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ORIGINAL ARTICLE

Complications of endodontically treated abutment teeth after restoration with non-precious metal double crowns

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Abstract

Objectives This study aimed to evaluate the effects of endodontic treatment on the complication rate in abutment teeth following double crown treatment.

Materials and methods Data of 233 patients supplied with 278 prostheses on 773 teeth were retrospectively analyzed. The 60-month cumulative complication rate for vital, root filled, and post and core reconstructed abutment teeth is calculated using the Kaplan-Meier method. Cox regression is performed to evaluate factors including age, sex, jaw, and tooth number.

Results After 60 months, the cumulative complication rate for all abutment teeth was 24.1% (CI: 19.7–28.5%). A significantly higher cumulative fracture rate (log-rank test, $p < 0.001$) was found for devital (51.7%; CI: 35.3–68.1%) compared to vital abutment teeth (20.6%; CI: 16.2–25%). Devital teeth restored with post and core reconstructions (46.3%; CI: 26.1–66.5%) showed a lower cumulative fracture rate than abutment teeth with only root fillings (60.9%; CI: 33.5–88.3%). Abutment teeth in severely reduced dentitions (≤ 3 teeth) were found to have significantly lower survival rates than abutment teeth in not severely reduced dentitions (≥ 4 teeth, $p = 0.031$, HR = 0.609).

Conclusion Lower abutment teeth survival rates were associated with non-vitality and a reduced number of abutment teeth. Devital teeth with post and core reconstructions showed higher survival rates than root filled devital teeth.

Clinical relevance After 5 years, devital teeth with double crowns have a fracture rate twice as high as vital teeth. This prognosis should be taken into account during treatment planning, especially in the severely reduced dentition.

Keywords Double crowns · Endodontic treatment · Post and core · Fracture rate · Complication rate

Introduction

The use of partial dentures anchored with double crowns has been an established therapy for decades [1, 2]. On average, such dentures have an effective lifetime of 6–10 years. A common reason for the eventual failure of partial dentures anchored with double crowns is the fracture of the abutment teeth. Depending on the study design, fracture rates ranging between 0.4% and 14.8% have been reported [1, 3–6].

Compared to that for vital abutment teeth, a worse prognosis is noted for endodontically treated devital teeth supplied with double crowns due to their susceptibility to fracture [7–9]. For single-tooth crowns, post and core systems do not reinforce devitalized teeth and should only be use for anchoring the crown if there is advanced coronary loss of tooth structure. To stabilize single-crown teeth, it is important to create a "ferrule design" during preparation [10–14]. However, it is unclear whether this generalization also applies to anchoring of double crowns for devital teeth. It is conceivable that the rigid physical frame present in double crowns leads to high tension in the tooth when there is strain in the area of the free-end saddle, especially in cases of severely reduced dentitions [15, 16]. Therefore, posts might possibly contribute to stabilization of these teeth.

This retrospective analysis, therefore, compared the fracture rates of root-filled, post- and core-treated double-crown abutment teeth, taking into consideration additional potentially influencing factors such as age, sex, jaw, and the number of abutment teeth.

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Materials and methods

We retrospectively analyzed the data of patients who received non-precious double crowns at the Department of Dentistry, Oral and Maxillofacial Medicine of the Martin-Luther-University between 2006 and 2016. The protocols were approved by the medical faculty's ethics committee at the Martin-Luther-University Halle-Wittenberg and conducted in accordance with the Declaration of Helsinki on ethical principles for medical research. Patients treated with high-dose irradiation were excluded due to possible radiogenic tooth damage [17].

Pretreatment

In accordance with the clinical guidelines of the Department of Prosthodontics at the Martin-Luther-University, all patients received a detailed clinical examination and screening. Conventional treatment, including preliminary periodontal treatment, build-up fillings, and functional preconditioning, was conducted where necessary.

