Sci Forschen
Open HUB for Scientific Research

International Journal of Dentistry and Oral Health
ISSN 2378-7090 | Open Access

RESEARCH ARTICLE

Volume 7 - Issue 5

Which Factors have an Impact on the Retention of Cemented Crowns on Implant Abutments? A Literature Review

Elisabeth Prause[1,*], Martin Rosentritt[2], Florian Beuer[1], and Jeremias Hey[1]

[1]Department of Prosthodontics, Geriatric Dentistry and Craniomandibular Disorders, University Charité Berlin, Berlin, Germany
[2]Department of Prosthetic Dentistry, UKR University Hospital Regensburg, Regensburg, Germany

***Corresponding author:** Elisabeth Prause, Department of Prosthodontics, Geriatric Dentistry and Craniomandibular Disorders, University Charité Berlin, Berlin, Germany, Tel: +49 (0) 30 450 662 557; E-mail: elisabeth.prause@charite.de

Received: 21 Jul, 2021 | **Accepted:** 20 Aug, 2021 | **Published:** 27 Aug, 2021

Citation: Prause E, Rosentritt M, Beuer F, Hey J (2021) Which Factors have an Impact on the Retention of Cemented Crowns on Implant Abutments? A Literature Review. Int J Dent Oral Health 7(5): dx.doi.org/10.16966/2378-7090.378

Abstract

Background: The review presents the scientific state of the art in the field of cementation of crowns on implants. Because semipermanent cements have been specially developed for the cementation of crowns on implants, the question arises whether this cement group offers an advantage compared to other available and widely used cements in everyday clinical practice. Various factors play a role on the retentive strength of superstructures on implants and should therefore be taken into account in this review.

Materials and methods: A thorough search of the literature, mainly PubMed as well as a manual search, was conducted between 2005 and 2020 to screen relevant articles for data regarding retention forces of different cements used on single crowns and implants by three independent investigators. 37 studies were included in this review because they met the inclusion criteria (prospective and an *in vitro* study design about implant-supported single crowns; English language; all-ceramic or metal-ceramic superstructures on titanium or zirconia implants) and did not relate to the exclusion criteria (fixed dental prostheses, articles describing other studies; reviews and clinical studies; screw-retained single crowns; neglecting the focus on the retention force after cementation).

Results: In recent years, a high number of various cements for use on implants have been scientifically investigated. A wide range of retention values have been published for each cement type. Furthermore, various influencing factors exist regarding retention of semipermanent cements. Significant correlations have been demonstrated between retention force and cement type, crown pretreatment, taper, abutment surface, internal surface cleaning, cement gap, and the presence of grooves on the abutment (Pearson's bivariate correlation; $P<0.01$ and $P<0.05$). Artificial ageing, such as a chewing simulation, have been neglected so far in the majority of studies. Thermocycling mostly reduced retentive strength.

Conclusion: This review revealed that there are several influencing factors on the retention of crowns which were temporary cemented on implants abutments. It could be shown that there are significant correlations between retentive strength and different parameters. Due to the inconsistent data situation caused by noncomparable study methodologies, the question of the whether semipermanent cements is superior to the conventional definitive or conventional provisional cements available cannot yet be answered.

Keywords: Implantology; Cementation; Semipermanent; Single crowns; Retention

Abbreviations: N: Newton; CAD/CAM: Computer Aided-Design/ Computer Aided-Manufacturing

Background

Implant-supported crowns can be retained by screws or cement. The advantages of screw fixation primarily affect the peri-implant tissue [1]. A further advantage is the option of accessing the screw channel to loosen or reattach the implant-supported restoration easily [2-5].

Technical complications, including loosening or fracture of the abutment screw, occurred significantly more often with screw-retained single crowns than they did with cement-retained single crowns [6]. Although cemented crowns on implants have a lower rate of technical complications compared to screw-retained crowns, they are often only temporarily cemented.

The advantage of cementation is that it is independent of the axial alignment of the implants. Esthetic limitations caused by the visible access are eliminated with cementation [7]. Finally yet importantly, the clinical procedure of cementation is firmly anchored in the everyday practice of dentists. The procedure can be carried out routinely [3,8].

With regard to cementation of the superstructure on implants, a distinction is made between temporary and permanent cements. The bond strength values differ significantly between the bond to implant abutments and natural teeth. In particular, zinc phosphate, zinc polycarboxylate and glass ionomer cements showed a wide range between retention values [9-12]. Nevertheless, these cements, including self-adhesive resin cements, are used for permanent cementation of single-tooth crowns on implants [13]. They also serve as comparative values in scientific studies regarding retention values [4,10,13,14]. However, provisional cements, such as zinc oxide or eugenol cements, have been recommended for cementation in other studies because of the possibility of retrievability [4,13,15,16] and to allow non-destructive removal of the crown in case of screw loosening. Different studies have described and recommended this treatment option [17-19]. A disadvantage is that temporary cements have poor physical properties. These include high solubility and low tensile strength [4,13,16].

Previous studies have recommended that definitive cements should be used for the cementation of single-tooth restorations and provisional cements for the cementation of multi-unit restorations [9,20,21], as larger restorations may be more likely to require retrievability. Definitive resin cements are the cement of choice for definitive cementation of single-tooth restorations [9,22,23]. In general, there is a disagreement as to whether temporary or definitive cements should be used for superstructures on implants [17,18,20,24].

