc-oxide cement and 10.9% of RDPs cemented with glass-ionomer cement (or 81.6 and 87.2%, respectively, of the total of all prostheses!) [40]. Wenz reported 8% for telescopic double crown-retained RDPs [33].

FDP/shortened arch

At 2 years, there was one case of endodontic treatments (3.7%) in the FDP group of Budtz-Jørgensen [9]. The number at 5 years was two (7.7%) for the same population [2].

Tooth fracture

RDP/clasps

At 2 years, there was one (5.3%) tooth fracture in the titanium RDP/clasps group of Au [38], and three tooth fractures (1.9%) in the CoCrMo group of Jepson [6].

At 5 years, there were three abutment and two non-abutment fractures in the RDP/clasp group of Budtz-Jørgensen [2].

Bergman reported two tooth fractures (1.7%) at 25 years [13].

RDP/attachments

Heydecke reported seven fractures (12.7%) at 2 years [30].

In the RDP/attachments group of Schmitt, four non-splinted abutment teeth (20%) had fractured in bilateral group RDPs and one (12.5%) in unilateral group RDPs at 5 years [39].

At 6 years, there were 29 (40%) failures due to fractures of abutment teeth in the study by Studer [4].

RDP/double crowns

At 5 years, 4.4% of teeth had fractured in telescopic double crown-retained prostheses, with no difference regarding root fillings, in the study by Dittmann [36], and 0.4% in the study by Nickenig [34].

FDP/shortened arch

Jepson reported 0.6% fractures of abutment teeth at 2 years [6] and Budtz-Jørgensen reported two fractures (7.7%) at 5 years [2].

Tooth mobility

RDP/clasps

After 2 years of following clasp-retained prostheses, Akaltan [14] and Bergman [8] reported a significant decrease in tooth mobility (compared to the control group in the case of Bergman). Akaltan found a significantly higher tooth mobility in RDPs with lingual bars than in RDPs with lingual plates. Isidor [21] reported a slight decrease in the mobility of all teeth.

At 3 years, Bergman found slightly better results for the 14 patients with clasp-retained RDPs receiving regular check-ups. Differences were small, probably because of good initial instructions, and might increase with time [20].

At 5 years, there was no change in the RDP/clasps group of Kapur [12] while Isidor reported a slight but statistically significant decrease [22].

Bergman found a slight decrease in tooth mobility for clasp-retained prostheses at 6 years [17]. At 10 years, the same

patient population showed no evident changes [18] and still no apparent changes at 25 years [13].

RDP/double crowns

For conical double crown abutments, Piwowarczyk reported an increase of 0.15 units per year [32].

FDP/shortened arch

Isidor [21] reported a slight decrease in mobility of all teeth at 2 years. Besimo also found a decrease in tooth mobility of abutments and adjacent teeth fixed at 3 years in the group with resin-bonded FDPs [41].

Probing depth

RDP/clasps

After 2 years of follow-up of clasp-retained prostheses, Akaltan found a significant reduction in probing depths with no difference regarding RDP design [14]. In contrast, no significant difference was found by Bergman [8] or Isidor [21].

At 3 years, Bergman found slightly better results for the 14 patients with clasp-retained RDPs receiving regular check-ups. Differences were small, probably because of good initial instructions, and might increase with time [20].

At 5 years, the clasp-retained prostheses group followed by Budtz-Jørgensen and Isidor exhibited no progression of periodontal disease around abutment teeth [2, 22].

Comparing a group with clasp-retained prostheses with a group treated with fixed restorations on implants, Kapur found a slight and non-significant deterioration in periodontal parameters in both groups over 5 years [11].

Bergman found no changes in probing depth at 6 years [17]. At 10 years, the same patient population showed no evident changes [18] and still no apparent changes at 25 years [13].

RDP/attachments

In a group of attachment-retained RDPs, Heydecke found an increase in probing depth in two teeth (3.6%) [30]. At 5 years, Schmitt reported no increase in probing depth around abutment teeth of attachment-retained RDPs [39].