In the case of devital teeth, root canal treatment and fillings were performed before the dental prostheses were manufactured (lateral condensation, ROEKO gutta-percha points, Coltène/Whaledent, Langenau, Germany, AH Plus, DENTSPLY DeTrey, Konstanz, Germany). Post-endodontically, teeth classified as having destruction degrees I–III (at least 2 cavity walls preserved) did not receive post and core reconstructions, according to the recommendations of Peroz et al., and were built up using only a dual-curing composite (LuxaCore Dual, DMG, Hamburg, Germany) [18]. Teeth with destruction degree IV (only one cavity wall preserved) received metal post and resin reconstructions (ER System, Komet Dental, Lemgo, Germany and LuxaCore Dual, DMG, Hamburg, Germany). Teeth with destruction degree V received non-precious cast post and core reconstructions (ER System, Komet Dental, Lemgo, Germany; and Okta-C, SAE Bremerhaven, Germany).

Double-crown-denture fabrication

The fabrication of double-crown-dentures was performed according to a standard protocol in the same dental laboratory (Rübeling+Klar Dental-Labor, Berlin, Germany). Materials used are listed in Table 1. Whenever possible, the preparation chamfer ended at least 2 mm below the reconstruction ("ferrule design") [10, 12–14]. Conventional tooth impressions were performed using polyether (Impregum, Permadyne, 3 M ESPE, Neuss, Germany). A wax template was used to record the jaw relationship, and this was followed by a try-in with a wax denture. Primary crowns were fabricated with a cobalt–chrome–molybdenum alloy with a 2°-groove angle (Okta-c, SAE Bremerhaven, Germany) and fit was controlled before fixation impression. After framework fabrication (Okta-M, SAE Bremerhaven, Germany), friction pins were inserted. Passive fit was gained by the spark-erosion procedure, where an insertion groove (0°) was placed in one approximal surface of the primary crown. The corresponding friction pin (Ø = 0.7–0.9 mm, Okta-C, SAE Bremerhaven, Germany) was fixed within the secondary crown by laser welding [19–22]. A final try-in was performed to assess jaw

Table 1 Composition of materials used for denture fabrication

	Material	Manufacturer	Composition
Sealer	AH Plus	DENTSPLY DeTrey, Konstanz, Germany	Bisphenol A diglycidylether, Bis-[4-(-2,3-epoxypropoxy) phenyl]-methane
Root filling material	ROEKO gutta-percha points	Coltène/Whaledent, Langenau, Germany	Guttapercha, zinc oxide bariumsulfate, coloring agents
Fabricated root posts	ER System ELO-Stift	Komet Dental, Lemgo, Germany	Titanium
Reconstruction filling	LuxaCore Dual	DMG, Hamburg, Germany	Acrylate
Impression material	Impregum/Permadyne	3 M ESPE, Neuss, Germany	Polyether
Cast posts, Primary crowns	Okta-C	SAE, Bremerhaven, Germany	Cobalt 60–66%, chromium 27–32%, molybdenum 5-7%
Secondary crowns Dentures frameworks	Okta-M	SAE, Bremerhaven, Germany	Cobalt 60–66%, chromium 27–32%, molybdenum 5–7%
Denture base material	FuturaGen	Schütz Dental GmbH, Rosbach v.d.H., Germany	Polymethylmethacrylat, dibenzoylperoxid, methyl-methacrylat
Prosthetic teeth	Primodent	Polident d.d., Dental Products Industry, Volčja Draga, Slovenija	Polymethylmethacrylate, dimethacrylates, pigments
Luting agent	Hoffmann's CEMENT normal setting	Hoffmann Dental Manufaktur, Berlin, Germany	Zinc oxide, phosphoric acid
Indicator silicone	Fit Checker TM Advanced	GC Corporation, Tokyo, Japan	VPES-Silicone, vinylpolyether

relation, occlusion, framework design, and esthetics. A significant emphasis was placed on aspects of denture design to facilitate periodontal health, and in the case of free-end saddles, maximum saddle extension (so called snow shoe effect) in combination with omission of the last molars to reduce load in the mucosal-supported areas. If dentures in the maxilla were not supported by molars on both sides, a transversal belt with a width of at least 10 mm was provided.