Furthermore the industry offers special cements (ie, semipermanent cements) for the use on implants. They have become popular in recent years because they combine the advantages of removability and increased retentive strength [25].

Because implant abutments are not susceptible to caries, it appears that in addition to the classical properties of cements, such high biocompatibility, low solubility, easy manipulation, and a sufficiently long working time [26,27], the primary focus is on the required retention. It should be high enough to prevent spontaneous loosening of the crown. Furthermore, semipermanent cements should have the property whereby the restoration can be detached from the tooth or abutment without destruction.

Currently, no official classification exists for provisional, semipermanent, and definitive cements regarding retention values.

It is known that there are various factors influencing successful cementation and adequate retention. A cement gap of 20-40 µm is considered ideal [13,28-31]. This should allow the outflow of excess cement and consequently guarantee adequate seating forces of the restoration [13]. Other influencing factors such as the abutment surface size, the taper, the geometry of the abutment or the pretreatment of the internal surface of the crown have already been investigated in previous studies and identified as factors influencing retention [18,32-34].

To test the hypothesis that different factors have an influence on retention of temporary cementation of crowns on implant abutments and semipermanent cements do not have relevant advantages compared to conventional definitive cements and conventional temporary cements, a thorough search of the literature was conducted to summarize the data gained so far about cementation on implants.

Materials and Methods

For this review, a thorough search of the literature was done. The primary database used was PubMed. Additionally, the search was supported by a manual search to check references of relevant studies to find more useful publications. Inclusion, exclusion, and eligibility criteria were calculated to develop a specific search strategy (Tables 1-5). The time range of 2005 to 2020 was chosen for selecting the

Table 1: Inclusion criteria.

Study Design	Prospective; *in vitro*
Language	English
Prosthetic type	Implant-supported single crowns
Material (superstructure)	All-ceramic, metal-ceramic
Material (implant + abutment)	Titanium, zirconia
Year of publication	2005-2020

Table 2: Eligibility criteria.

Eligibility criteria
Any kind of root-form implant with a single crown as the superstructure cemented with different types of cements (definitive, semipermanent, and temporary) to compare retention values after pull-off tests. There were no restrictions regarding the type of implant.

Table 3: Exclusion criteria.

Exclusion criteria
Fixed dental prostheses
Articles describing other studies
Reviews and clinical studies
Screw-retained single crowns
Focus not on retention force after cementation

Table 4: Overview of the average retention forces for different kinds of cementation.

Cementation	Retention (N) (after water storage)	References	Duration
Temporary	7-100	Botega 2004 [35]	Weeks
		Lehmann 1976 [36]	
		Mehl 2010 [3]	
		Breeding 1992 [17]	Medium to long term
Semipermanent	50-200	Covey 2000 [37]	
		Di Felice 2007 [38]	
		Dudley 2008 [23]	
		Kaar 2006 [39]	
Definitive	Polycarboxylate cements: 307 ± 96	Mehl 2013 [3]	Long term
	Resin-based cements: 480 ± 48		

Table 5: Percentage changes of the decementation load related to abutment height for different cement classes.

Cement	Changes of the decementation load (%)	
	4.0 mm	5.5 mm
Zinc oxide, eugenol-free	-45	-90
Zinc phosphate	-4	+92
Glass ionomer	+23	+33
Resin based, self-adhesive	+35	+16
Methacrylate based	-80%	-68%

