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Original article

The 3-year cumulative survival rates of posterior monolithic zirconia crowns and their antagonist teeth, and their influencing factors

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Abstract

Purpose: The purpose of this study was to evaluate the 3-year cumulative survival rates of posterior single monolithic zirconia crowns (MZCs) and their antagonists, and to analyze the influencing factors.
Methods: The clinical outcomes of posterior single MZCs and their abutment teeth with antagonists, and the antagonists between April 2014 and September 2020 were evaluated retrospectively. The 3-year cumulative survival rates were calculated and associations between the survival time and predictor variables (“Jaw”, “Tooth”, and “Pulpal condition”) were also verified using Cox proportional hazards models and hazard ratios (HRs).
Results: The 3-year cumulative survival rate of single MZCs was 89.8% (9 of 177 MZCs, 95% confidence interval (CI): 80.0-95.1%). Cox proportional hazards models showed non-vital teeth were significantly associated with failure (HR: 2.76e + 9, $P = 0.012$). The 3-year cumulative survival rate of antagonists was 94.8% (7 of 171 antagonists, 95% CI: 89.3-97.6%). Non-vital antagonists were also identified as an independent predictor for failure in Cox proportional hazards models (HR: 7.83, $P = 0.03$).
Conclusion: Although posterior single MZCs were clinically acceptable, non-vital pulpal condition could be a potential risk factor for failures in the abutment and antagonist teeth of MZCs.

Keywords: antagonists, Cox proportional hazards models, cumulative survival rate, monolithic zirconia crown

Introduction

Monolithic zirconia crowns (MZCs) to restore natural teeth were introduced into clinical dentistry due to their excellent mechanical and biocompatible properties [1]. MZCs have been widely used to avoid the chipping and fracture of the veneering ceramic [2,3]. Although the thickness of MZC has been considered to be associated with fracture, some previous studies suggested that excellent mechanical properties as one of the features of MZC can allow less invasive preparation [4-6]. In addition, MZCs provide fewer adverse effects on periodontal tissues clinically [7-9]. These favorable features and predictable results from a number of clinical studies have rapidly increased the application of MZCs for the restoration in the posterior region [7-13]. Recent systematic reviews and meta-analyses also presented the clinical availability of MZCs from multiple points of view [14,15]. The procedures for MZC restoration including tooth preparation and cementation were stated in these studies [14,15]. This means that these well-established techniques lead to promising results and enhance the success and survival rates.

However, it is also important to identify the reasons for failures and complications in MZC restorations. In general, complications are classified into 2 categories: biological and technical complications [15,16]. Examples of biological complications include secondary caries, bleeding on probing, loss of abutment tooth vitality, and abutment tooth fracture. Examples of technical complications include chipping of veneering materials, loss of retention and fracture of framework. These complications were associated with the failures of MZCs and survival rates. However, it is noteworthy that a large number of reports have evaluated the wear of opposing antagonist teeth [17-23]. This concern was raised from the hardness of MZC. Although the surface roughness was also considered as one of the reasons for the wear of the teeth, the polished surface of MZC has been reported to cause less wear to enamel antagonists when compared to glazed zirconia in recent studies [24]. Two systematic reviews were conducted, one of which concluded that MZC caused similar or greater wear of opposed enamel compared to natural tooth and less wear caused by metal-ceramic [20]. The other showed that wear of antagonist teeth tends to be significant over time [21]. Polishing was considered to be effective for the prevention of antagonist enamel wear. Whereas the effect of MZC with high strength and hardness on antagonist wear has been investigated, few studies have examined the prognosis of antagonist teeth of MZCs. Some previous studies reported the complications of antagonist teeth, but not primary outcome [7,8,12].

The aims of this study were to evaluate the survival rates of single MZCs for natural teeth and their antagonist in premolar and molar sites, and to examine the factors related to the survival of single MZCs and antagonist retrospectively. The null hypothesis in the present study was that no factors affected the survival rates of single MZCs and their antagonists.

Materials and Methods

This retrospective study was undertaken in the Department of Prosthodontics, Kyushu University Hospital after the ethical approval by the institutional ethical review board (approval number: 2021-451). This study was prepared in accordance with the strengthening the reporting of observational studies in epidemiology (STROBE) statement.