Primary crowns were fixed with zinc oxide phosphate cement (Hoffmann's CEMENT normal setting; Hoffmann Dental Manufaktur, Berlin, Germany) and the correct handling and maintenance of the dentures were explained to all patients.

Patient follow-up

All patients completed 6-month follow-up consultations. Subsequent dental check-ups were arranged depending on patients' individual needs. Whenever possible, biannual recalls were performed. At each follow-up, the basal fit of the denture was checked with an indicator silicone (Fit Checker Advanced, GC Corporation, Tokyo, Japan). Re-alignment was performed where necessary. Existing dentures were modified in cases of tooth loss due to extraction, or where decapitation of abutment teeth was required. Dental treatment or technical repairs were offered in cases of biological or technical failures.

Statistical analysis

Patients were divided according to the number of abutment teeth per denture: >3 teeth, not severely reduced dentitions (NSRD); ≤3 teeth, severely reduced dentitions (SRD). The treatment start date was defined as the day of final denture insertion. The date of abutment tooth failure was defined as the day on which the supporting function of the tooth was lost due to fracture or extraction. The last follow-up date was July 15, 2016, when the study was terminated. Anonymized data for survival analysis were acquired from the patient records.

Complication-free survival was determined using the Kaplan-Meier method 60 months after treatment, with 95% CIs used as random fluctuation ranges. The survival distributions between vital and devital abutment teeth, and devital abutment teeth with and without posts, were compared using the log-rank test. In order to set the factor "vitality" in relation to other factors which potentially influenced abutment teeth survival, Cox proportional hazards regression was performed with the following factors: age, sex, jaw, number of abutment teeth, and vitality. Significance was set at $\alpha = 0.05$. Analyses were performed using Microsoft Office Excel 2010 (Microsoft Corp., Redmond, USA) and IBM SPSS 25 (IBM Incorp., Armonk, USA).

Results

Patients' cohort

In the period from 2006 to 2016, 233 patients (52.4% men, mean age 62 years [range 24 to 87 years]) received dentures with non-precious double crowns. A total of 278 prostheses (132 maxillary [47.5%] and 146 mandibular [52.5%]) and 773 abutment teeth were recorded. Of these, 692 and 81 were vital and devital, respectively, before double crowns were fabricated (see Table 2). The median observation time was 39.5 months (range, 6.5–103.5 months). Nine patients died during the observation period, and 14 patients were lost to follow-up due to moving. Sixty-eight percent of all patients adhered to recommendations for biannual recalls.

Thirty-four devitalized teeth exhibited a degree of destruction of classes I–III and received only a root canal filling. Forty-five teeth were of class IV, and two of class V and received posts in addition to root fillings.

A total of 459 abutment teeth were located in residual dentitions with more than 3 residual teeth, thus being classified as NSRD, and 314 abutment teeth were located in residual dentitions with ≤ 3 residual teeth, thus being classified as SRD. A mean of 2.78 abutment teeth was utilized for each denture. Two hundred thirty prostheses were placed on natural teeth using exclusively double crowns. Twenty-eight prostheses had additional clasps and 15 had root post caps as additional anchoring elements. Another five prostheses were placed on double crowns but had implants in addition to the natural abutment teeth. All prostheses were placed periodontal/implant mucosal.

Of the 278 examined prostheses, 70 were relined during the observation period (34 maxillary prostheses, 36 mandibular prostheses). Of the 70 relined prostheses, 55 were relined once. Multiple relines were performed in 15 prostheses, with 11 and four prostheses being relined two and three times, respectively.