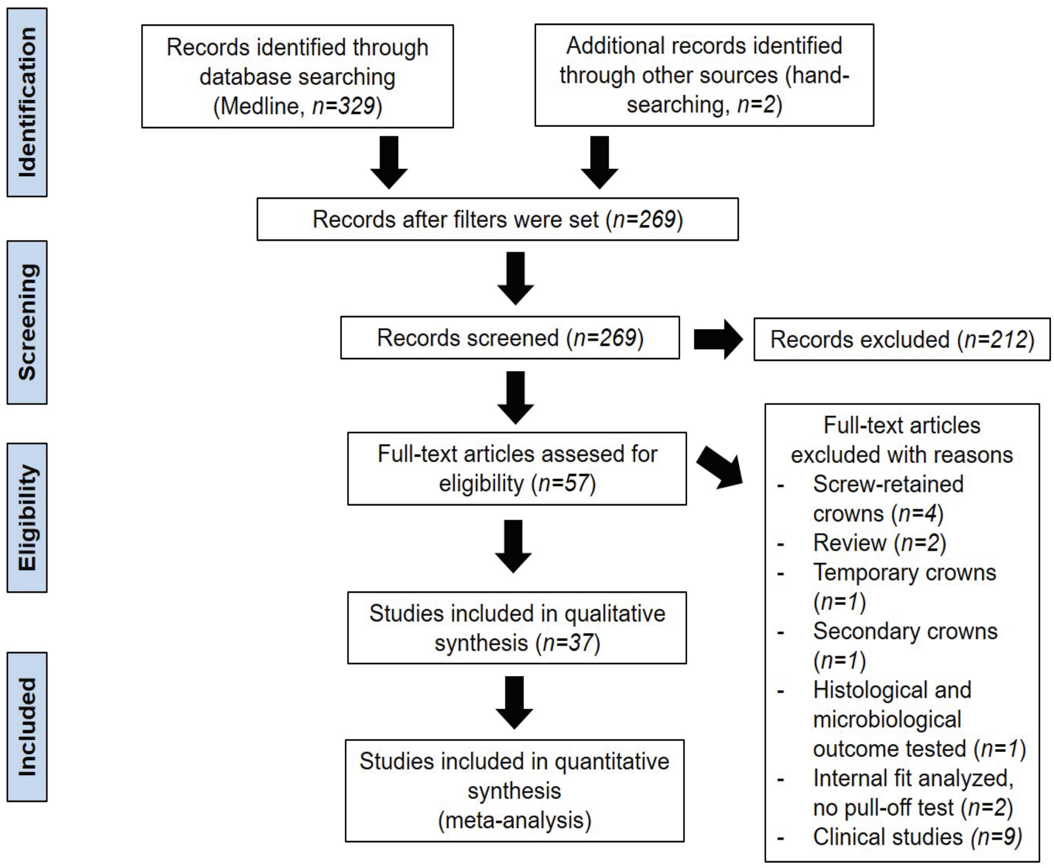

Figure 1: Study selection.

studies (Table 1). The following article types were chosen: journal article, case report, classical article, clinical study, and clinical trial protocol. Regarding the search strategy, a combination of medical subject heading terms and free text words was applied. Various keywords were used to find relevant articles appropriate for answering the hypothesis ("dental AND implant AND crown AND cementation AND retention" and other combinations).

The retention forces found in the studies and the factors influencing them were summarized in table 6. The correlation between relevant factors and the retention force was determined using Pearson's correlation test (IBM SPSS Statistics for Windows, version 27.0. Armonk, NY, USA, 2020) (Table 7).

Results

Study selection

The results of the literature search were 329 hits for the Medline search for the period between 01/01/2005 and 12/01/2020 (last search date: 12/22/2020). For these initially identified papers, 60 articles were excluded because they did not meet the inclusion criteria (Tables 1,3). Two hundred and sixty-nine were screened regarding the titles and abstracts. A further 212 articles were excluded because of the mentioned inclusion and exclusion criteria (Tables 1,3). From checking references, 2 additional articles were found that met the criteria. As a result, 57 articles were evaluated by full-text analysis. In the end, 37 articles were used as data for the analysis in this review (Figure 1, Table 7).

Comparison of retentive strength for different types of cement

The literature search revealed the following retention values for temporary, semipermanent and definitive cements: For temporary cements, it is important to know the range in which the retention force may be in order to be able to remove the restoration undamaged. At the same time, the retention must be appropriately high to prevent loosening of the crown in everyday use [15,17]. For temporary cementation retention values between 7-100 Newton (N) are considered appropriate (Table 4) [3,35,36]. The minimum value of 7 N results from the retention values for partial dentures that generate sufficient denture retention in the range of 3.5-7 N [35,36]. The maximum value of 100 N is based on investigations by Mehl C, et al., [3]. Therefore, the number of strokes needed to loosen a cemented implant crown from an abutment was measured [3]. A static force of about 21 ± 5.6 N per blow and 10 attempts on average were needed for a dentist to loosen the crown. The upper limit was set to 100 N, which corresponds to approximately 5 blows [3].

For semipermanent cementation, retention values between 50 and 200 N were measured (Table 4) [17,23,37-39]. In this area, sufficient retention of the crown on the abutment should be ensured. Alternatively, damage-free removal of the crown should be possible if required. Therefore, resin cements with low solubility have been developed in recent years. However, only limited data are available regarding retention values of these newly developed resin cements

Table 6: Significant correlations between retention force and various parameters as well as the P value.

Parameter	Retention in Newton (N)	P value
Cement	-0.205**	0.000
Pretreatment internal crown surface (sandblasting)	0.158**	0.000
Taper	-0.211**	0.000
Cleaning internal crown surface (alcohol)	-0.153**	0.001
Abutment surface size	-0.118*	0.034
Cement gap	-0.232*	0.031
Grooves on abutment	0.139**	0.002

*P< 0.05, **P< 0.01

created especially for semipermanent cementation of superstructures on implant abutments [13,15,40].

As representatives of the definitive cements, glass ionomer cements, polycarboxylate cements, and resin-based cements were used and tested in most studies [4]. After 3 days of water storage and a pull-off test, the following retention values were obtained for the cements mentioned for a 50 µm cement gap: glass ionomer cements 144 ± 53 N; polycarboxylate cements 307 ± 96 N; and resin-based cements 480 ± 48 N (Table 4) [4].

Parameters influencing retention forces

Cement film thickness: The included studies that examined the cement film thickness showed that for the glass ionomer cement, retention was reduced by 28% between the 50 µm cement gap and the 80 µm cement gap, respectively, and the 110 µm cement gap. The same did the polycarboxylate cement (-69%). The resin-based cement showed homogeneous values for all 3 cements' gap thicknesses [3].