RDP/double crowns

For telescopic double crown abutments, Mock found an increase from 2.0 to 2.7 mm in probing depth at 3 years [7].

Piwowarczyk reported no significant changes for conical double crowns at 5 years [32].

Nickenig, by contrast, found that after 5 years in a telescopic double crown-retained prostheses group, 25% of abutments required periodontal therapy [34].

FDP/shortened arch

Comparing a group with clasp-retained prostheses with a group treated with fixed restorations on implants, Kapur found a slight and non-significant deterioration in periodontal parameters in both groups over 5 years [11].

Radiological bone loss

RDP/clasps

Bergman reported a significant attachment loss distally of the abutment teeth at 2 years [8] while Isidor found no attachment level loss [21].

At 5 years, Kapur also found no changes in bone height [12].

At 6 years, Bergman reported a relative increase in height mesially and distally of 3 and 2%, respectively, in abutment teeth in wearers of clasp-retained RDPs, compared to 3 and 5% in controls [17]. At 10 years, the same patient population showed no evident changes [18] and still no apparent changes at 25 years [13].

RDP/double crowns

For conical double crowns, Piwowarczyk found an increase of 0.02 units per year [32].

FDP/shortened arch

Isidor recorded no loss of attachment levels in either the removable or the fixed group at 2 years [21].

Gingival recession

RDP/clasps

At 2 years, Au found one case of gingival recession (5.3%) with titanium clasp-retained RDPs and one case (3.6%) with CoCrMo RDPs [38]. Akaltan found significantly higher tooth mobility in RDPs with lingual bars than in RDPs with lingual plates [14].

At 5 years, the RDP/clasps group of Kapur exhibited slight but significant increase in lingual recessions [12].

Other parameters or biological complications

Oral hygiene

Isidor found a significantly higher plaque index in the RDP compared to the FDP group, especially on proximal surfaces in contact with RDP, at 2 years [21]. Budtz-Jørgensen found for the same population that the gingival index was higher in the RDP group than in the FDP group [9]. Akaltan found a significantly higher gingival index in RDPs with lingual bars than in RDPs with lingual plates [14].

At 3 years, Bergman found slightly better results for gingiva and plaque indices for the 14 patients with clasp-retained RDPs receiving regular check-ups. Differences were small probably because of good initial instructions and might increase with time [20].

In telescopic double crown-retained RDPs, Mock found an increase in the sulcular bleeding index [7].

At 5 years, Kapur found no significant change of oral hygiene and gingival inflammation in wearers of clasp-retained RDPs [12]. In another study, he found a slight and non-significant deterioration in periodontal parameters over 5 years [11].

Budtz-Jørgensen, by contrast, found a higher plaque index in the RDP than in the FDP group, but only the first 2 years were statistically significant. Proximal surfaces in contact with RDPs have a significantly higher plaque index. The gingival index was also higher in the RDP group [2].

For wearers of attachment-retained RDPs, Schmitt reported that the plaque index and sulcus bleeding indices had decreased significantly at 5 years [39].

At 6 years, Bergman reported a decrease in the gingival index, while the plaque index remained unchanged for wearers of clasp-retained prostheses [17]. At 25 years, the same patient population exhibited no apparent changes in their plaque and gingival indices [13].

Other parameters

Budtz-Jørgensen found that after only 2 years, the need for dental treatment was more pronounced in the RDP than in the FDP group: denture-induced stomatitis, 18 (69%); denture ulcers, 5 (19.2%); and irritation caused by the sublingual bar, 8 (30%). TMD was significantly aggravated and oral mucosa lesions occurred more often in the RDP compared to the FDP group, while the FDP group exhibited only 15 cases of denture-induced stomatitis (55%) and 2 cases of denture ulcers (7.4%) [9].

For telescopic double crowns, there were eight cases (8.7%) of denture-induced stomatitis at 3 years in the study by Mock [7].