Table 2 Characteristics of abutment teeth [n = 773]

Abutment teeth	Variables	Number	Percentage
(n = 773)	Maxilla	376	48.6%
	Mandible	397	51.4%
	SRD	314	40.6%
	NSRD	459	59.4%
	Vital	692	89.5%
	Devital	81	10.5%
	Root filling	34	4.4%
	Root filling with post	47	6.1%
	Incisors	124	16%
	Canines	334	43.2%
	Premolars	233	30.1%
	Molars	82	10.6%
	Total	773	100%

Complications for abutment teeth

The average observation period was 39.5 months, with a maximum observation time of 103.5 months. A total of 84 abutment teeth fractured, of which 46 (34 vital, 6 root-filled, and 6 root-filled with posts) were directly extracted. Repairs were carried out on 38 other fractures. Due to another fracture, 5 (4 formerly vital, 1 root-filled tooth with post) of these repaired abutment teeth were extracted. Over the entire examination time, 10.9% of all teeth fractured. In addition to fractures, other complications for abutment teeth included caries (17 teeth), periodontal damage (15 teeth), and endodontic problems (15 teeth) (see Table 3).

Root canal treatment after double crown restoration

Of the 692 vital teeth treated with double crowns, 52 (7.5%) were subsequently given root canal treatments. Of the 81 (10.4%) teeth that had received root canal treatments before double crown restoration, 4 teeth endodontically re-treated.

Cumulative complication rate determined using Kaplan–Meier method – total number of abutment teeth

The cumulative complication rate for abutment teeth after 60 months was 24.1% (CI: 19.7–28.5%) for all types of complications (Fig. 1). The cumulative fracture rate of all abutment teeth was 17.2% (CI: 13.2–21.2%, Fig. 2).

Cumulative fracture rate determined using Kaplan–Meier method—vital vs. devital

After 60 months, the cumulative fracture rate for devital abutment teeth (47.5%; CI: 30.5–64.5%) was higher by a clinically significant amount, compared to that of vital abutment teeth (13.4%; CI: 9.8–17%; log-rank test, $p < 0.001$; Fig. 3).

Cumulative fracture rate according to Kaplan–Meier—root-filled vs. root-filled with post

After 60 months, the cumulative fracture rates for root-filled abutment teeth (57.1%; CI: 27.5–86.7%) and root-filled abutment teeth with posts (42.9%; CI: 22.5–63.3%) showed no significant differences (log-rank test, $p = 0.590$; Fig. 4).

Cumulative fracture rate according to Kaplan–Meier—SRD vs. NSRD

After 60 months, the cumulative fracture rates for NSRD denture teeth (12.3%; CI:7.9–16.7%) were significantly lower than for SRD dentures (24.5%; CI:17.5–31.5%, $p = 0.006$; Fig. 5).

Cox regression

For the multivariate Cox model, incisors and vital teeth were chosen as the reference for the analysis of tooth type and tooth vitality. The estimated HRs and 95% confidence intervals are presented in Table 4. Age, sex, tooth vitality, and residual dentition were found to have a significant influence on general abutment teeth survival.