Furthermore great differences existed between the retentive strength before and after thermocycling for the tested temporary cements [41]. Retention values were significantly lower after thermocycling and it also influenced the cement film thickness significantly [41].

Artificial ageing

Artificial ageing (thermocycling) showed in the majority of the studies that retention decreased afterwards [9,14,24,40-56]. Studies that carried out measurements before and after thermocycling published reduced retentive strengths of about 68% for noneugenol acrylic/urethane resin-based temporary cement, 88% for zinc oxide noneugenol cement, and 94% to 98% for 3 different dual-polymerizing semipermanent resin cements [43].

Effects of compressive cyclic loading on the retention of implant-supported crowns are only available to a limited extent [40,50,51,53,57,58]. Compressive cyclic loading leads to a reduced retention of the superstructure of about 50% for glass ionomer cement, 53% for compomer cement, and 59% for resin urethane-based cements [58].

Sandblasting

The majority of included studies performed sandblasting as a pretreatment of the internal surface of the crowns. The influence of thermocycling and sandblasting on retention was found to affect both components more or less significantly, depending on the cement type [14]. Zinc oxide cements showed the highest retentive strength. Sandblasting was effective for improving the durability. For the other tested cements, the effect of sandblasting was negligible. The retentive strength of zinc oxide cements decreased significantly after thermocycling, even with sandblasting. Consequently, zinc oxide cements were not recommended for the cementation of single crowns on implants [14].

Different geometry of the abutments

With regard to 2 different abutment heights (4.0 and 5.5 mm), it was shown that a higher abutment exhibited higher retention values for all tested cements except zinc phosphate cement after water storage (Table 5).

Bivariate correlation analysis

Pearson's correlation results revealed significant correlations between retention force and various parameters (Tables 6,7). The correlations were significant at the level of $p<0.01$ and $p<0.05$, 2-sided, respectively.

Discussion

Regarding the hypothesis that different factors have an influence on retention of temporary cementation of crowns on implant abutments, this literature review showed, that significant correlations between some factors could be proven. As a consequence, when interpreting the retention, it is important to note that it depends not only on the cement properties but also on factors such as the abutment geometry (angle, length, taper and height) and the surface size of the abutment [4]. A significant correlation between retention force and the taper could be shown. The usual taper of abutments is 6° [4]. Smaller tapers increase the retention, but make cement flow more difficult and can lead to an increase of the occlusion. Larger conicities lead to increased pull-off forces acting on the cement. Retention is therefore closely related to the preparation and decreases with increasing taper [2].

Furthermore the abutment surface size and the abutment geometry (grooves) showed significant correlations regarding retention force. In general, factors such as the abutment height, the diameter, and the surface area have a positive effect on the retention of crowns on abutments [54,59-64]. Height and surface are closely related [7]. The higher the surface and the height of the abutment are, the higher the retention is [3,18]. The effect might lose importance when adhesive resin-based cements were used [59]. Axial wall modifications also showed positive effects on retention [65]. Other surface configurations did not always show higher retention values [24]. Additional grooves also increased retention [44]. However, Carnaggio TV, et al., [59] used 3 abutments of different surface sizes (42, 60, and 82 mm^2). The results were heterogeneous because the height of the different abutments was the same. Only the circumference was increased. Therefore, there is no linear relationship and a corresponding increase in the pull-off forces between the smallest and the largest abutment surface. For the 2 self-adhesive resin cements, retention values increased by 24% and 73% from the 42 to 82 mm^2 abutment surface. However the resin-modified glass ionomer cement showed the opposite development (-42%). Zinc oxide, noneugenol cements only exhibited increased retention values of about 37% between the smallest and the largest abutment surface sizes. The acrylic-urethane provisional cement showed the highest retentive strength at the middle-abutment surface size.

The cement gap also showed a significant correlation regarding retention. According to Mehl C, et al., [3], the cement film thickness has an influence on retention of the superstructure even if crowns are designed with the help of Computer aided-design/Computer aided-manufacturing technology (CAD/CAM) to obtain identical restorations and thus to obtain a homogeneous cement gap [3]. In addition, each specimen, consisting of a crown and abutment, should only be used once to eliminate possible sources of error [59]. Cement residues could damage the abutment surfaces during cleaning. A second cementation would falsify the results [59].

A precise statement with regard to the hypothesis regarding semipermanent cements cannot be made at this time. It can neither be confirmed nor completely rejected. The data situation is heterogeneous. A clear definition of the term semipermanent cementation does not yet exist. Based on this review, a precise definition cannot be established. The biggest problem here is the durability of the crown and various influencing factors. An unambiguous classification into definitive, semipermanent, and temporary cements is hardly possible. In general, retention values of the individual cements differed greatly in various studies. Therefore, some studies published guidelines for clinicians because no cement served for all demands [13,66]. Furthermore, the retention values were very different in the individual material classes and therefore not comparable [13]. In detail, it was found that glass ionomer cements might be suitable for semipermanent cementation [4,41,45,46,60] because retention forces should lie between 50-200 N for semipermanent cementation [17,23,37-39]. Glass ionomer cement develops its full retention over time. In most studies, pull-off tests were immediately performed 24 hours from when the cementation took place. At this time, full retention of the glass ionomer cements had probably not yet been achieved [59]. The use of temporary cements, particularly eugenol-free zinc oxide phosphate cements, led to reduced retention values, especially after thermocycling [43,54,59,67]. Consequently, they are not suitable for semipermanent cementation. If retrievability is required after a short time, they might offer a solution to ease removal of the crown [4,59,68]. Self-adhesive resin cements, zinc oxide cements, and polycarboxylate cements showed mostly higher retentive strengths regardless of the crown material compared to temporary cements [4,24,69,70]. However, retrievability is not possible without destruction of the superstructure [23,71-73].

