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Review

Loss of natural abutment teeth with cast copings retaining overdentures: a systematic review and meta-analysis

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ABSTRACT

Purpose: To analyze the available evidence in the English, German and Japanese literature on the survival and complications of natural teeth with cast copings used to retain overdentures (ROD).
Study selection: A systematic search strategy was conducted using MeSH terms and pre-defined criteria. Two groups of researchers searched Pubmed, CENTRAL, Embase (English, German), Ichushi-web (Japanese) as well as hand searching. Data were extracted independently by the two groups. The estimated frequency of abutment tooth loss was calculated from data on the number of lost teeth and exposure time. A meta-analysis was conducted to estimate the annual frequency of abutment tooth loss across all included studies.
Results: A total of 4791 eligible studies from PubMed, Embase, and CENTRAL. An additional 316 articles were identified from the Ichushi-Web plus another 131 articles from additional sources. From those manuscripts, 19 reported relevant outcome data that was then extracted. The pooled data included a total of 1954 abutment teeth with a combined total exposure time of 9098 years. The estimated linear rate of loss was 1.76 %/year (95 %CI 1.13; 2.72). Caries and periodontal infections were identified as the most common reasons for abutment tooth loss.
Conclusions: Natural tooth retained overdentures often constitute the last resort before edentulism and might aid in this transition, especially in very old patients with reduced adaptive capacities. Given correct design, preparation and aftercare, RODs with cast copings, still are a valid treatment option in partially edentulous patients.

1. Introduction

In most of the western world, tooth loss is increasingly delayed into old age and the prevalence of edentulism is declining [1–3]. This can lead to challenging clinical situations where elderly patients struggle to perform oral hygiene measures but retain a number of natural teeth [4]. In these circumstances one of the prosthodontic treatment options available is the use of natural root-supported overdentures (RODs), as the shortening of the abutment teeth might increase their survival [5]. According to the Academy of Prosthodontics, the term overdenture (OD) is defined as *"any removable dental prosthesis that covers and rests on one or more remaining natural teeth, the roots of natural teeth, and/or dental implants; a dental prosthesis that covers and is partially supported by natural teeth, natural tooth roots, and/or dental implants"* [6] (Fig. 1).

If further tooth loss occurs, RODs can easily be transformed into complete dentures. This can provide a smooth transition to edentulousness without overstretching patients' adaptive capacity. RODs are indicated when the remaining natural teeth cannot adequately serve as abutment teeth for fixed or clasp-retained partial dentures due to an unfavorable distribution in the arch, loss of periodontal attachment, complex functional or aesthetic needs or severe attrition. They may also be indicated when provision of endosseus implants to support overdentures (IODs) is not possible [7,8].

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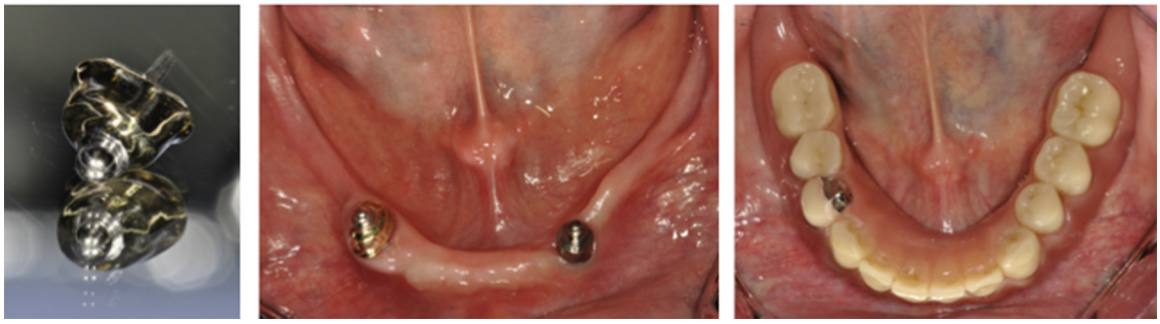

Fig. 1. Clinical example of a cast coping with spherical attachment for the retention and support of an overdenture.

RODs are typically designed as complete dentures and cover the remaining natural abutments. In most cases, these abutments need to undergo elective devitalisation as the teeth are significantly shortened to provide sufficient restorative space for the prostheses. The abutments can either be covered by plastic filling materials, such as glass ionomer cement, amalgam or composite [9,10], or restored with cast copings, commonly constructed from gold alloy [11]. The abutment teeth will then serve to transmit masticatory forces thus protecting the underlying mucosa and alveolar bone [12]. They also serve to maintain a degree of proprioception as the periodontal ligament receptors remain intact [13]. Fontijn-Tekamp et al. has demonstrated that patients with RODs show a chewing efficacy similar to those with a shortened dental arch and better than implant-ODs or complete dentures [14]. Newton et al. also demonstrated that the loss of muscle mass of the jaw-closing muscles could be delayed if natural roots supported an overdenture [15].

Where cast copings are used on the natural abutment teeth these can also be utilized to provide precision attachments which add extra retention to the overdenture [16]. The precision attachments consist of two elements: a male cast root cap, on which the retentive element is soldered (e.g., spherical attachment, cylinder, magnet) [16,17] and a corresponding female matrix which is incorporated into the fitting surface of the prostheses. Retention within the matrices can be modified and the components can be changed if they become worn out. RODs are expensive removable prostheses because of the complexity of treatment and the laboratory components used in their production. Unfortunately a number of studies have demonstrated that the natural teeth used to support RODs are susceptible to caries and periodontal disease [11,18–20] (Fig. 2). The need to prevent such complications and the high maintenance burden can generate additional expenses.

The aim of this systematic review was to collect and analyze all the available evidence in the English, German and Japanese literature on the survival and complications of roots with cast copings and precision attachments used to retain a ROD. A meta-analysis was conducted to calculate the estimated annual frequency of loss of the natural abutment teeth. The focused question for the review was: “In partially edentulous patients with RODs, what is the estimated annual loss of abutment teeth and complications of the abutment teeth in clinical studies published in English, German and Japanese literature?”

2. Materials and methods

This systematic review was conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [21].