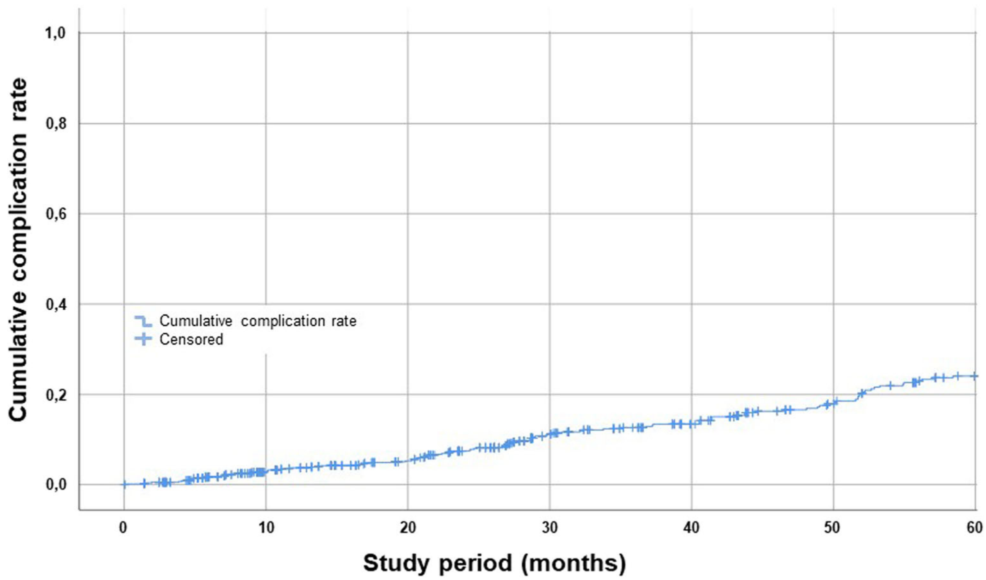
Discussion

Compared to previous reports, the number of patients and therefore abutment teeth formed a larger cohort in the present study [1, 2, 8, 23, 24]. After 60 months, the cumulative complication rate for abutment teeth was 24.1%, which was of a similar order of magnitude to that observed in other studies [1, 2, 25]. In the present study, the calculated fracture susceptibility rate of 10.9% was also within the range of values previously reported in the literature [1, 3–6]. Furthermore, the proportion of abutment teeth requiring endodontic post-treatment was within the range reported by previous studies (5.7–11%).

Table 3 Complication rates for the abutment teeth over the study period [$n = 773$]

Complications	Vitality			Total	
	Positive	Negative			
		Without post	With post		
No incident	587	21	34	642	83.1%
Loosening due to periodontitis	15	0	0	15	1.9%
Fracture	63	9	12	84	10.9%
Caries	16	1	0	17	2.2%
Endodontic problems	11	3	1	15	1.9%
Total	692	34	47	773	100%

Fig. 1 Cumulative complication rate of all abutment teeth



With regard to the cumulative fracture rate after 60 months, endodontically treated abutment teeth (47.5%) were found to be significantly more susceptible to fracture than vital abutment teeth (13.4%; log-rank test, $p < 0.001$). Other studies also arrived at comparable results to those observed here [2, 4, 5, 9, 26, 27].

In the present study, abutment teeth treated with post and core systems (42.9%) showed a lower fracture rate after 60 months than abutment teeth that underwent root filling treatment alone (57.1%), although the latter were initially less severely damaged. However, the difference between the two groups was not statistically significant. Cox regression showed that the failure risk of root-filled abutment teeth was nearly 350% higher ($p < 0.001$, HR = 4.467), and failure risk of root-filled abutment teeth that received post and core reconstructions was nearly 150% higher ($p = 0.006$, HR = 2.538), than the failure risk of vital abutment teeth (Table 4). This suggests that post and core reconstructions may be advised for root-filled teeth that are going to be restored with double crowns. Nevertheless, there is a dearth of other evidence from previous studies to support or refute this recommendation.

Dammaschke et al. (2003) conducted a study on the long-term survival of endodontically treated teeth, and reported an increase in the survival rate for teeth that underwent a combination of post and core treatment and crowning [28]. However, their study did not consider abutment teeth for removable dentures. In a follow-up investigation, Raedel et al. (2015) reported the lowest survival rates for teeth that received a combination of cast post and core treatments and double