Patients who satisfied the following inclusion criteria were enrolled in this study: 1) patients whose molars or premolars with antagonists (natural teeth, artificial teeth in removable dentures or implant-supported suprastructures) were restored with single MZCs between April 2014 and September 2020; 2) patients who were followed-up at least one time at 6 months or more after the delivery of single MZCs. However, patients who lost single MZCs within 6 months would be included. The exclusion criteria included 1) MZCs which had no occlusal contact with the antagonist; 2) MZCs whose antagonist teeth were not confirmed. In addition, an artificial tooth (a removable denture) was excluded in the analyses of antagonists. Patient profiles such as gender, age and Eichner classification were retrieved from a medical chart. Additionally, the information about abutment and antagonist teeth (teeth position and pulpal condition: vital or non-vital) was examined. To calculate the cumulative survival rate, the functional periods of single MZCs and antagonists after the delivery of single MZCs were also recorded. A single MZC that was in situ and used at the last follow-up visit was defined as the surviving MZC regardless of re-cementation due to crown detachment or minor fracture. An MZC which has been removed including tooth extraction at a follow-up visit was defined as a failure (not surviving). An antagonist tooth that needed the intervention (restorative and prosthetic intervention or tooth extraction) except for re-cementation and occlusal adjustment alone was defined as a failure.

Kaplan Meier curves were constructed to provide the cumulative survival rates of single MZCs and these antagonists up to 3 years. Cox

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Table 1 Distribution of 177 monolithic zirconia crowns and their abutment teeth

	Maxilla		Mandible		Total crowns
	vital	non-vital	vital	non-vital	
Premolar	3	28	15	30	76
Molar	11	32	12	46	101
Total crowns	74		103		177

Table 2 Cumulative survival rates of monolithic zirconia crowns (MZCs) up to 3 years

Month	Number of MZCs	Loss	Cumulative survival rate (%)	95% confidence interval
0-6	177	2	98.9	95.6-99.7
7-12	172	1	98.3	94.7-99.4
13-18	137	1	97.4	93.3-99.0
19-24	109	2	95.6	90.3-98.0
25-30	79	1	93.9	87.1-97.3
31-36	57	2	89.8	80.0-95.1

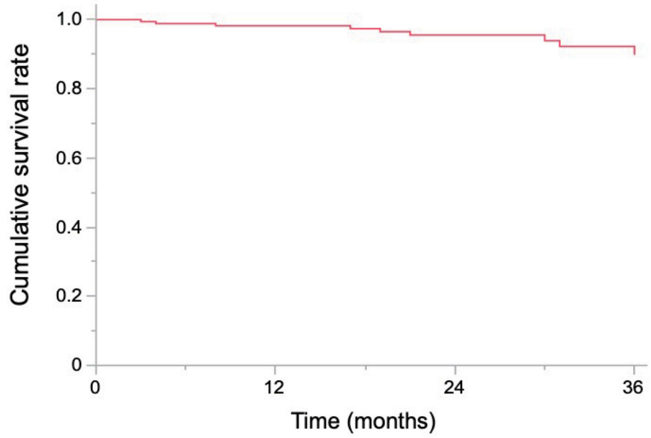

Fig. 1 Kaplan-Meier curve showing the cumulative survival rate of MZCs. Cumulative survival rate was 89.8% (95% confidence interval, 80.0% to 95.1%) at 36 months.

Table 3 Detailed information on the failed monolithic zirconia crowns

Case number	Age	Gender	Period (month)	Tooth number	Complication	Zirconia material	Cement	Eichner classification
1	78	female	4	36	root crack	Aadva NT	self-adhesive cement	A1
2	70	male	19	47	periapical periodontitis	Cercon ht	self-adhesive cement	A1
3	63	female	36	15	periapical periodontitis	Cercon ht	adhesive cement	A1
4	73	female	30	26	periapical periodontitis	Cercon ht	adhesive cement	A3
5	65	male	31	47	periapical periodontitis	inCoris TZI	adhesive cement	A2
6	71	female	3	46	root fracture	Sakura Zirconia	self-adhesive cement	A3
7	86	female	8	35	root fracture	inCoris TZI	adhesive cement	B2
8	69	female	17	15	root fracture	inCoris TZI	self-adhesive cement	A2
9	79	female	21	46	restoration fracture	Katana Zirconia	self-adhesive cement	A1

All failed abutment teeth were non-vital teeth

Table 4 Cox regression survival models for monolithic zirconia crowns (adjusted models)