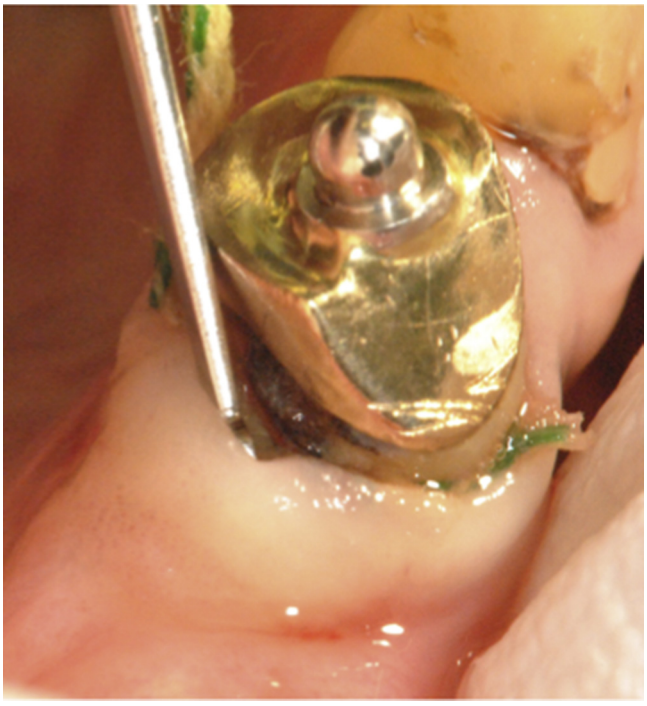

Fig. 2. Caries is a frequently observed complication in abutment teeth with cast copings.

2.1. Information sources

A systematic literature search was conducted using the combined MeSH terms “overdenture” or “dental prosthesis” and “root supported overdenture” or “denture bases” or “tooth root” and “anchor system” or “denture retention” or “dental abutment” or “root cap” or “attachment” or “abutment” and limited by “German” and “English” and “Japanese” in the databases. The electronic databases PubMed, CENTRAL and EMBASE were searched for relevant scientific reports published in English or German as well as the Japanese databases Ichushi-Web for articles published in Japanese with the translated terms (Table 1). The electronic search by combined MeSH term was further augmented in the Web of Science (96 titles) and then by hand searched through the following journals: *British Dental Journal*, *International Journal of Prosthodontics*, *Quintessence International*, *Journal of Oral Rehabilitation*, *Dental Update*, *The Journal of Prosthetic Dentistry*, *Journal of Dental Restoration*, *International Journal of Periodontics & Restorative Dentistry*, *International Journal of Prosthetic Dentistry*, *Journal of Clinical Periodontology*, *Journal of Dental Research*, and *Journal of Periodontology*. The aim was to identify all publications

Table 1
Search strategy.

Focused question	In partially edentulous patients with root retained overdentures, what is the estimated 10-year survival rate and respective complications of the abutment teeth with copings that can be pooled from retrospective and prospective studies in English, German and Japanese language?	
Search strategy	Population	#1 — ((overdenture [all fields]) OR (dental prosthesis [all fields]) OR (overdenture patients [all fields]))
	Intervention or exposure	#2 — ((Removable dental prostheses* [all fields]) OR (root supported Overdentures [all fields]) OR (denture basis [all fields]) OR (tooth root [MeSH] OR (anchor system [MeSH]) OR (denture retention [MeSH]) OR (dental abutment [all fields]) OR (root cap [all fields]) OR (attachment [all fields]) OR (abutment [all fields]) OR (Root retained overdenture [all fields]) OR (copings [all fields]))
	Outcome	#4 — ((dental restoration failure [Mesh]) OR (prosthesis failure [Mesh]) OR (treatment failure [Mesh]) OR (complication* [all fields]) OR (success* [all fields]) OR (failure* [all fields]) OR (Survival [Mesh]) OR (survival rate [Mesh]) OR (survival analysis [Mesh]))
	Filters (language)	#5 — ((English [Lang]) OR (German [Lang])) OR (Japanese [Lang]))
	Search combination	#1 AND #2 AND #3 AND #4 AND #5 #1 AND #2 AND #5
	Electronic	PubMed, Embase, The Cochrane Central Register of Controlled Trials (CENTRAL) and Ichushi-Web (Japanese)
Database search	Journals	All peer reviewed dental journals available in PubMed, Embase and CENTRAL. Japanese peer reviewed dental journals available in Ichushi-Web.
	Inclusion criteria	Root supported overdentures. Must specify the study design, number of patients, survival rate and complications.
Selection criteria	Exclusion criteria	Case reports. Implant-supported overdenture prostheses. Studies without abstracts

reporting these on attachment systems for root coping — supported overdentures up to July 1st of 2017.

2.2. Search strategy and study selection

All clinical studies, excluding case reports, reporting on partially edentate patients with overdentures retained by natural roots with cast copings and precision attachments including ball attachments, Gerber attachments or magnets that satisfied the listed predefined inclusion criteria were included in this systematic review.

The included studies had to report at least: number of participants, type of cast coping and attachment, number of abutment teeth at the beginning and end of the observation period and the mean observation period. Excluded studies included overdentures retained on roots restored with plastic restorations, case reports or technical reports without statistical comparisons.

The following information was extracted: name of author/s and year of publication, sample size, patient age, mean observation period in months, gender of participants, number of cast root caps, number of overdentures, survival rates, overdenture attachment type, prosthetic and biological complications. The number of natural abutment teeth with biological complications such as caries, periodontal disease, endodontic failure, fracture and mobility, as well as prosthetic complication such as coping remake, denture repair, chipping, matrix repairs and change of activations were noted.

Two groups of investigators worked independently in order to analyze the English and German (AM and NR) literature and the Japanese literature (KI and ST). Each investigator created a list of studies for full text analysis. The lists were compared within the language groups and studies common to both lists were shortlisted. Mutual agreement on any included study was necessary to proceed with further analysis. Data extraction for the two groups was performed independently and the researchers were blinded. Disagreements were solved by a consensus discussion presided over by the senior author (MS). A sensitivity analysis was performed at the level of the data extraction. Therefore, the inter-investigator reliability was calculated using kappa (κ) statistics [22]. In cases of identified studies reporting on the same cohort at different time points, only the most recent publication was included in the review. Furthermore, a subgroup analysis that compared cast copings with or with or without precision attachments was performed.

2.3. Risk of bias and quality assessment of the included studies

The Newcastle–Ottawa scale (NOS) was used for the assessment of the risk of bias and quality assessment of the included prospective cohort/case-control studies [23,24].

2.3.1. Primary outcome measure

The primary outcome measure was the estimated loss of abutment teeth with cast copings in overdenture patients, i.e., frequency of loss per 100 years. Therefore, the number of abutment teeth, the total exposure time (mean observation period), the frequency of abutment tooth loss and the annual rate of loss were calculated.

2.3.2. Secondary outcome measures

Information on the biological and technical complications in abutment teeth and overdentures were also extracted; this data has been reported qualitatively due to the heterogeneity of the information provided.