Fig. 2 Cumulative fracture rate of all abutment teeth

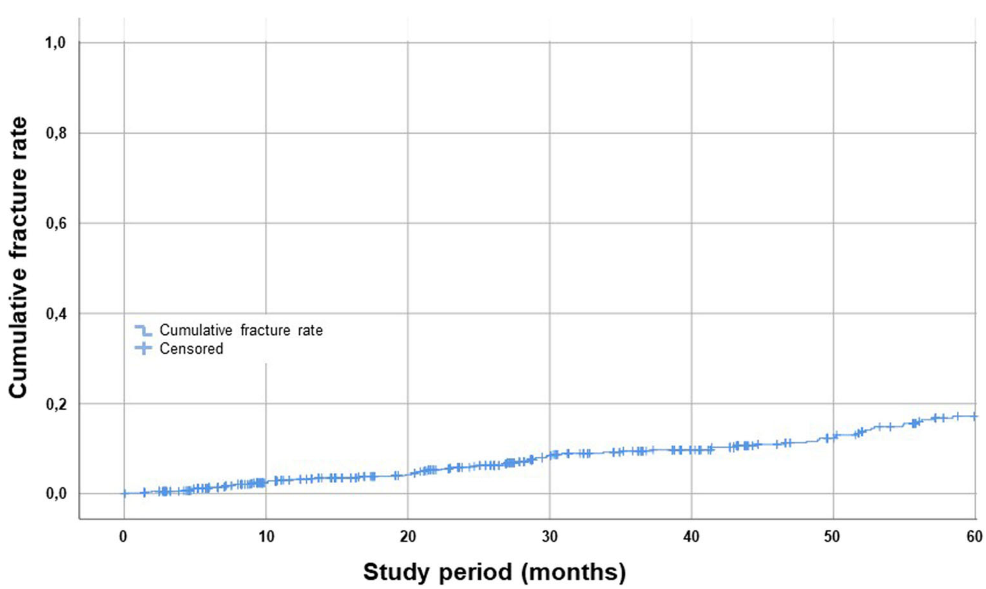
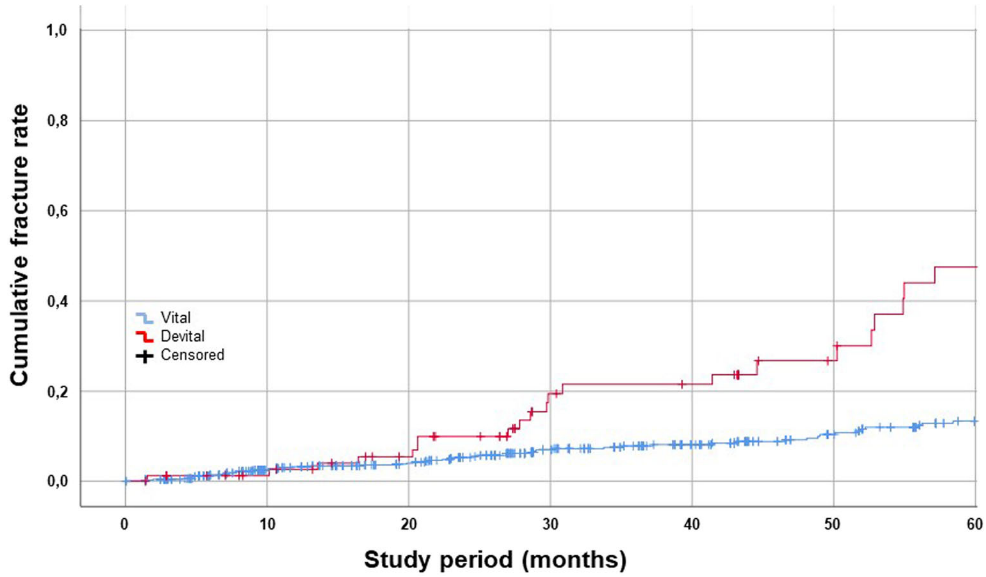