The correlation analysis showed that certain parameters could have a relevant influence on the retention force of cements. These include cement type, pretreatment and cleaning of the internal crown surface, taper, abutment surface size, cement gap, and grooves on the abutment. However, the interrelationships span the entire spectrum of cementation options (temporary, semipermanent, and definitive).

Retention of cements is mostly measured with the help of pull-off tests that are performed with a universal testing machine. To increase the clinical relevance of *in vitro* studies, some studies used clinical removal devices for the pull-off tests [4,45]. However, the measured values are not comparable with the pull-off forces required intraorally. The Coronaflex device is a special tool that uses compressed air to trigger an impact pulse. This acts on the cement and destroys its structure. The retentive strength is dissolved. The superstructure can be removed and usually it is possible to reuse it. A smaller amount of space in the patient's mouth and the fact that Coronaflex is not always straightforward to apply also makes clinical removal of the crowns more difficult, so that more force is required [4]. *In vitro*, a simplified removal with less force is possible because the device can be freely positioned and rotated. Schierano G, et al., [74] reported that Coronaflex is more repeatable with higher peak amplitudes of forces, which can be considered as positive.

Some studies have performed thermocycling and evaluated the retention forces of the cements tested [9,14,24,40-56]. Thermocycling has been introduced to imitate artificial ageing. Temperature changes as they occur naturally intraorally can be mimicked easily *in vitro*. The reduction of retention by thermocycling is caused by the regular temperature fluctuations. The thermal stress affects the bonding strength of the cements. Structural changes of the bonds lead to a breakdown of the chemical bond and thus to a failure of the retention between crown and abutment [75]. However, some authors confirmed that thermocycling did not affect retention capacity [53]. Besides, thermocycling is not sufficient for an accurate assessment of the clinical suitability of cements. Long-term mechanical loading (chewing simulation) was only performed to a limited extent [58]. Generally, compressive cyclic loading leads to a reduced retentive strength of cements. Therefore, crowns are easier to remove. Retrievability of the superstructure is achievable, regardless of the cement class [9,54,58,71].

Retentive strength depends on many different factors: the cement type, the cement gap, the cementing technique, the film thickness, the abutment geometry, the surface treatment, and the crown material [3,14,32,42,44,47,49,51,52,55,57,59,61-65,76-91]. In addition, the saliva contamination affects retentive values [48]. Furthermore, many various cements were investigated in different studies with regard to their retention values. Due to noncomparable study protocols and different methodologies, the results cannot reliably be compared.

Conclusion

The present literature review showed that retention of cemented single crowns on implants depends on a lot of different factors. Significant correlations between retentive strength and different parameters (cement type, cleaning and pretreatment of the internal crown surface, taper, abutment surface size, cement gap, grooves on the abutment) could be proven.

Semipermanent cements that have recently appeared on the market have only shown very limited data so far. From today's point of view, it is not yet possible to say whether they have an advantage compared to conventional definitive or provisional cements. Further studies are required to determine the limitations and possibilities of semipermanent cements.

Declarations

Ethics approval and consent to participate: Not applicable.

Consent for publication: Not applicable.

Availability of data and material: All data generated can be found online (see Materials and Methods for the search strategy) at PubMed.

Competing interests: Not applicable.

Funding: Not applicable.

Authors' contributions: Jeremias Hey initiated this review. He supervised the entire preparation of this study, gave groundbreaking ideas and supported the literature research. Martin Rosentritt prepared the statistical analysis concerning the factors influencing the retention force (Table 6) and supported the literature search. Florian Beuer performed the final proofreading of the manuscript and supported the creation of this review with helpful tips regarding structuring and outlining. Elisabeth Prause did the literature research and composed the review.

Acknowledgments: Not applicable.

Table 7: Overview of the included studies with the following information: the cement class used, the material combination between the abutment and the crown, the retention values in Newtons (N), a pretreatment of the crown (alcohol or sandblasting), the particle size of sandblasting in micrometers (µm), a conducted thermocycling or chewing simulation, the taper in degrees (°), the abutment height in millimeters (mm), the size of the abutment surface in (mm²), the size of the cement gap in mm and the geometry of the abutment in terms of grooves.