2.4. Statistical analysis

The total exposure time was calculated as the number of abutment teeth multiplied by the reported mean follow-up period of the study. For example, Ratanen et al. [25] this was 156 years, as the product of 52 abutment teeth observed over 36 months (=1872 months = 156 years). The frequency of abutment tooth loss was calculated as the difference between the number of abutment teeth at the beginning of the study and the end of the study. The estimated frequency of abutment tooth loss per 100 years was calculated as a percentage from the 100x number of losses/exposure time. For example, a rate of 3.21 would mean that for 100 abutment teeth, a loss of 3.21 % could be expected after a period of one year [25]. Additionally the 95 % confidence intervals (CI) for the frequency are reported on the assumption that the frequency shows a Poisson distribution. The cumulated estimated frequency over all studies was weighted according to the ratio (percentage) of the follow-up of a given study in respect to the cumulated overall exposure time. The heterogeneity of the included studies was analyzed by plotting a funnel plot.

The analysis was performed by a senior bio-statistician using Stata/IC 14.2 for Windows.

3. Results

3.1. Study selection

The search strategy identified a total of 4791 eligible studies from PubMed, Embase, and CENTRAL, another 131 articles from additional sources as well as 316 articles from the Ichushi-Web. After the first screening and removal of duplicates 154 titles remained. Inclusion and exclusion criteria were applied which produced 77 articles from the English and German literature plus 14 articles from the Japanese literature for full-text analysis. Of

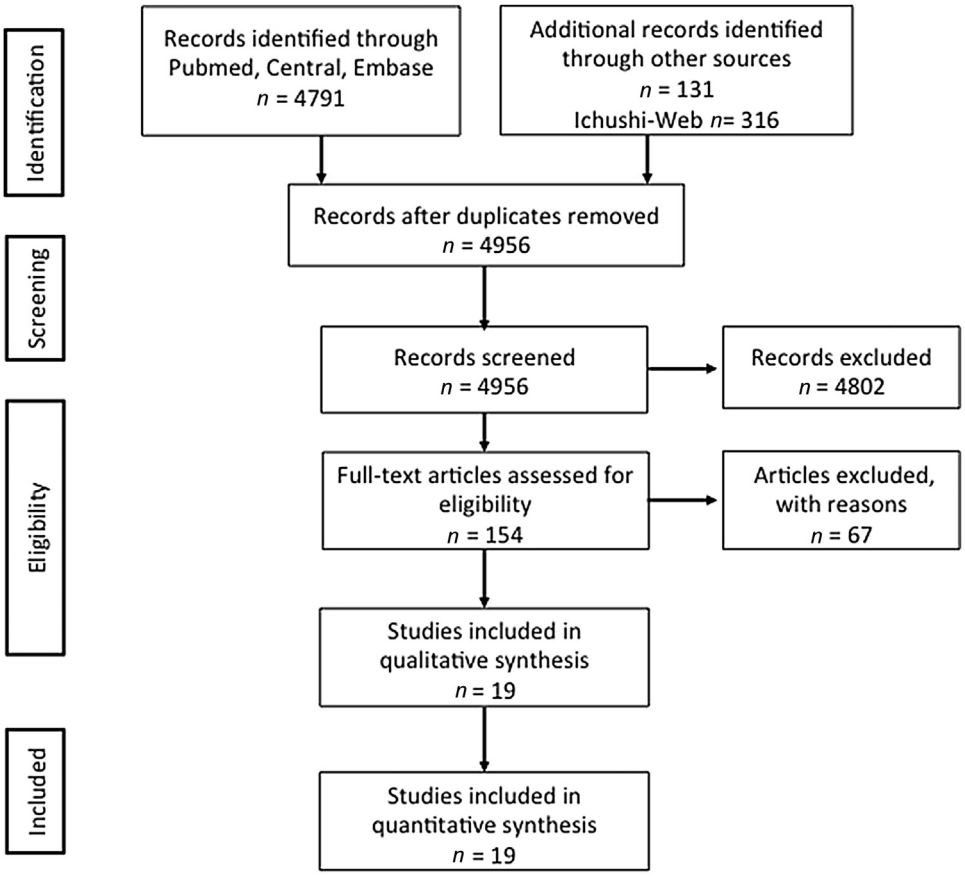

Fig. 3. Flowchart of the search strategy, according to the PRISMA guidelines.

those manuscripts, 19 reported on the defined outcome parameters from which information could be extracted (Fig. 3, [21]). The inter-rater agreement for study selection was substantial ($\kappa = 0.6576$) and ranged for the data extraction from substantial to almost perfect ($0.6269 < \kappa < 1$).

3.2. Frequency of loss of abutment teeth with cast copings

The 19 studies provided pooled information on a total of 1954 abutment teeth with a combined total exposure time of 9098 years. The estimated linear rate of loss per 100 years was calculated as 1.76 (95 %CI 1.13; 2.72), i.e., 1.76 % of the abutment teeth were lost every year assuming that the loss occurs linearly (Table 2, Fig. 4).

3.3. Biological complications

3.3.1. Caries

Eleven studies [4,11,17,25–32] with an observation period ranging from 2 to 16 years reported data on caries in abutment teeth with cast copings. The prevalence of caries varied considerably between studies, ranging from 0.5 % to 83 % (Table 3).

3.3.2. Periodontal disease

Thirteen studies [11,25,27–37] reported on periodontal outcomes for abutment teeth during observation periods ranging from 2 to 15 years. The outcomes of these studies vary significantly, out of the 19 studies, 13 reported on periodontal disease with reported prevalence ranging from 4 % to 86 %. The largest retrospective study by Angermeider and Stadelmann showed a 10 % increase in pocket depths around abutment teeth after up to 16 years of observation [35].

3.3.3. Tooth mobility

Seven studies [17,25,28,29,32,33,37] with a follow-up period ranging from 2 to 12 years presented data on the mobility of the abutment teeth. Five of the articles stated a slight increase in mobility (Table 3). A long-term study by Coca et al. [29] showed, that after 12 years 73.7 % of the abutment teeth showed no mobility.

3.3.4. Tooth fracture

Five studies [11,20,28,30,35] presented data on fracture of the abutment teeth during an observation period ranging from 2 to 16 years. The rate of fractures reported was small, with a range from 1.0 to 1.7 %. The long-term study from by Angermeider and Stadelmann showed a 1.1 % rate of abutment fracture after up to 16 years of observation [35].

3.4. Technical complications

Prosthetic complications such as coping remakes, denture repairs, activation or repair of matrices, overdenture fracture, decementation, reline and remakes of the overdentures were recorded. Reports of technical complications varied widely amongst the included studies (Table 4). Studies reported frequent prosthetic maintenance was required, mainly for overdentures with exclusive root support [20].