Fig. 3 Cumulative fracture rate as a function of vitality

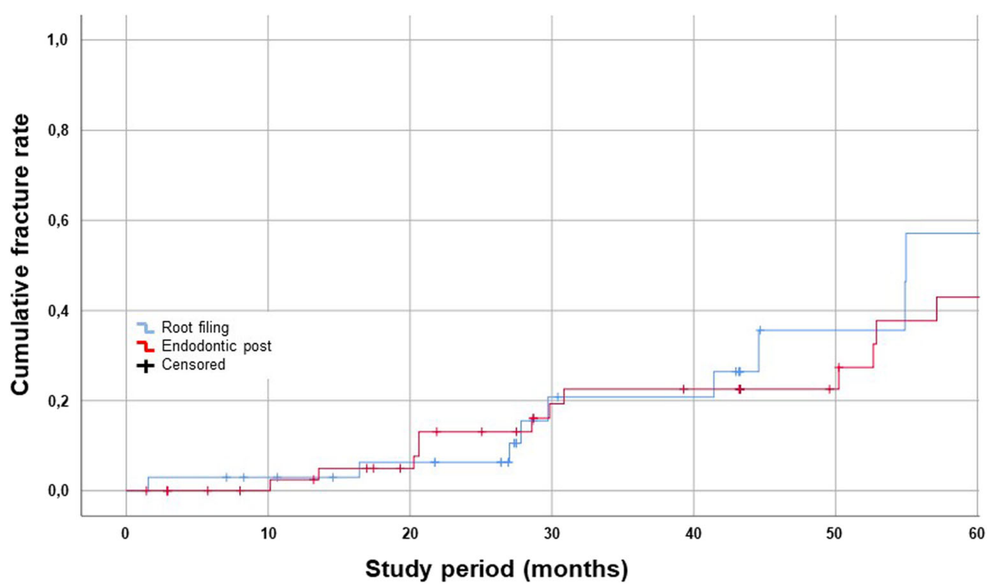


crowns, and the highest survival rates for fixed dentures. These results supported those of earlier studies conducted by Wegner et al. (2006) [9, 29].

A study by Naumann et al. (2016) showed that direct posts and cores are used in more than three quarters of cases for the restoration of abutment teeth prior to combined-fixed denture treatment [13]. In a model experiment with comparable destruction of the hard tooth tissues and a pronounced ferrule design, Mizuno et al. (2016) compared the loading of abutment teeth when using different direct posts and cores [30]. They reported that fiber-reinforced posts reduced stress concentration in the root compared to metallic posts with a plastic coating. As this type of post was not used in the present study, the results might have been different if fiber-reinforced posts were used. Nevertheless, it was ensured that a ferrule was prepared at least 2 mm apical to the chamfer margin. Thus, any difference in susceptibility to complications between root-filled teeth built up with composite, compared to those built up with metal post and resin reconstructions or cast post and core reconstructions, was expected to be minimal in the present study. In cases where an adequate ferrule was unable to be placed, surgical crown lengthening was performed, or the tooth was not restored with a double crown.

Prior studies have shown that the most favorable prognosis for endodontically treated teeth is achieved when adjacent teeth are present medially and distally, i.e., when proximal contacts are made through the neighboring teeth. This leads to stabilization of the teeth under pressure from chewing forces [31]. However, according to Sahin et al. and Saito et al., high tensions in terminal abutment teeth are expected

Fig. 4 Cumulative fracture rate as a function of post and core treatment before crowning