After 5 years of follow-up, Budtz-Jørgensen reported significantly more symptoms of TMD in the RDP group, which had occurred already at year 1, and a significant deterioration in occlusal stability [2],

At 6 years, Witter found in a prospective cohort study that the absence of molar support is not a risk factor for TMD for wearers of clasp-retained RDPs. Free-end RDPs (in the lower jaw) in the shortened dental arch did not prevent signs and symptoms of TMD. The shortened dental arch (three to five occlusal units) provided sufficient long-term oral comfort. Free-end RDPs (in the lower jaw) in the shortened dental arch did not improve oral comfort and were a frequent cause for re-treatment. The shortened dental arch provided long-term occlusal stability. Free-end RDPs did not contribute to occlusal stability in the shortened dental arch. Shortened dental arches periodontally involved teeth showed continuing periodontal breakdown [25, 26].

At the 10-year follow-up, Vermeulen found that the retreatment of abutment teeth had occurred at 5 years in 24 to 41% of cases and at 10 years in 52 to 70% of cases [42].

After 10 years of observation, Müller identified by Poisson regression prosthodontic treatments, age, lower socio-economic status, diabetes mellitus, mean initial bone loss, and aggressive periodontitis as factors that significantly contributed to tooth loss in general. There was a highly significant correlation between abutment tooth loss and total loss of the prosthetic reconstruction [5].

In a group of attachment-retained RDPs, Heydecke found two cases of tooth migration (3.6%) at 2 years [30].

Shugars analyzed the survival rate of bounded edentulous spaces in the posterior jaw after 3 years as a function of the treatment option selected: untreated, RDP, or FDP. For combined sites, no significant difference existed between the survival rates of bounded edentulous spaces in untreated and RDP groups but a significant difference did exist between the untreated and RDP groups compared to the FDP group [43].

Pre-treatment and supportive care

The details of individual publications are listed in Table 1.

The level of information on pre-treatment and supportive care varies greatly between the different publications.

For pre-treatment, there is some information on oral hygiene instructions with or without check-ups all the way to conservative and periodontal pre-treatments.

For supportive therapy, irregular, annual, or semi-annual recall intervals are reported.

Some authors did not offer any information on any pre-treatment or supportive care.

Wöstmann found a 5.3 times higher risk for RDPs to cease functioning in patients not participating in any follow-up [27].

Discussion

The aim of the present publication was to create a systematic review on the biological complications of removable dental restorations in the moderately reduced dentition and subsequent meta-analysis. The multiple therapeutic forms of removable dental prosthesis (clasp-retained, attachment-retained, or double crown-retained prostheses in their varying incarnations) as well as the heterogeneous and sometimes precarious data have made a meta-analysis impossible. For this reason, the analysis performed was exclusively descriptive in nature. The individual parameters were tabulated as a function of time and type of restoration and presented in graphic form wherever possible.

While in some cases, results from several publications with different evidence levels and patient populations have been available, evaluations of other parameters may be based on only a few publications or even a single publication. No conclusions could be drawn for some parameters of individual treatment concepts. Furthermore, evaluations were carried out differently by different authors. For example, "tooth loss" might be further subdivided into "abutment loss," "non-abutment loss," or "tooth loss in the treated jaw." All aspects retrievable from the published data were numerically evaluated. Percentages were usually based on the total number of teeth initially present, but sometimes they were calculated based on the number of cases. This is why percentage results can only be compared to a very limited extent. For reasons of clarity, absolute values were also reported whenever specified or retrievable.

The tooth loss, in the form of abutment or non-abutment loss, is considered a "hard" criterion for biological failure and may well be defined as treatment failure. Depending on the type of restoration, abutment loss may be catastrophic. While a lost abutment can relatively easily be replaced in the case of clasp-retained or double crown-retained prostheses, allowing continued use of the restoration, attachment-retained prostheses, or a fixed prostheses/shortened arch may require a complete redesign and remake of the restoration. Abutment loss may be co-conditioned by the treatment itself and may in turn have a significant influence on treatment success.