Seven studies presented data about the decementation of the cast copings which occurred in 6–32 % of all abutments [20,25,27,30,32,34,35]. Gonda et al. reported that after 5 years only 9 % of the cast copings on the abutment teeth had decemented. Their data suggests that cast copings cemented/bonded with a resin cement showed fewer episodes of decementation [35].

Table 2
Frequency of loss of abutment teeth.

Pooled results[a]		Number of root caps	Total exposure time (years)	Losses	Calculated loss/100 years (95 %-CI)[a]			Weight
		1954	9098	128	1.76	1.13	2.72	
Rantanen	1971	52	156	5	3.21	1.04	7.48	1.71
Akira Manabe	1976	128	288	0	0	–	–	3.17
Eiichi Nagaoka	1982	32	35	0	0	–	–	0.38
Shaw	1984	53	371	14	3.77	2.06	6.33	4.08
Masayuki Murakami	1985	12	60	1	1.67	0.04	9.29	0.66
Meriscke	1993	359	2118	24	1.13	0.73	1.69	23.28
Hirofumi Kido	1994	57	43	0	0	–	–	0.47
Schriber	1999	151	1073	14	1.30	0.71	2.19	11.80
Coca	2002	99	495	8	1.62	0.70	3.18	5.44
Hug	2006	88	264	1	0.38	0.01	2.11	2.90
Otani Ryuichiro	2006	31	140	10	7.17	3.44	13.18	1.53
Brkovic-Popovic 10y	2007	17	170	5	2.94	0.95	6.86	1.87
Brkovic-Popovic 6y	2007	33	198	5	2.53	0.82	5.89	2.18
Monfrin	2007	60	135	5	3.70	1.20	8.64	1.48
Meriscke	2008	419	1816	27	1.49	0.98	2.16	19.96
Yang	2012	70	484	0	0	–	–	5.32
Gonda	2013	211	1055	8	0.76	0.33	1.49	11.60
Yao Xi	2013	60	130	0	0	–	–	1.43
Yang	2014	22	68	1	1.47	0.04	8.21	0.75

Estimation assuming poisson-distributed loss-rate.
[a] Calculation of the rate and the confidence interval with a Poisson regression with random effect study.

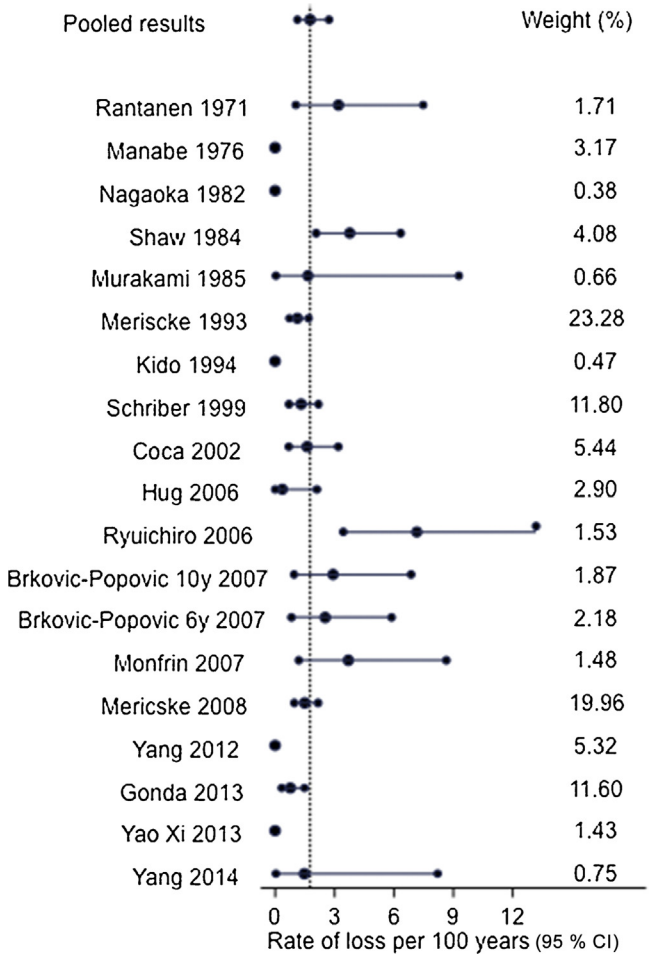

Fig. 4. Graphical representation of the meta-analysis for the losses with their 95 % confidence intervals (95 % CI).

The rate of chipping of the overdenture was reported in three studies and ranged from 9 to 17 % [20,25,27]. The rate of fracture of the overdenture was recorded in seven studies and ranged from 2 to 27 % [17,20,25,28,32–34]. Gonda et al. reported that complications such as decementation and overdenture fractures could be prevented with the use of an adhesive resin primer on the matrix at insertion and the appropriate denture design with a reinforced framework [32].

Two studies reported data on the number of overdenture relines required and ranged from 28 to 35.2 % [17,38]. Shaw reported that relining is indicated as soon as the matrix contacts the fitting surface of the prosthesis to ensure that the overdenture remains mucosa supported and attachment is well retained [38].

Five articles reported on overdenture repairs illustrating a range from 21 to 88 % of the prostheses [20,27,29,34,38]. Coca et al. reported after 12 years, half of the overdentures needed repairs. All the denture repairs involved a puncture fracture of the acrylic covering the matrix [29].

Two studies reported the rate of remake of the cast copings. Shaw described after up to 7 years, 11 % of the root caps required to be remade compared to 5 % in the study by Coca [29,38].

Concerning complications with the matrices; four studies reported repair rates of 22–30 % further activation was required in 36–21 % of cases and a change in retention level was required in 9 % [20,25,35,38].

The subgroup analyses of abutment teeth with cast coping without precision attachments [17,30,39] versus copings with precision attachments [11,17,20,25,27–29,31–35,37,38,40,41] did not show a difference in the frequency of abutment tooth loss between them ($p = 0.538$, Table 5).

3.5. Risk of bias and heterogeneity

The risk of bias of most of the included studies was as high, mostly because of the retrospective study designs and the absence of control-groups (Table 6). The analysis of heterogeneity, i.e., the risk of a publication bias was analyzed with a funnel plot (Fig. 5).

4. Discussion

4.1. Principal findings

This systematic review and meta-analysis of the English, German and Japanese literature reveals a relatively low rate of linear loss of abutment teeth with cast copings retaining an overdenture of less than 2 % per year. The prevalence of caries and

Table 3
Attachment type and biological complications.