Author	Cement	Material (abutment/ crown)	Retention (N)	Pretreatment crown	Particlesize sand-blasting (µm)	Thermo-cycling	Taper (°)	Abutment height (mm)	Chewing simulation	Abutment surface size (mm²)	Cement gap (mm)	Groove (abutment)
	zinc phosphate	titanium-metal alloy	215.73					5.5	yes	33.07		
	zinc phosphate		161.79					5.5	yes	33.07		
	zinc phosphate		311.34	yes	50			5.5	yes	33.07		
	zinc phosphate		253.48	yes	50			5.5	yes	33.07		
	zinc phosphate		383.41	yes				5.5	yes	33.07		
	zinc phosphate		301.53	yes				5.5	yes	33.07		
	zinc phosphate		547.17	yes	50			5.5	yes	33.07		
	zinc phosphate		531.98	yes	50			5.5	yes	33.07		
Al Hamad KQ, et al., [62]	glass ionomer	titanium-metal alloy	183.13			yes	8	4				
	glass ionomer		305.14	yes	50	yes	8	4				
	glass ionomer		239.95			yes	8	6				
	glass ionomer		523.71	yes	50	yes	8	6				
	zinc phosphate		268.59			yes	8	4				
	zinc phosphate		418.69	yes	50	yes	8	4				
	zinc phosphate		647.66			yes	8	6				
	zinc phosphate		700.93	yes	50	yes	8	6				
	zinc oxide eugenol		65.53			yes	8	4				
	zinc oxide eugenol		139.79	yes	50	yes	8	4				
	zinc oxide eugenol		73.48			yes	8	6				
	zinc oxide eugenol		207.09	yes	50	yes	8	6				
	zinc oxide eugenol + petroleum jelly		9.86			yes	8	4				
	zinc oxide eugenol + petroleum jelly		42.09	yes	50	yes	8	4				
	zinc oxide eugenol + petroleum jelly		17.36			yes	8	6				
	zinc oxide eugenol + petroleum jelly		48.27	yes	50	yes	8	6				
Abbo B, et al., [63]	resin based	titanium-zirconia	124.89					5.5		33.07		
	resin based		198.09					6.5		36.03		
Carnaggio TV, et al [59]	zinc oxide noneugenol	titanium-zirconia	83							42	100	
	zinc oxide noneugenol		82							60	100	
	zinc oxide noneugenol		114							82	100	
	resin based		92							42	100	
	resin based		127							60	100	
	resin based		104							82	100	
	glass ionomer		96							42	100	
	glass ionomer		84							60	100	

	glass ionomer		56							82	100	
	resin based		199							42	100	
	resin based		241							60	100	
	resin based		246							82	100	
	resin based		184							42	100	
	resin based		237							60	100	
	resin based		318							82	100	
Derafshi R, et al., [65]	zinc oxide eugenol	titanium-metal alloy	46.88					5.5		31.64	20	
	zinc oxide eugenol		46.31					5.5		31.64	20	
	zinc oxide eugenol		65.3					5.5		31.64	20	
	zinc oxide eugenol		62.25					5.5		31.64	20	
Gultekin P, et al., [13]	resin based	titanium-metal alloy	136.97	yes	50			6.5		30.77	20	
	resin based		139.5	yes	50			6.5		30.77	20	
	resin based		155.79	yes	50			6.5		30.77	20	
	resin based		150.28	yes	50			6.5		30.77	20	
	resin based		86.16	yes	50			6.5		30.77	20	
	resin based		105.66	yes	50			6.5		30.77	20	
	resin based		301.6	yes	50			6.5		30.77	20	
	zinc oxide noneugenol		39.65	yes	50			6.5		30.77	20	
	resin based		171.35	yes	50			6.5		30.77	40	
	resin based		179.54	yes	50			6.5		30.77	40	
	resin based		187.3	yes	50			6.5		30.77	40	
	resin based		190.75	yes	50			6.5		30.77	40	
	resin based		83.63	yes	50			6.5		30.77	40	
	resin based		118.57	yes	50			6.5		30.77	40	
	resin based		378.85	yes	50			6.5		30.77	40	
	zinc oxide noneugenol		42.72	yes	50			6.5		30.77	40	
Gumus HO, et al., [41]	zinc oxide eugenol	titanium-metal alloy	45.1	yes			6	2		17.97		
	zinc oxide noneugenol		90.7	yes			6	2		17.97		
	resin based		36.1	yes			6	2		17.97		
	zinc oxide eugenol		34.4	yes			6	2		17.97		
	glass ionomer		82.8	yes			6	2		17.97		
	zinc oxide noneugenol		67.7	yes			6	2		17.97		
	zinc oxide eugenol		23.3	yes		yes	6	2		17.97		
	zinc oxide noneugenol		6.2	yes		yes	6	2		17.97		
	resin based		8.8	yes		yes	6	2		17.97		
	zinc oxide eugenol		12.7	yes		yes	6	2		17.97		
	glass ionomer		32.9	yes		yes	6	2		17.97		
	zinc oxide noneugenol		24.6	yes		yes	6	2		17.97		
Güncü MB, et al., [24]	zinc oxide noneugenol	titanium-metal alloy	33.7	yes	50	yes				48.29	25.4	
	zinc phosphate		262.6	yes	50	yes				48.29	25.4	