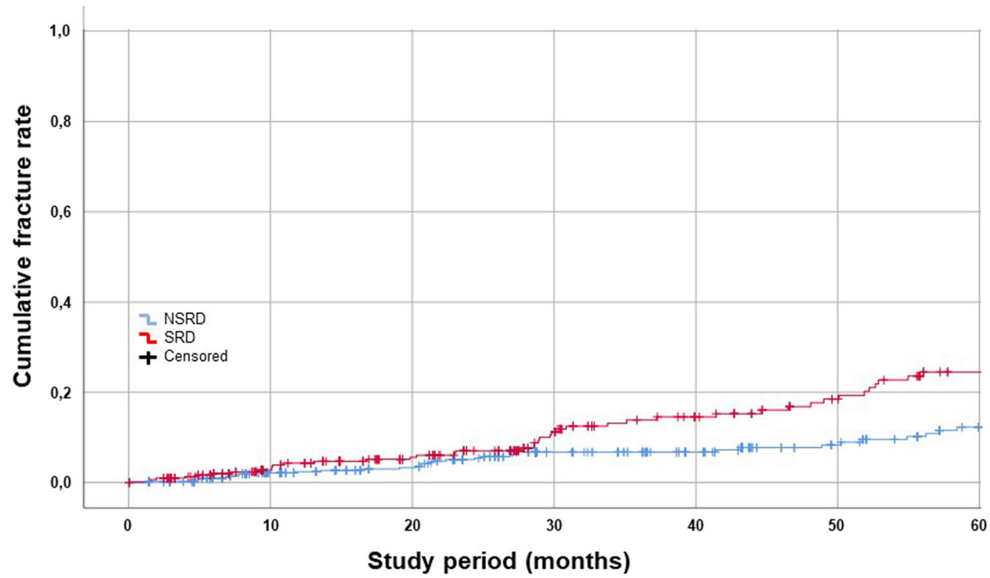


Fig. 5 Cumulative fracture rate as a function of the number of abutment teeth

when loading the free-end saddle for double-crown anchored dentures [15, 16]. This is in accordance with the findings of our study. Cox regression revealed that besides tooth vitality, the number of supporting teeth significantly influenced the survival rate of the abutment teeth (Table 4).

Thus, it should be noted that more than 40% of the abutment teeth were located in SRD. In such situations where there is a lack of proximal contacts, high vertical and horizontal loads on the remaining abutment teeth are expected. Cox regression revealed that SRD abutment teeth showed significantly lower survival rates than NSRD abutment teeth (p = 0.031). This is in accordance with the results of previous studies [32, 33]. In the current study, no further subdivision concerning tooth number and distribution was performed. Future studies should investigate this aspect more precisely in order to evaluate whether, especially in SRD, post and core reconstructions might be recommendable to increase abutment teeth survival.

Besides abutment tooth vitality and number, Cox regression revealed that age and sex were also significantly associated with abutment tooth survival rate. Females were found to have a 107% higher risk for abutment tooth failure compared to males (HR = 1.072, p = 0.001). This is in contrast to the results of Szentpétery et al. who found that telescopic crowns located in males provide higher survival rates than in females [5]. This discrepancy may have been due to differences in the study population and the proportion of SRDs included. Survival rate was found to decrease with increasing patient age (2.7% per year, p = 0.011). This might not be surprising, given the reduction of manual dexterity and associated difficulties with oral hygiene observed in older patients. Elders have also been shown to have more difficulties with denture removal and insertion, thus increasing the risk of biological or technical complications.

However, the reliability of our results has to be discussed critically. Data included in this study were analyzed retrospectively using patient records. Thus, several parameters potentially influencing abutment teeth survival, such as the incidence of parafunctional habits, were not considered. Moreover, observation range varied widely. Although a consistent treatment program was followed, different dentists with varying experience levels were involved in prosthesis fabrication.

Table 4 Hazard ratios of the different variables calculated with multivariate analysis

Variable		Hazard Ratio	95%–CI	p value
Age		1.027	1.006–1.049	0.011
Sex	Male vs. female	2.067	1.317–3.244	0.002
Jaw	Maxilla vs. mandible	1.042	0.647–1.678	0.866
Tooth type	Incisors vs. canines	1.120	0.571–2.198	0.742
	Incisors vs. premolars	0.760	0.366–1.579	0.463
	Incisors vs. molars	0.291	0.081–1.039	0.057
Tooth vitality	Vital vs. root filling	4.467	2.151–9.275	< 0.001
	Vital vs. root filling + post	2.538	1.304–4.941	0.006
Number of abutment teeth	SRD vs. NSRD	0.609	0.388–0.955	0.031

Conclusion

Devital abutment teeth showed higher complication rates compared to vital teeth. Abutment teeth treated using a post and core system were associated with a lower probability of complications than teeth that were exclusively root-filled and built up with composite. However, this difference was not statistically significant.

Moreover, the number of abutment teeth was found to be a relevant factor for abutment teeth survival. Further studies are necessary to evaluate the influence of post and core reconstructions on the survival rate of vital and devital abutment teeth in relation to their number and localization within the jaw.

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Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflicts of interest.

Ethical approval The protocols were approved by the medical faculty's ethics committee at the Martin-Luther-University Halle-Wittenberg and conducted in accordance with the Declaration of Helsinki on ethical principles for medical research.

Informed consent For this type of study, formal consent was not required.

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