Study (first author)	Year	Observation period (months)	Mean age	Participants	WSK (start)	WSK (end)	Overdentures	Attachment type	Caries (%)	Root fracture (%)	Periodontal disease (%)	Mobility (%)	Lost (%)
Rantanen	1971	48	48	31	52	47	33	Bar	39	–	35	35 stable	5
Manabe	1976	42	–	47	128	128	71	Bar	–	–	86	0.7	–
Nagaoka	1982	30	–	16	32	32	18	Ball	15	–	–	–	–
Shaw	1984	84	62	23	52	47	33	Bar	–	–	–	–	–
Murakami	1985	60	62	5	12	11	7	Dome	83	–	83	36	8
Mericske	1993	120	74.1	109	359	335	125	Gerber	5	0.1	4	–	2
Kido	1994	14	–	40	57	57	42	Magnet	–	–	10	10	–
Schriber	1999	24	70	38	151	137	40	Gerber	20.4	1.7	8.3	less	9.2
Coca	2002	144	65	66	99	79	–	Caps/ magnets	9	–	53	73,7 stable	8
Hug	2006	24	67	14	88	87	59	Gerber/ball	–	1.1	–	–	–
Ryuichiro	2006	54	69.4	16	31	21	–	Magnet	–	–	32	–	32
Brkovic-Popovic	2008	72	71.4	15	33	28	–	Copings	–	–	–	–	15.2
Brkovic-Popovic	2008	120	75.4	7	17	12	–	Copings	–	–	–	–	29.4
Monfrin	2007	48	62	29	60	55	–	Copings	1	1	5	–	8.3
Angermeider	2008	192	66.3	159	419	392	183	Gerber/ball	14.7	1	11.2	–	6.4
Yang	2012	84	65.2	35	70	70	–	Copings	12.8	–	25.7	–	–
Gonda	2013	60	67.5	131	211	203	133	Magnets	0.5	–	52 increase	27 increase	3.8
Yao xi	2013	36	68	45	60	60	–	Magnet/ ball/clasp	–	–	–	Magnet	–
Yang	2014	37	66.8	16	22	21	17	Magnet	16.5	–	29.3	No change	–

Table 4
Attachment type and prosthetic complications.

Study (first author)	Year	Observation period (months)	Participants	Overdentures	Attachment type	Refabricate (%)	Decementation (%)	Overdenture fracture (%)	Repairs matrices (%)	Chipping (%)	Reline (%)	Remake coping (%)	Repair denture (%)
Rantanen	1971	48	31	33	Bar	–	6	27	9	9	–	–	–
Manabe	1976	42	47	71	Bar	5.6	–	5.6	–	–	–	–	–
Nagaoka	1982	30	16	18	Ball	–	–	–	–	–	–	–	–
Shaw	1984	84	23	33	Bar	–	–	–	22.2	–	28	11	88
Murakami	1985	60	5	7	Coping	–	16.7	–	–	14.3	–	–	42.9
Meriscke	1993	120	109	125	Gerber	–	–	–	–	–	–	–	–
Kido	1994	14	40	42	Magnet	–	–	–	–	–	–	–	–
Schriber	1999	24	38	40	–	–	–	5	–	–	–	–	–
Coca	2002	144	66	–	Cap/magnet	–	–	–	–	–	–	5	50
Hug	2006	24	14	59	Gerber/ball	–	5.7	1.7	36	16.9	–	–	22
Ryuichiro	2006	54	16	–	Magnet	–	32	21	–	–	–	–	21
Brkovic-Popovic	2008	72	15	–	Coping	–	–	–	–	–	–	–	–
Brkovic-Popovic	2008	120	6	–	Coping	–	–	–	–	–	–	–	–
Monfrin	2007	48	29	–	Coping	–	11	–	–	–	–	–	–
Angermeider	2008	192	159	183	Coping	–	26	–	30	–	–	–	–
Yang	2012	84	35	–	Coping	–	–	–	–	–	–	–	–
Gonda	2013	60	131	133	Magnet	–	9	14	–	–	–	–	–
Yao xi	2013	36	45	–	Magnet/ ball/clasp	–	–	–	–	–	–	–	–
Yang	2014	37	16	17	Magnet	–	–	11.7	–	–	35.2	–	–

Table 5
Frequency of abutment tooth loss in the two subgroups with 95 % CI and the p-value for comparison. The calculation of the rates, 95 % CI and the p-value is done with a Poisson regression with random effect study.

Attachment type	Number of root caps	Total exposure time (years)	Losses	Calculated loss/100 years 95 %-CI			*p*-Value
Cast coping/no attachment	1774	8111	113	1.65	0.97	2.82	
Cast coping/with attachment	180	978	115	2.16	1.11	4.21	0.538

periodontal disease is high and those conditions contribute to the majority of lost abutment teeth. Technical complications are most frequently seen in the first year of service and often comprise of issues around activation of matrices and decementation of the cast copings.

4.2. Strengths and weaknesses of the review

Prospective clinical studies that investigate RODs are scarce and rarely comprise control-groups. The indication to provide a patient with a ROD is often an ultima-ratio decision, and aims to delay the

Table 6
Results of quality assessment of the comparative studies analyzed.

Study	Year	Design	Selection (max. 4*)	Comparability (max. 3*)	Outcome (max. 3*)	Risk of bias
Rantanen	1971	Prospective	*	*	*	High
Manabe	1976	Prospective	* *	* *	*	Unclear
Nagaoka	1982	Prospective	* *	* *	*	High
Shaw	1984	Prospective	*	*	*	High
Murakami	1985	Prospective	* * * *	* *	*	High
Meriscke	1993	Retrospective	* *	* *	*	High
Kido	1994	Prospective	* * * *	* *	*	High
Schriber	1999	Retrospective	* *	* *	*	High
Coca	2002	Retrospective	* *	* *	*	High
Hug	2006	Prospective	* *	*	*	High
Ryuichiro	2006	Prospective	* * * *	* *	* *	Low
Brkovic-Popovic	2008	Prospective	* *	* *	*	High
Brkovic-Popovic	2008	Prospective	* *	* *	*	High
Monfrin	2007	Case-control	* *	*	*	High
Angermeider	2008	Retrospective	* *	* *	*	High
Yang	2012	Retrospective	*	*	*	High
Gonda	2013	Retrospective	*	*	*	Unclear
Yao xi	2013	Retrospective	* *	* *	*	High
Yang	2014	Prospective	* *	* *	*	High