When analyzing the tooth loss rates (Table 3) among wearers of clasp-retained prostheses, these rates are found to be considerably lower in studies including a substantial pre-treatment and recalls at 6-month intervals, Bergman [20] vs. Rehmann [29] at 3 years and Kapur [12] vs. Tada [3], Thomason [1], or Budtz-Jørgensen [2] at 5 years. In the study by Bergman, very low tooth loss rates were achieved with appropriate follow-ups after 10 or even 25 years [13, 18]. In this study, which had by far the longest observation period, it was shown that, given an appropriate pre-treatment of the primary cause of tooth loss and consistently supportive therapy, a simple clasp-retained partial denture does not need to present an increased risk of tooth loss.

The tooth loss rates are higher for attachment-retained prostheses than for clasp-retained prostheses. However, the data does not permit any differentiation between custom-milled and pre-fabricated precision abutments.

The tooth loss rates for double crown-retained prostheses are also higher than those for clasp-retained prostheses. However, no reliable comparisons with attachment-retained prostheses are possible due to different patient populations. Wöstmann noted that the tooth loss rates were significantly higher in patients with no follow-up [27]. In contrast, authors differ in their assessment of the risk of tooth loss as a function of the presence or absence of endodontic treatments. Wegner found significant better survival rates for vital teeth in removable prostheses. By contrast, there were no differences in survival rates between vital and endodontically treated teeth in the presence of fixed prostheses. Specifically, direct core buildups had a significant better prognosis than cast post and cores, and adhesively connected posts had a significantly better prognosis than conventionally cemented posts [35]. Dittmann noted a 3.298 higher probability of loss for endodontically treated abutments [36]. By contrast, Piwowarczyk reported the loss of significantly more vital abutments [32].

When comparing fixed and removable treatment options for the shortened dental arch, higher tooth loss rates were found for removable restorations. While the difference was not significant in the randomized controlled trial by Walter [10], it did rise to significance level in Budtz-Jørgensen und Müller [2, 5]. The higher loss rates for fixed restorations in the randomized controlled trial by Kapur [11] must be attributed to a loss of restoration supported by blade implants. Because rotationally symmetrical implants are generally used today, these data can no longer be considered representative.

Shugars examined the survival rate of bounded edentulous spaces and found no significant difference between non-treatment and removable treatment. However, the difference between these two forms of treatment and fixed rehabilitations was statistically significant. Removable restorations seem to present no additional risk factor for tooth loss in bounded edentulous spaces [43].

With regard to the tooth-loss parameter, there seems to be some evidence that removable therapy tends to have more negative effects in other way similar baseline situations. Invasive retention methods such as precision attachments or double crowns also seem to have a negative impact. In cases where esthetic aspects are of secondary importance, the less invasive clasp-retained prostheses should be given preference from this point of view. It should be noted, however, that in some of the studies, the abutment teeth supporting the clasps had received crown restorations. Against this background, the potentially less pronounced loss of dental hard tissue with single-tooth crowns in the context of clasp-retained partial

prostheses compared to the parallelism required when preparing teeth for double crown- or attachment-retained prostheses could be an explanatory hypothesis. Alternatively, differences in periodontal pre-treatment and follow-up could be considered as potential sources of differences in tooth loss rates. This question can ultimately be answered only within the framework of a randomized controlled trial.

An appropriate pre-treatment with oral hygiene instructions and control and a stringent and at least semi-annual follow-up with post-cleaning are considered suitable measures to improve the prognosis.

For the caries parameter, data are usually provided in terms of the number of newly affected teeth. However, some authors examined the number of affected surfaces. Some authors differentiated between primary and secondary dental caries, caries, and abutment and non-abutment teeth or in teeth in contact or not in contact with the removable restoration. Here, too, percentage calculations were predominantly based on the baseline number of teeth/surfaces. Some authors also calculated the number of cases. For reasons of comparability, the present review calculated, wherever possible, the number of newly affected teeth relative to the initial number of teeth.

The caries rate varied greatly between studies. For clasp-retained prostheses with good pre-treatment and stringent supportive care, it was sometimes significantly lower than in groups without comparable pre-care and aftercare [12, 18]. However, Budtz-Jørgensen [2] and Jepson [6] found significantly more caries with removable than with fixed rehabilitations, meaning that the clasp-retained restoration would present a greater risk than a fixed restoration in patients without sufficient follow-up.