	glass ionomer		75.7	yes	50	yes				48.29	25.4	
	zinc oxide noneugenol		20.5	yes	50	yes				90	25.4	
	zinc phosphate		258	yes	50	yes				90	25.4	
	glass ionomer		42.1	yes	50	yes				90	25.4	
Jugdev J, et al., [85]	zinc oxide eugenol	titanium-metal alloy	120	yes	50							
	zinc oxide eugenol		140	yes	50							
	resin based		150	yes	50							
	resin based		300	yes	50							
	resin based		150	yes	50							
	resin based		360	yes	50							
Kilicarslan MA, et al., [83]	resin based	titanium-metal alloy	455.1		50		6	5.7		37.53	20	
	resin based		565.52		50		6	5.7		37.53	20	
	resin based		534.78		50		6	5.7		37.53	20	
	resin based		678.6		50		6	5.7		37.53	20	
Kim Y, et al., [32]	calcium-hydroxide	titanium-PMMA	48					4				
	calcium-hydroxide		58					4				
	calcium-hydroxide		52					4				
	zinc oxide noneugenol		39					4				
	zinc oxide noneugenol		53					4				
	zinc oxide noneugenol		40					4				
	zinc oxide eugenol		11					4				
	zinc oxide eugenol		20					4				
	zinc oxide eugenol		23					4				
	zinc oxide eugenol		10					4				
	zinc oxide eugenol		12					4				
	zinc oxide eugenol		14					4				
Kokubo Y, et al., [14]	polycarboxylate	zirconia-zirconia	300	yes			8	7.4		51.39		
	polycarboxylate		120	yes		yes	8	7.4		51.39		
	polycarboxylate		250	yes	50		8	7.4		51.39		
	polycarboxylate		275	yes	50	yes	8	7.4		51.39		
	polycarboxylate		60	yes			8	7.4		51.39		
	polycarboxylate		40	yes		yes	8	7.4		51.39		
	polycarboxylate		50	yes	50		8	7.4		51.39		
	polycarboxylate		20	yes	50	yes	8	7.4		51.39		
	zinc oxide eugenol		100	yes			8	7.4		51.39		
	zinc oxide eugenol		60	yes		yes	8	7.4		51.39		
	zinc oxide eugenol		70	yes	50		8	7.4		51.39		
	zinc oxide eugenol		70	yes	50	yes	8	7.4		51.39		
	zinc oxide noneugenol		120	yes			8	7.4		51.39		
	zinc oxide noneugenol		10	yes		yes	8	7.4		51.39		

	zinc oxide noneugenol		80	yes	50		8	7.4		51.39		
	zinc oxide noneugenol		5	yes	50	yes	8	7.4		51.39		
	zinc oxide eugenol		60	yes			8	7.4		51.39		
	zinc oxide eugenol		10	yes		yes	8	7.4		51.39		
	zinc oxide eugenol		70	yes	50		8	7.4		51.39		
	zinc oxide eugenol		40	yes	50	yes	8	7.4		51.39		
Kurt M, et al., [42]	resin based	titanium-metal alloy	249.41			yes		4				
	resin based		315.14			yes		4				
	resin based		506.02	yes	50	yes		4				
	resin based		223.26			yes		4				
	resin based		412.91			yes		4				
Lennartz A, et al., [43]	zinc oxide eugenol	zirconia-zirconia	234	yes	50		6	6		34.55		
	resin based		110	yes	50		6	6		34.55		
	resin based		103	yes	50		6	6		34.55		
	resin based		61	yes	50		6	6		34.55		
	resin based		49	yes	50		6	6		34.55		
	zinc oxide eugenol		20	yes	50	yes	6	6		34.55		
	resin based		10	yes	50	yes	6	6		34.55		
	resin based		10	yes	50	yes	6	6		34.55		
	resin based		25	yes	50	yes	6	6		34.55		
	resin based		10	yes	50	yes	6	6		34.55		
Lewinstein I, et al., [44]	zinc oxide noneugenol	titanium-metal alloy	170	yes	110	yes	6	6				
	zinc phosphate		362	yes	110	yes	6	6				
	zinc oxide noneugenol		188	yes	110	yes	6	6				yes
	zinc phosphate		580	yes	110	yes	6	6				yes
	zinc oxide noneugenol		204	yes	110	yes	6	6				yes
	zinc phosphate		549	yes	110	yes	6	6				yes
	zinc oxide noneugenol		242	yes	110	yes	6	6				yes
	zinc phosphate		587	yes	110	yes	6	6				yes
Mehl C, et al., [45]	glass ionomer	titanium-metal alloy	292	yes	50		5	6		34.55		yes
	glass ionomer		264	yes	50	yes	5	6		34.55		yes
	polycarboxylate		556	yes	50		5	6		34.55		yes
	polycarboxylate		471	yes	50	yes	5	6		34.55		yes
Mehl C, et al., [3]	glass ionomer	titanium-metal alloy	605	yes	50		6	4		28.78	20	
	glass ionomer		144	yes	50		6	4		28.78	50	
	glass ionomer		104	yes	50		6	4		28.78	80	
	glass ionomer		105	yes	50		6	4		28.78	110	
	polycarboxylate		1041	yes	50		6	4		28.78	20	
	polycarboxylate		307	yes	50		6	4		28.78	50	
	polycarboxylate		94	yes	50		6	4		28.78	80	