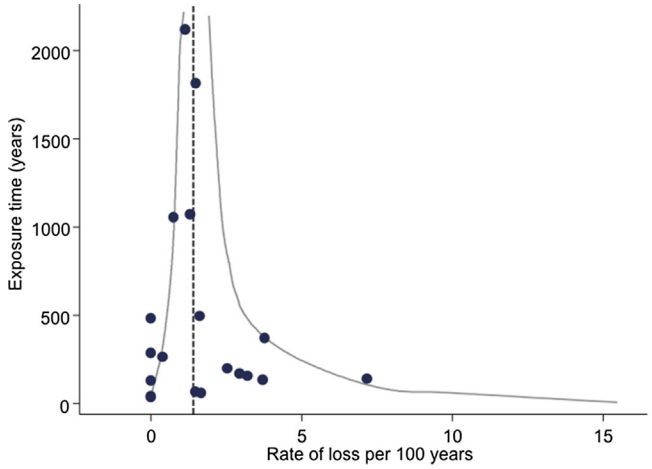

Fig. 5. In the current meta-analysis, the frequency of abutment teeth loss was related to the exposure time. The weight of the study was therefore the exposure time. It also determines the accuracy of the loss rate, since the width of the 95 % confidence intervals of the loss rate of the individual studies depends on the exposure time (the smaller the time, the broader the 95 % CI). In the depicted graphy, the exposure time of the 19 studies was plotted against the losses per 100 years. The black vertical line is the pooled loss rate (1.76/100 years). The gray lines describe the interval in which the loss rate of 95 % of the studies would be expected if the 'true' loss rate corresponds to the pooled rate and if there is neither a publication bias nor heterogeneity. Because of the assumption of poisson-distributed losses, the interval is not distributed symmetrical around the pooled rate.

time until a complete denture must be provided. Thus, the introduction of appropriate control-groups may be almost impossible. As RODs are usually provided for elderly or geriatric patients, prospective study designs and the introduction of comparable parameters are especially challenging, due to a number of logistical and ethical challenges. One could argue to compare RODs to IODs, but this comparison cannot be justified, as teeth should only be replaced by implants as a last resort of treatment. Therefore, most of the included studies show a high risk of bias, due to their retrospective design and the absence of valid controls. Unlike implants, abutment teeth are very heterogeneous in regard to endodontic anatomy, structural deficits or periodontal condition. Furthermore, different clinicians may judge the prognosis of abutment teeth on varying parameters, resulting in a further increase of heterogeneity between individual subjects, data sets and publications.

In order to reduce, but also reflect this heterogeneity, the authors of the current systematic review included studies from a large geographical base. Therefore, and contrary to other reviews, the language restrictions that constitute a major inclusion bias in other systematic reviews were widened, as German and Japanese articles and theses were included.

The analysis of heterogeneity with the funnel plot method further strengthens the impression, that different clinicians judge the prognosis of abutment teeth differently and that different treatment concepts result in varying survival rates of the abutments. If there is neither a publication bias nor a strong heterogeneity of the studies, then most of the points in the funnel plot are expected to be within the 95 % confidence interval. The points in the plot should roughly describe a triangular form. There should be no area of the y-axis where the dots cluster on one side of the vertical lines (pooled rate). If all studies with a low exposure time have a loss rate below the pooled rate, this may indicate a publication bias. The included studies are therefore more heterogeneous than one would expect. In particular, there are unexpectedly many studies reporting on low frequencies of abutment tooth loss, which are outside the confidence interval.

For the meta-analysis studies were weighted according to the proportion (percentage) of the observation time of a study on the sum of the observation times of all studies. The weighting of the studies will give preference to large studies and not necessarily well conducted ones. For example, the largest weight has the study of Mericske and Mericske-Stern (2118 years) [11], which had a retrospective design and is thus prone to be at risk for numerous forms of inclusion bias. Studies with a prospective design; those which are more difficult to conduct and more expensive like the study by Brkovic-Popovic et al. [39] or Ryuichiro et al. [34] have a small weight, but might provide more reliable results. This could have introduced a risk of bias into the results of the meta-analysis.

4.3. Frequency of loss of abutment teeth retaining an overdenture

Due to the retrospective design of most of the included studies and the varying expose times of the abutment teeth, the cumulative loss had to be estimated. The mean observation period was multiplied by the numbers of lost abutment teeth; however this calculation is based on the assumption that the loss occurs at a linear rate. In reality it is more likely that the frequency will

augment exponentially with time, but this behavior could not be calculated without the source data of each study. Thus, the calculated annual loss of 1.76 teeth per 100 may be unrealistic for shorter observation periods, but is likely to be a good indicator for long-term observations — and would therefore predict a loss of 8.8 % of abutment teeth after 5 years, or 17.6 % of abutment teeth after ten years.

Again, one should not directly compare these figures to implant survival. The considerations to provide a patient with one treatment modality or the other vary considerably. Also, if maintained well, teeth will last a lifetime that is longer than implants [42]. However, this may not apply to endodontically treated teeth that experience high mechanical stresses as they retain the overdenture. Retaining an overdenture by natural roots or implants are complementary, and not competing, options. Reported implant survival varies between 73.0–95.5 % depending on the experience of the surgeon, whereas tooth survival rates after endodontic treatment is reported as 89.7 % or 98.1 % for general practitioners or specialists, respectively [43].

4.4. Biological complications

4.4.1. Caries

Caries represents one the main conditions that could result in the extraction of abutment teeth. Therefore effective caries prevention measures will increase the prognosis of both the abutment teeth and the prostheses. This is described in the study by Toolson and Smith [9], who advocated the use of fluoride to prevent caries in abutment teeth without cast copings. The plaque scores of the group of patients who continued using a fluoride gel were superior when compared to the group of patients who elected not to use the fluoride gel [9]. Over the course of the study 16 patients who used the fluoride had a total of 36 teeth, 35 of which had no caries present. In comparison the group of patients who were not using fluoride had a total of 94 teeth, of which 20 showed clinical signs of caries. The use of fluoride gel was shown to be an effective means to prevent caries on the retained overdenture abutments [9]. It has also been reported that caries development in overdenture abutments could be inhibited with a daily application of chlorhexidine–fluoride gel [44].

4.4.2. Periodontal disease

The maintenance of periodontal health appears to be another major challenge in overdenture wearers as periodontal complications have been shown to be a major cause of abutment loss [45–47]. The majority of the studies showed an increase in pocket depths around the abutment teeth over the observation periods. In general, after five years moderately deep pockets around the abutment teeth decreased; but the deeper pockets tended to remain [44].

Further studies showed no significant periodontal breakdown in despite of severely reduced periodontal support of many abutment teeth [11]. In many studies the periodontal health, while not optimal, was not responsible for the loss of a significant number of abutment teeth [9].