		Total number	Number of failures	*P*-value	Hazard ratio	95% confidence interval
Jaw	maxilla	74	3	0.834	1	0.18-3.33
	mandible	103	6		1.16	
Tooth	premolar	76	3	0.183	1	0.07-1.59
	molar	101	6		2.72	
Pulpal condition	vital	41	0	0.012	1	0.00-0.01
	non-vital	136	9		2.76^{e+9}	

proportional hazards regression was used to investigate the association between the survival time of MZCs including abutment teeth or antagonist teeth and predictor variables (“Jaw”: maxilla or mandible, “Tooth”: premolar or molar, and “Pulpal condition”: vital or non-vital) and to calculate hazard ratios (HRs). These statistical analyses were conducted using a data analysis software (JMP Pro 16, SAS Institute Inc., Cary, NC, USA). The significance level in these statistical analyses was 5%.

Results

Totally, 105 patients (male: 25, female: 80) with 177 single MZCs were included in this study. The average age was 64.2 ± 11.3 years old. The average observation period was 22.7 ± 10.5 months. Table 1 shows the position of single MZCs and pulpal conditions. Of 177 abutment teeth, 139 teeth belonged to Eichner A group (78.5%), and 36 (20.3%) and 2 (1.1%) teeth belonged to Eichner B and C, respectively. Medical chart reviews demonstrated that 9 of 177 single MZCs were defined as failures. In addition, 4 single MZCs were detached and re-cemented. The 3-year cumulative survival rate of single MZCs was 89.8% (95% confidence interval: 80.0-95.1%) (Fig. 1). Detailed information on the cumulative survival rates of single MZCs is shown in Table 2, and Table 3 shows detailed information on the failed single MZCs. All failures were detected in non-vital abutment teeth, indicating that the 3-year cumulative survival rates of single MZCs with vital and non-vital teeth were 100% and 86.8% (95% confidence interval: 74.6-93.6%), respectively. Five abutment teeth (3.4%) were extracted due to root fracture (3 teeth, 1.7%) and periapical periodontitis (2 teeth, 1.1%). Three single MZCs were removed for endodontic treatment due to periapical periodontitis (1.7%). One single MZC was removed and refabricated due to the crack of MZC (0.6%). Cox proportional hazards regression revealed that a significant HR (2.76e + 9) was identified in non-vital abutment teeth ($P < 0.01$) because no vital teeth were defined as failures whereas no significant HRs were found in “Jaw” and “Tooth” (Table 4).

The profiles of 171 antagonist teeth in 101 patients (male: 25, female: 76) are shown in Table 5. The average age and the average observation period were 64.1 ± 11.5 years old and 25.5 ± 16.4 months, respectively. Antagonists included 31 implant-supported suprastructures (natural teeth: 140). Six artificial teeth in removable partial dentures were excluded. Of 171 antagonist teeth, 138 (80.7%) and 33 (19.3%) antagonists belonged to Eichner A and B, respectively. Seven antagonists (4.1%) were defined as failures and notably, 4 of them were observed within 6 months. Detachment was observed in 1 antagonist (0.6%). This was re-cemented uneventfully. The 3-year cumulative survival rate of antagonists was 94.8% (95% confidence interval: 89.3-97.6%) (Fig. 2). Detailed information on the cumulative survival rates of antagonist teeth is shown in Table 6, and Table 7 shows detailed information on failed antagonist teeth. In terms of pulpal conditions, which meant that implant antagonists were excluded, the 3-year cumulative survival rates of single MZCs with vital and non-vital teeth were 98.5% (95% confidence interval: 90.3-99.8%) and 88.6% (95% confidence interval: 75.9-95.0%), respectively. Two teeth were extracted due to root fracture and secondary caries. The failed antagonists included 2 vital teeth (chipping of restoration and pulpectomy for new restoration). In failed non-vital antagonists, 2 antagonists showed chipping of restoration (composite resin and veneered porcelain) and 1 antagonist showed crack

Table 5 Information on antagonist teeth

	Maxilla			Mandible			Total
	abutment teeth		implant	abutment teeth		implant	
	vital	non-vital		vital	non-vital		
Premolar	13	22	7	16	12	1	71
Molar	27	25	6	13	12	17	100
Total	40	47	13	29	24	18	171