Two studies by Bergman reported slightly increased caries rates on contact surfaces with clasp-retained prostheses, although these results were not statistically significant for treatment [17, 19].

The caries rates of attachment-retained, double crown-retained, and fixed prostheses appeared to be comparable. Only the study by Studer reported a higher number of new lesions in attachment-retained prostheses at 6 years. However, the data permit no conclusions about potential risk factors or localization [4].

The summary of the results present some evidence that caries is a variable that is highly dependent on the pre-treatment and follow-up care. In case of insufficient supportive care, clasp-retained prostheses are a risk factor for new carious lesions.

Endodontic treatments can be regarded as a measure of the preparation trauma. While occlusal adjustments to healthy teeth can be minimally invasive in wearers of clasp-retained prostheses, they are clearly more invasive in the case of crown restorations. In the studies by Kapur and Bergman, abutments carried crowns. The other authors studied prostheses that were supported by healthy teeth. However, the data are not sufficient to work out the differences. Comparisons of individual groups of prostheses are difficult due to a lack of suitable data, but one study stands out in that the endodontic treatment rate after 10 years is very high for double crown-retain prostheses (sample size calculation) [40].

Abutment fractures are complications that may be related to the biomechanics of the prostheses or to the weakening of the teeth as a result of the preparation.

Relatively low fracture rates have been reported for clasp-retained prostheses even with longer observation periods. The data do not permit any differentiation between abutment teeth with or without crown restorations. Fracture rates for double crown-retained prostheses are similarly low.

For attachment-retained prostheses, the fracture rates were higher at the 5- and 6-year follow-ups, especially in the case of non-splinted terminal abutments [4, 39].

The biomechanics of the prostheses thus appears to be a higher risk factor for abutment fractures in attachment-retained then clasp-retained or double crown-retained prostheses.

Splinting appears to be beneficial for tooth mobility. But the better the pre-treatment and supportive care is, the smaller the differences are. Depending on the study reviewed, anything between no changes at 5 years [12], slight improvements [21] and a statistically significant reduction in mobility at 2 years [8] can be found for clasp-retained prostheses. Bergman found slightly better results for patients who had regular recalls [20].

Studies on conical double crown-retained prostheses report a slight increase in tooth mobility [32, 44].

To a very large extent, the pocket depth parameter seems to be dependent on the extent of pre-treatment and follow-up. In studies with wearers of clasp- or attachment-retained prostheses, no or only slight changes were found even after observation periods of 5 years or more. In the study on double crown-retained prostheses with intensive periodontal pre-treatment [32], there were no significant changes, while two other studies without data on for pre-treatment or follow-up care reported significantly inferior results [7, 34].

Statements regarding radiological bone loss can be based only on a few studies. Most report no or only a slight increase. Only Bergman reported significant bone loss on the distal side of the abutment [8].

In terms of gingival recession, the major connector in the mandible appears to be a risk factor. Lingual bars with their direct contact with the mucous membrane induced significantly more recessions in wearers of clasp-retained prostheses [12, 14].

The plaque and gingival indices remain constant over extended periods in patients with good pre-treatment and follow-up care, and where they did not, the results were similar in groups with clasp-retain prostheses and fixed rehabilitations. If

pre-treatment or follow-up care were not performed stringently, index values were higher for wearers of clasp-retention prostheses, especially on surfaces in contact with the prostheses.

In conical double crown-retained prostheses, there was an improvement in oral hygiene parameters at 3 years but a slight deterioration at 6 years [44, 45]. This group had received good pre-treatment and supportive care. In the group of telescopic double crown-retained prostheses observed by Mock, a deterioration was seen at 3 years. No data were available on pre-treatment and follow-up [7].

Schmitt reported a decrease of inflammation and gingival indices for a group of attachment-retained prostheses at 5 years. Here, too, there was no information on pre-treatment and follow-up [39].