In the study by Yao et al. in 2013 [37] after 3 years, the gingival health in the magnetic attachment group was better than the ball-cap attachment group. However, the amount of attached tissue present decreased significantly between the 2nd and 5th year-recall examinations.

It must be stated how important mechanical cleaning and the use of fluoride is to prevent abutment tooth loss due to periodontal breakdown with RODs. In the study by Yao et al. [37], oral health maintenance and periodic checks after provision of the overdentures was shown to maintain abutment health and sustain long-term treatment effects. Fluoride-releasing materials such as glass ionomer cement could also be incorporated into coping materials to further decrease secondary caries and pocket depths. In a study by Toolson et al. with conventional overdentures [9], the plaque scores of the group of patients who were motivated to continue using fluoride gel were superior when compared to the group of patients who elected not to use the fluoride solution.

4.4.3. Tooth mobility

Coca et al. [29] also showed, that after 12 years, 73.7 % of the teeth had no mobility. Tooth mobility showed an interesting pattern especially after the reduction of the teeth for the cast coping. It was reported, also for abutment teeth without copings that after reducing the height of the abutment teeth to approximately 2 mm above the gingival margin there was a marked reduction in mobility [44].

The study by Yao et al. in 2013 [37] showed, that the mobility in abutment teeth restored with magnetic attachments was less than those with balls.

4.4.4. Tooth fracture

Fracture of abutment teeth was frequently reported. Reasons for this could be very wide or long cast posts [48], inadequate tooth preparation or overloading [49]. However, fracture of the abutment teeth was reported as a reason for tooth loss much less frequently than caries or periodontal breakdown. Monfrin et al. established that periodontal disease problems were the cause of 3 extractions, subgingival decay caused one and root fracture also one extraction [30]. In the retrospective study with the longest observation period by Angermeider and Stadelmann, 4 of 54 abutment teeth failures were reported as root fractures with caries and periodontal disease more frequent causes [35]. Schriber reported 3 out of 14 lost abutment teeth originated from fractures [28].

The type of attachments was too heterogeneous between the studies to perform a comparison between them. It would have been interesting to compare more rigid attachments like the Gerber cylinder or the Fae attachment to those that allow more degrees of freedom like the ball attachments or the magnets. However, we performed a subgroup analysis of cemented root caps with or without attachment and did not find a significant difference. We believe that the design of the overdenture, with an open or closed flange, might have a much more important influence; however there is rarely information on the specific denture designs marked in the available articles. Airoldi et al. described the “perio-overdenture” that is successfully used to provide partially edentate patients with root cap-retained removable prostheses. The root caps in this perio-overdenture are designed to support prostheses with an open design, thus facilitating oral hygiene and promoting periodontal health. [50]. The good results of the perio-overdenture according to the Zurich school with regard to the survival rate of the prostheses, the survival rate of the abutment teeth, the low caries incidence and the extremely low-inflammatory condition of the gingiva, suggest that the increased constructive effort for manufacturing the perio-overdenture compared to the conventional overdenture is worth it in long-term [28].

5. Conclusion

RODs often constitute the last resort before rendering patients completely edentate. They may aid in this transition, especially in very old patients with reduced adaptive capacities. With correct design, preparation and aftercare, RODs with cast coping still are a valid treatment option in partially edentulous patients.