Table 6 Cumulative survival rates of antagonist teeth up to 3 years

Month	Number of antagonist teeth	Loss	Cumulative survival rate (%)	95% confidence interval
0-6	171	4	97.7	93.9-99.1
7-12	164	0	97.7	93.9-99.1
13-18	129	2	96.0	91.2-98.2
19-24	100	1	94.8	89.3-97.6
25-30	73	0	94.8	89.3-97.6
31-36	52	0	94.8	89.3-97.6

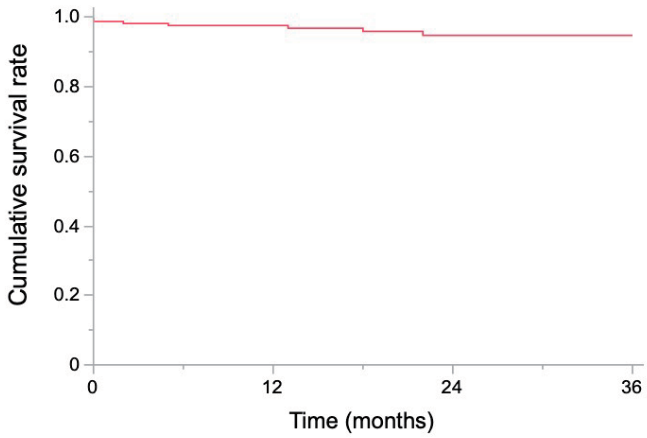

Fig. 2 Kaplan-Meier curve showing the cumulative survival rate of antagonist teeth. Cumulative survival rate was 94.8% (95% confidence interval, 89.3% to 97.6%) at 36 months.

Table 7 Detailed information on the failed antagonist teeth

Case	Age	Gender	Period (months)	Tooth number	Complication	Zirconia material	Cement	Pulpal condition	Eichner class
1	63	female	0	16	chipping of restoration (veneered porcelain)	Cercon ht	adhesive cement	non-vital	A1
2	76	female	0	24	chipping of restoration (composite resin)	inCoris TZI	adhesive cement	vital	B2
3	45	female	5	46	chipping for restoration (all-ceramic restoration)	FCZ crown	self-adhesive cement	non-vital	A1
4	65	female	18	47	crack of restoration (monolithic zirconia crown)	Cercon ht	self-adhesive cement	non-vital	B1
5	63	female	2	37	pulpectomy for new restoration	Cercon ht	adhesive cement	vital	A1
6	70	female	13	27	secondary caries	inCoris TZI	adhesive cement	non-vital	A1
7	70	male	22	27	root fracture	inCoris TZI	self-adhesive cement	non-vital	A3

Table 8 Cox regression survival models for antagonist teeth (adjusted models)

	Total number		Number of failures	*P*-value	Hazard ratio	95% confidence interval
Age			7	0.032		
Jaw	maxilla	100	3	0.168	1	0.63-13.44
	mandible	71	4		2.91	
Tooth	premolar	71	1	0.082	1	0.59-41.54
	molar	100	6		4.96	
Pulpal condition	vital	68	1	0.032	1	0.83-73.20
	non-vital	72	6		7.83	

of restoration (all-ceramic restoration), resulting in removal of restoration and new fabrication. Cox proportional hazards regression demonstrated that "Pulpal condition" was also a statistically significant factor (HR: 7.83, 95% confidence intervals: 0.83-73.2, $P = 0.03$), but not "Jaw" (maxilla or mandible) and "Tooth" (premolar or molar) (Table 8).

Discussion

This retrospective study examined the 3-year cumulative survival rate of single MZCs and their antagonists, revealing 89.8% and 94.8%, respectively. Although the 3-year follow-up is relatively short, some previous reports within 5 years demonstrated the clinical procedures which must be associated with clinical outcomes [10,14,15]. This study analyzed the clinical cases which complied with these indications as much as possible, and demonstrated relatively shorter 3-year clinical outcomes. The results suggested that a single MZC can be a clinically acceptable treatment option for posterior restoration due to the higher survival rate from the prognosis of abutment and antagonist tooth, although the survival rate of abutment teeth was comparatively lower than the previous reports [7-15].

The abutment and antagonist teeth included in this study were single teeth. Previous studies investigated the survival rate of single crowns or teeth [25-28] and these results might be applied to the reasons for failed teeth including the abutment and antagonist teeth. Above all, a report by Goodacre et al. reported the most common complications of single crowns, and these included endodontic disease, porcelain fracture, loss of retention, periodontal disease and caries [25].