Where sufficient data were available, many of the parameters analyzed appeared to be positively impacted by good pre-treatment and supportive care. For this reason, it is greatly recommended to take this aspect into account in future clinical studies.

Compared with fixed rehabilitations, removable dental prostheses exhibited higher biological complication rates in some controlled non-randomized clinical studies, such as denture sores, ulcerations, or TMD [9]. The prevalence of TMD appeared increased in groups with removable prostheses. Clasp-retained prostheses did not affect the stabilization of the occlusion or the course of a TMD [25, 26].

Conclusion

As in the study on the survival rate of removable prostheses [16], the data situation is precarious when it comes to looking at their biological complications. It provides only a few reliable findings with a high level of evidence. More studies with standardized-parameter evaluations would be important to improve review ability and comparability. These parameters should include the following.

Tooth loss

Tooth loss in the treated jaw, differentiating between the loss of abutments and non-abutments, total tooth loss. Percent indications based on the initial number of teeth and the number of cases.

Caries

Distinction between caries on abutment and non-abutment teeth and possibly distinction between primary and secondary caries with information on localization.

Detailed information on prosthetic designs that allow a clear evaluation and differentiation of the parameters endodontic treatment, tooth fracture, or periodontal parameters such as tooth mobility, probing depth, attachment/bone loss, or gingival recession.

Accurate information on pre-treatment and supportive care to allow evidence-based statements.

Funding This study was funded by the German Society of Dental, Oral, and Craniomandibular Sciences (*Deutsche Gesellschaft für Zahn-, Mund- und Kieferheilkunde*).

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not include any studies with human participants or animals performed by any of the authors.

Informed consent There was no need to obtain informed consent, as no individual participants were involved in this study.

References

1. Thomason JM, Moynihan PJ, Steen N, Jepson NJ (2007) Time to survival for the restoration of the shortened lower dental arch. J Dent Res 86(7):646–650
2. Budtz-Jorgensen E, Isidor F (1990) A 5-year longitudinal study of cantilevered fixed partial dentures compared with removable partial dentures in a geriatric population. J Prosthet Dent 64(1):42–47
3. Tada S, Ikebe K, Matsuda K, Maeda Y (2013) Multifactorial risk assessment for survival of abutments of removable partial dentures based on practice-based longitudinal study. J Dent 41(12):1175–1180. https://doi.org/10.1016/j.jdent.2013.07.018
4. Studer SP, Mader C, Stahel W, Scharer P (1998) A retrospective study of combined fixed-removable reconstructions with their analysis of failures. J Oral Rehabil 25(7):513–526
5. Muller S, Eickholz P, Reitmeir P, Eger T (2013) Long-term tooth loss in periodontally compromised but treated patients according to the type of prosthodontic treatment. A retrospective study. J Oral Rehabil 40(5):358–367. https://doi.org/10.1111/joor.12035
6. Jepson NJ, Moynihan PJ, Kelly PJ, Watson GW, Thomason JM (2001) Caries incidence following restoration of shortened lower dental arches in a randomized controlled trial. Br Dent J 191(3):140–144
7. Mock FRSH, Stark HK (2005) Eine klinische Langzeitstudie zur Bewährung von Teleskopprothesen. Success of telescopic crowns - a prospective long-term study. Dtsch Zahnaerztl Z 60(3):148–153
8. Bergman B, Hugoson A, Olsson CO (1971) Periodontal and prosthetic conditions in patients treated with removable partial dentures and artificial crowns. A longitudinal two-year study. Acta Odontol Scand 29(6):621–638
9. Budtz-Jorgensen E, Isidor F (1987) Cantilever bridges or removable partial dentures in geriatric patients: a two-year study. J Oral Rehabil 14(3):239–249
10. Walter MH, Hannak W, Kern M, Mundt T, Gernet W, Weber A, Wostmann B, Stark H, Werner D, Hartmann S, Range U, Jahn F, Passia N, Pospiech P, Mitov G, Bruckner J, Wolfart S, Busche E, Luthardt RG, Heydecke G, Marre B (2013) The randomized shortened dental arch study: tooth loss over five years. Clin Oral Investig 17(3):877–886. https://doi.org/10.1007/s00784-012-0761-x
11. Kapur KK (1989) Veterans administration cooperative dental implant study–comparisons between fixed partial dentures supported