References

[1] Slade GD, Akinkugbe AA, Sanders AE. Projections of U.S. edentulism prevalence following 5 decades of decline. J Dent Res 2014;93:959–65.
[2] Stock C, Jürges H, Shen J, Bozorgmehr K, Listl S. A comparison of tooth retention and replacement across 15 countries in the over-50s. Community Dent Oral Epidemiol 2016;44:223–31.
[3] Schneider C, Zemp E, Zitzmann NU. Oral health improvements in Switzerland over 20 years. Eur J Oral Sci 2017;125:55–62.
[4] Peltola P, Vehkalahti MM, Wuolijoki-Saaristo K. Oral health and treatment needs of the long-term hospitalised elderly. Gerodontology 2004;21:93–9.
[5] Tada S, Allen PF, Ikebe K, Zheng H, Shintani A, Maeda Y. The impact of the crown-root ratio on survival of abutment teeth for dentures. J Dent Res 2015;94:220S–5S.
[6] The Academy of Prosthodontics, Ferro KJ, Morgano SM, Driscoll CF, Freilich MA, Guckes AD, Knoernschild KL, et al. The glossary of prosthodontic terms: ninth edition. J Prosthet Dent 2017;117:e1–e105.
[7] Budtz-Jörgensen E. Prosthodontics for the elderly: diagnosis and treatment. Chicago, Berlin, London, Tokyo, Paris, Barcelona, Sao Paulo, Moscow, Prague, and Warsaw: Quintessence Publishing Co, Inc.; 1999.
[8] Carlsson GE. Implant and root supported overdentures — a literature review and some data on bone loss in edentulous jaws. J Adv Prosthodont 2014;6:245–52.
[9] Toolson LB, Smith DE. A five-year longitudinal study of patients treated with overdentures. J Prosthet Dent 1983;49:749–56.
[10] Ettinger RL, Jakobsen J. Denture treatment needs of an overdenture population. Int J Prosthodont 1997;10:355–65.
[11] Mericske EA, Mericske-Stern R. Overdenture abutments and reduced periodontium in elderly patients. A retrospective study. Schweiz Monatsschr Zahnmed 1993;103:1245–51.
[12] Van Waas MA, Jonkman RE, Kalk W, Van't Hof MA, Plooij J, Van Os JH. Differences two years after tooth extraction in mandibular bone reduction in patients treated with immediate overdentures or with immediate complete dentures. J Dent Res 1993;72:1001–4.
[13] Mericske-Stern R. Oral tactile sensibility recorded in overdenture wearers with implants or natural roots: a comparative study. Part 2. Int J Oral Maxillofac Implant 1994;9:63–70.
[14] Fontijn-Tekamp FA, Slagter AP, Van Der Bilt A, Van'T Hof MA, Witter DJ, Kalk W, et al. Biting and chewing in overdentures, full dentures, and natural dentitions. J Dent Res 2000;79:1519–24.
[15] Newton JP, McManus FC, Menhenick S. Jaw muscles in older overdenture patients. Gerodontology 2004;21:37–42.
[16] Basker RM, Harrison A, Ralph JP. Overdentures in general dental practice. Part 5 — the use of copings and attachments. Br Dent J 1983;155:9–13.
[17] Yang TC, Maeda Y, Gonda T. Clinical performance and satisfaction of removable prostheses with self-adjusting magnetic attachments. J Prosthet Dent 2014;111:131–5.
[18] Singer H, Frediani R, Vetturelli F. Overdentures on endodontically and periodontally treated roots. Quintessenz 1987;38:1989–99.
[19] Ettinger RL. Tooth loss in an overdenture population. J Prosthet Dent 1988;60:459–62.
[20] Hug S, Mantokoudis D, Mericske-Stern R. Clinical evaluation of 3 overdenture concepts with tooth roots and implants: 2-year results. Int J Prosthodont 2006;19:236–43.
[21] Moher D, Shamseer L, Clarke M, Ghersi D, Liberati A, Petticrew M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Syst Rev 2015;4:1.
[22] Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33:159–74.
[23] Higgins JP, Altman DG, Gøtzsche PC, Jüni P, Moher D, Oxman AD, et al. The Cochrane collaboration's tool for assessing risk of bias in randomised trials. BMJ 2011;343:d5928.
[24] Wells GA, Shea B, O'Connell D, Peterson J, Welch V, Losos M, et al. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. 2014 Available from: http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp. [Accessed 2 February 2018].
[25] Rantanen T, Mäkilä E, Yli-Urpo A, Siirilä HS. Investigations of the therapeutic success with dentures retained by precision attachments. I. Root-anchored complete overlay dentures. Suom Hammaslaak Toim 1971;67:356–66.
[26] Nagaoka E, Okuno Y. A case treated with overdenture utilizing a root-submergence procedure and its follow-up evaluation. J Osaka Univ Dent Sch 1981;21:233–44.
[27] Murakami M, Yoneda M, Asai K, Higashi H, Yoshida M, Takigawa H, et al. A clinical survey of overdentures with short metal copings. Gifu Shika Gakkai Zasshi 1985;12:36–48 [Article in Japanese].
[28] Schriber C. Erfahrungen mit der perio-overdenture; befragung und klinische untersuchung. Klinik für kaufunktionsstörungen und totalprothetik. Dr. med. dent. Zürich: University of Zürich; 1999 p. 83. http://www.recherche-portal.ch/ZAD:default_scope:ebi01_prod004583662. [Article in German].
[29] Coca I, Lotzmann U, Prisender K. A clinical follow-up study of magnetically retained overdentures (dyna-system). Eur J Prosthodont Restor Dent 2002;10:73–8.
[30] Monfrin SB, Previgliano V, Ceruti P, Preti G. A new coping for overdentures. Part 2: preliminary results of a clinical study. Int J Prosthodont 2007;20:179–80.
[31] Yang TC, Sugie M, Maeda Y, Ikebe K. Effects of different root coping materials for abutment teeth on secondary caries and periodontal conditions: a retrospective study. Int J Prosthodont 2012;25:63–5.
[32] Gonda T, Yang TC, Maeda Y. Five-year multicenter study of magnetic attachments used for natural overdenture abutments. J Oral Rehabil 2013;40:258–62.
[33] Manabe A. A clinical survey of partial dentures retained by precision attachments — changes in periodontal conditions of the abutment teeth. Nihon Hotetsu Shika Gakkai Zasshi 1976;20:156–72 [Article in Japanese].
[34] Ryuichiro O, Fumiko T, Jiro K, Akihiko N, Masatoshi I, Yosifumi H, et al. The clinical observation of early-type magfit. Gifu Shika Gakkai Zasshi 2006;33:33–7 [Article in Japanese].
[35] Angermeider MA, Stadelmann AR. Langzeitresultate von wurzelstiftkappen bei hybridprothesen. Eine retrospektive studie. Klinik für zahnärztliche prothetik. Dr. med. dent. Bern: University of Bern; 2008 [Article in German].
[36] Hirotomi T, Yoshihara A, Ogawa H, Miyazaki H. Tooth-related risk factors for periodontal disease in community-dwelling elderly people. J Clin Periodontol 2010;37:494–500.
[37] Yao X, Li YS, Dai YY. Comparison of magnetic attachment and ball-cap attachment for retained mandibular over-denture. CJTER 2013;17:8841–8.
[38] Shaw MJ. Attachment retained overdentures: a report on their maintenance requirements. J Oral Rehabil 1984;11:373–9.
[39] Brkovic-Popovic S, Stanisic-Sinobad D, Postic SD, Djukanovic D. Radiographic changes in alveolar bone height on overdenture abutments: a longitudinal study. Gerodontology 2008;25:118–223.
[40] Nagaoka E, Yamamoto T. A clinical survey of overdentures. Nihon Hotetsu Shika Gakkai Zasshi 1982;26:85–97 [Article in Japanese].
[41] Kido H. A statistical study of the clinical applications of the MAGFIT 600 dental magnetic attachment. Nihon Jiki Shika Gakkai Zasshi 1994;3:44–52 [Article in Japanese].
[42] Holm-Pedersen P, Lang NP, Müller F. What are the longevities of teeth and oral implants? Clin Oral Implants Res 2007;18:15–9.
[43] Setzer FC, Kim S. Comparison of long-term survival of implants and endodontically treated teeth. J Dent Res 2014;93:19–26.
[44] Budtz-Jörgensen E. Prognosis of overdenture abutments in elderly patients with controlled oral hygiene. A 5 year study. J Oral Rehabil 1995;22:3–8.
[45] Graser GN, Caton JG. Influence of overdenture abutment tooth contour on the periodontium: a preliminary report. J Prosthet Dent 1983;49:173–7.
[46] Renner RP, Gomes BC, Shakun ML, Baer PN, Davis RK, Camp P. Four-year longitudinal study of the periodontal health status of overdenture patients. J Prosthet Dent 1984;51:593–8.
[47] Salvi GE, Siegrist Guldener BE, Amstad T, Joss A, Lang NP. Clinical evaluation of root filled teeth restored with or without post-and-core systems in a specialist practice setting. Int Endod J 2007;40:209–15.
[48] Grieznis L, Apse P, Soboleva U. The effect of 2 different diameter cast posts on tooth root fracture resistance in vitro. Stomatologija 2006;8:30–2.
[49] Mezzomo E, Massa F, Suzuki RM. Fracture resistance of teeth restored with 2 different post-and-core designs fixed with 2 different luting cements: an in vitro study. Part II. Quintessence Int 2006;37:477–84.
[50] Airoldi RL, Allais G, Ernst B, Witt E, Palla S. Abutment tooth preparation for the perio-overdenture. A new technic for the preparation of the abutment tooth and the fashioning of the root cap for the perio-overdenture. Schweiz Monatsschr Zahnmed 1999;109:618–32 [Article in German].