The number of abutment teeth of single MZCs was 177 and 6 antagonists of them were removable dentures. In this study, MZCs and their abutment teeth with antagonists were included. Although occlusal force from removable dentures might be weaker, MZCs or abutment teeth with antagonists were defined as functioning teeth and were included. The number of non-vital (endodontically treated) teeth was 136 (76.8%). Notably, all failures were identified in non-vital teeth. Root fractures of abutment teeth were observed in 3 non-vital teeth after the delivery of single MZCs and 2 of them were founded within 1 year (3 months in Eichner A3 patient and 8 months in Eichner B2 patient). Root fracture is one of the common complications in non-vital tooth and is caused multifactorially [29-31]. Previous studies also reported root fractures of abutment teeth [9-11,13], although they were not common in failed teeth. This result might be attributed to the conditions of abutment teeth (coronal and radicular tooth structure, dentin thickness, occlusal force and so on). This study could not evaluate these factors due to the fact that it was a retrospective study. Two root fractures within 1 year were founded in patients with Eichner A3 and B2. A future study might focus on the effect of the number of occlusal supports on the prognosis of MZC and its abutment tooth. Periapical periodontitis was observed in 5 abutment teeth and 2 of them were extracted, although no secondary caries was identified. Some previous studies reported these complications in definite proportions [10,13]. These findings suggested that the diagnosis of abutment tooth and patient's characteristics prior to the restoration procedure influenced the prognosis of a single MZC. Meanwhile, crack of MZC, one of major technical complications, was found in one MZC. It is well-known that multiple factors were related to chipping, crack, fracture or load-bearing capacity of MZC and these technical complications might be related to the procedure including preparation and dental laboratory work based on the previous reports [4-6, 32-35]. In addition, 4 MZCs were detached and re-cemented. Similar to chipping, crack or fracture, proper bonding procedure plays a critical role in enhancing bond strength [36].

To the best of the authors' knowledge, no research has reported the prognosis of opposing antagonist teeth of MZCs as a primary outcome, although some studies reported the complications of antagonist teeth [7,8,12]. The 3-year cumulative survival rate of the antagonists of single MZCs was 94.8% as described above. Technical complications such as chipping and crack might be associated with the mechanical features of single MZC, although these complications were limited. However, 3 of 4 technical complications were founded within 6 months and might be attributed to insufficient occlusal adjustment in addition to superior mechanical feature of MZCs. Especially, chippings of restorations were found in 2 antagonists immediately (within 1 month) and this could also be attributed to mandibular lateral movement or chewing condition including food hardness. Two antagonists were extracted due to secondary caries and root fracture, and one antagonist had pulpectomy for new restoration. As mentioned above, these interventions are required to some extent and the higher cumulative survival rate of antagonists suggested the clinical availability of single MZC applications.

Cox proportional hazards regression models identified a significant association between "Pulpal condition" and the prognosis of abutment and antagonist teeth of single MZCs, although "Jaw" (maxilla or mandible) and "Tooth" (premolar or molar) did not show any significant associations. A previous study by Solá-Ruiz et al. also evaluated the effects of these 3 factors on survival rates and concluded that there were no significant differences between survival rates and them. However, previous studies also demonstrated that significantly superior outcomes of vital teeth were reported [37,38]. Non-vital teeth had additional prognostic factors including pre- and post-root canal treatment factors (e.g. remaining tooth structure, presence of cracks or quality of root filling) [39]. In general, non-vital teeth were biologically inferior to vital teeth and it was understandable that more complications were founded in non-vital teeth. Some considerations should be given to improve treatment planning and to inform patients of the clinical situations.

The limitation of the present study was that the data collected from the medical chart was not sufficient for detailed information. All procedures for the fabrication and delivery of MZCs could not be clarified including the remaining coronal and radicular tooth structure and dentin thickness, which could be considered to be critical for the prognosis of teeth. Well-established procedures for MZC restoration including tooth preparation and cementation have been reported [4-15] and a prospective study based on these procedures will be required. Further analyses to evaluate the effect of the occlusal support, the precondition of abutment teeth such as the remaining tooth structure, and the survival rates of other remaining teeth on the prognosis would be important from the prosthetic point of view.

Conflict of interest

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. One of the authors (K.K.) belongs to the Division of Advanced Dental Devices and Therapeutics, Faculty of Dental Science, Kyushu University. This division is endowed by GC Corporation, Tokyo, Japan. However, GC Corporation did not play any role in this study and no funds from GC Corporation were received as stated above.

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