by blade-vent implants and removable partial dentures. Part II: comparisons of success rates and periodontal health between two treatment modalities. J Prosthet Dent 62(6):685–703
12. Kapur KK, Deupree R, Dent RJ, Hasse AL (1994) A randomized clinical trial of two basic removable partial denture designs. Part I: comparisons of five-year success rates and periodontal health. J Prosthet Dent 72(3):268–282
13. Bergman B, Hugoson A, Olsson CO (1995) A 25 year longitudinal study of patients treated with removable partial dentures. J Oral Rehabil 22(8):595–599
14. Akaltan F, Kaynak D (2005) An evaluation of the effects of two distal extension removable partial denture designs on tooth stabilization and periodontal health. J Oral Rehabil 32(11):823–829
15. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gotzsche PC, Ioannidis JP, Clarke M, Devereaux PJ, Kleijnen J, Moher D (2009) The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. J Clin Epidemiol 62(10):e1–e34. https://doi.org/10.1016/j.jclinepi.2009.06.006
16. Moldovan O, Rudolph H, Luthardt RG (2016) Clinical performance of removable dental prostheses in the moderately reduced dentition: a systematic literature review. Clin Oral Investig 20: 1435–1447. https://doi.org/10.1007/s00784-016-1873-5
17. Bergman B, Hugoson A, Olsson CO (1977) Caries and periodontal status in patients fitted with removable partial dentures. J Clin Periodontol 4(2):134–146
18. Bergman B, Hugoson A, Olsson CO (1982) Caries, periodontal and prosthetic findings in patients with removable partial dentures: a ten-year longitudinal study. J Prosthet Dent 48(5):506–514
19. Bergman B, Ericson G (1986) Cross-sectional study of patients treated with removable partial dentures with special reference to the caries situation. Scand J Dent Res 94(5):436–442
20. Bergman B, Ericson G (1989) Cross-sectional study of the periodontal status of removable partial denture patients. J Prosthet Dent 61(2):208–211
21. Isidor F, Budtz-Jørgensen E (1987) Periodontal conditions following treatment with cantilever bridges or removable partial dentures in geriatric patients. A 2-year study. Gerodontics 3(3):117–121
22. Isidor F, Budtz-Jørgensen E (1990) Periodontal conditions following treatment with distally extending cantilever bridges or removable partial dentures in elderly patients. A 5-year study. J Periodontol 61(1):21–26
23. Walter MH, Weber A, Marre B, Gitt I, Gerss J, Hannak W, Hartmann S, Heydecke G, Huppertz J, Jahn F, Ludwig A, Mundt T, Kern M, Klein V, Pospiech P, Stumbaum M, Wolfart S, Wostmann B, Busche E, Boning K, Luthardt RG (2010) The randomized shortened dental arch study: tooth loss. J Dent Res 89(8): 818–822
24. Wolfart S, Marre B, Wostmann B, Kern M, Mundt T, Luthardt RG, Huppertz J, Hannak W, Reiber T, Passia N, Heydecke G, Reinhardt W, Hartmann S, Busche E, Mitov G, Stark H, Pospiech P, Weber A, Gernet W, Walter MH (2012) The randomized shortened dental arch study: 5-year maintenance. J Dent Res 91(7 Suppl):65S–71S. https://doi.org/10.1177/0022034512447950
25. Witter DJ, de Haan AF, Kayser AF, van Rossum GM (1994) A 6-year follow-up study of oral function in shortened dental arches. Part I: occlusal stability. J Oral Rehabil 21(2):113–125
26. Witter DJ, De Haan AF, Kayser AF, Van Rossum GM (1994) A 6-year follow-up study of oral function in shortened dental arches. Part II: Craniomandibular dysfunction and oral comfort. J Oral Rehabil 21(4):353–366
27. Wostmann B, Balkenhol M, Weber A, Ferger P, Rehmann P (2007) Long-term analysis of telescopic crown retained removable partial dentures: survival and need for maintenance. J Dent 35(12):939–945
28. Rehmann P (2006) Retrospektive Longitudinalstudie über die langfristige Bewährung von Teleskopprothesen unter besonderer Berücksichtigung der Instandhaltungskosten. Dtsch Zahnaerztl Z (8): 403-409
29. Rehmann P, Orbach K, Ferger P, Wostmann B (2013) Treatment outcomes with removable partial dentures: a retrospective analysis. Int J Prosthodont 26(2):147–150. https://doi.org/10.11607/ijp.2959
30. Heydecke G (2003) Longitudinale klinische Studie zur Bewährung von Teilprothesen mit Feder-Riegel-Geschieben - 5-Jahres-Daten. Dtsch Zahnaerztl Z (4):212-218
31. Stober T, Bermejo JL, Beck-Mussoter J, Seche AC, Lehmann F, Koob J, Rammelsberg P (2012) Clinical performance of conical and electroplated telescopic double crown-retained partial dentures: a randomized clinical study. Int J Prosthodont 25(3):209–216
32. Piwowarczyk A, Kohler KC, Bender R, Buchler A, Lauer HC, Ottl P (2007) Prognosis for abutment teeth of removable dentures: a retrospective study. J Prosthodont 16(5):377–382
33. Wenz HJ, Hertrampf K, Lehmann KM (2001) Clinical longevity of removable partial dentures retained by telescopic crowns: outcome of the double crown with clearance fit. Int J Prosthodont 14(3):207–213
34. Nickenig A (1995) Langzeitbewährung von Teleskop-Prothesen. Dtsch Zahnaerztl Z (50): 753-755
35. Wegner PK, Freitag S, Kern M (2006) Survival rate of endodontically treated teeth with posts after prosthetic restoration. J Endod 32 (10):928–931
36. Dittmann B, Rammelsberg P (2008) Survival of abutment teeth used for telescopic abutment retainers in removable partial dentures. Int J Prosthodont 21(4):319–321
37. Wagner B, Kern M (2000) Clinical evaluation of removable partial dentures 10 years after insertion: success rates, hygienic problems, and technical failures. Clin Oral Investig 4(2):74–80
38. Au AR, Lechner SK, Thomas CJ, Mori T, Chung P (2000) Titanium for removable partial dentures (III): 2-year clinical follow-up in an undergraduate programme. J Oral Rehabil 27(11):979–985
39. Schmitt J, Wichmann M, Eitner S, Hamel J, Holst S (2011) Five-year clinical follow-up of prefabricated precision attachments: a comparison of uni- and bilateral removable dental prostheses. Quintessence Int 42(5):413–418
40. Behr M, Kolbeck C, Lang R, Hahnel S, Dirschl L, Handel G (2009) Clinical performance of cements as luting agents for telescopic double crown-retained removable partial and complete overdentures. Int J Prosthodont 22(5):479–487
41. Besimo C, Gachter M, Jahn M, Hassell T (1997) Clinical performance of resin-bonded fixed partial dentures and extracoronal attachments for removable prostheses. J Prosthet Dent 78(5):465–471
42. Vermeulen AH, Keltjens HM, van't Hof MA, Kayser AF (1996) Ten-year evaluation of removable partial dentures: survival rates based on retreatment, not wearing and replacement. J Prosthet Dent 76(3):267–272
43. Shugars DA, Bader JD, White BA, Scurria MS, Hayden WJ Jr, Garcia RI (1998) Survival rates of teeth adjacent to treated and untreated posterior bounded edentulous spaces. J Am Dent Assoc 129(8):1089–1095
44. Bergman B, Ericson A, Molin M (1996) Long-term clinical results after treatment with conical crown-retained dentures. Int J Prosthodont 9(6):533–538
45. Ericson A, Nilsson B, Bergman B (1990) Clinical results in patients provided with conical crown retained dentures. Int J Prosthodont 3 (6):513–521