	polycarboxylate		96	yes	50		6	4		28.78	110	
	resin based		1237	yes	50		6	4		28.78	20	
	resin based		480	yes	50		6	4		28.78	50	
	resin based		448	yes	50		6	4		28.78	80	
	resin based		362	yes	50		6	4		28.78	110	
Mehl C, et al., [46]	glass ionomer	titanium-metal alloy	244	yes	50		6	4		28.78		
	resin based		307	yes	50		6	4		28.78		
	resin based		154	yes	50		6	4		28.78		
	resin based		107	yes	50		6	4		28.78		
	glass ionomer		264	yes	50	yes	6	4		28.78		
	resin based		311	yes	50	yes	6	4		28.78		
	resin based		93	yes	50	yes	6	4		28.78		
	resin based		81	yes	50	yes	6	4		28.78		
	glass ionomer		225	yes	50		6	4	yes	28.78		
	resin based		275	yes	50		6	4	yes	28.78		
	resin based		123	yes	50		6	4	yes	28.78		
	resin based		81	yes	50		6	4	yes	28.78		
	glass ionomer		235	yes	50	yes	6	4	yes	28.78		
	resin based		303	yes	50	yes	6	4	yes	28.78		
	resin based		102	yes	50	yes	6	4	yes	28.78		
	resin based		86	yes	50	yes	6	4	yes	28.78		
Nagasawa Y, et al., [67]	polycarboxylate	titanium-gold	72	yes	50		10	5		37.2	50	
	polycarboxylate		76	yes	50		10	5		37.2	50	
	polycarboxylate		110	yes	50		10	5		37.2	50	
	polycarboxylate		72	yes	50		10	5		37.2	50	
	zinc oxide eugenol		93	yes	50		10	5		37.2	50	
	zinc oxide eugenol		81	yes	50		10	5		37.2	50	
	zinc oxide noneugenol		82	yes	50		10	5		37.2	50	
	zinc oxide noneugenol		70	yes	50		10	5		37.2	50	
	zinc oxide eugenol		48	yes	50		10	5		37.2	50	
	zinc oxide eugenol		25	yes	50		10	5		37.2	50	
	zinc oxide eugenol		26	yes	50		10	5		37.2	50	
	zinc oxide eugenol		20	yes	50		10	5		37.2	50	
Naumova EA, et al. [47]	zinc oxide noneugenol	titanium-metal alloy	191.7	yes	50		6	5.8		33.95		
	glass ionomer		902.3	yes	50		6	5.8		33.95		
	glass ionomer		863.6	yes	50		6	5.8		33.95		
	zinc phosphate		615.8	yes	50		6	5.8		33.95		
	glass ionomer		740.1	yes	50		6	5.8		33.95		
	glass ionomer		588.5	yes	50		6	5.8		33.95		
	resin based		334.5	yes	50		6	5.8		33.95		
	glass ionomer		642.2	yes	50		6	5.8		33.95		
	zinc oxide noneugenol		49.09	yes	50		6	5.8		33.95		

	glass ionomer		213.6	yes	50		6	5.8		33.95		
	glass ionomer		251.4	yes	50		6	5.8		33.95		
	zinc phosphate		258.1	yes	50		6	5.8		33.95		
	glass ionomer		242.4	yes	50		6	5.8		33.95		
	glass ionomer		249.2	yes	50		6	5.8		33.95		
	resin based		205	yes	50		6	5.8		33.95		
	glass ionomer		229.1	yes	50		6	5.8		33.95		
	zinc oxide noneugenol		30.98	yes	50		6	5.8		33.95		
	glass ionomer		179.3	yes	50		6	5.8		33.95		
	glass ionomer		165.3	yes	50		6	5.8		33.95		
	zinc phosphate		185.3	yes	50		6	5.8		33.95		
	glass ionomer		178.8	yes	50		6	5.8		33.95		
	glass ionomer		188.6	yes	50		6	5.8		33.95		
	resin based		158.9	yes	50		6	5.8		33.95		
	glass ionomer		150.6	yes	50		6	5.8		33.95		
Nejatidanse F, et al., [49]	resin based	titanium-zirconia	203.49	yes	110	yes	8	5.5				
	resin based		190.61	yes	110	yes	8	5.5				
	resin based		172.16	yes	110	yes	8	5.5				
	zinc phosphate		72.01	yes	110	yes	8	5.5				
	polycarboxylate		44.18	yes	110	yes	8	5.5				
	glass ionomer		3.12	yes	110	yes	8	5.5				
	zinc oxide noneugenol		11.27	yes	110	yes	8	5.5				
	zinc oxide eugenol		4.52	yes	110	yes	8	5.5				
	resin based		4.03	yes	110	yes	8	5.5				
Nejatidanse F, et al., [48]	resin based	titanium-zirconia	183.9	yes		yes	6	5.5			30	
	resin based		123.64	yes		yes	6	5.5			30	
	resin based		190.57	yes		yes	6	5.5			30	
	resin based		195.43	yes	50	yes	6	5.5			30	
	resin based		204.79	yes		yes	6	5.5			30	
	resin based		232.65	yes		yes	6	5.5			30	
	resin based		193.11	yes		yes	6	5.5			30	
Ongthiemsak, et al., [57]	zinc oxide eugenol	titanium-gold	39.94	yes	50				yes			
	zinc oxide eugenol		43.77	yes	50				yes			
	zinc oxide eugenol		47.47	yes	50				yes			
Pan YH, et al., [16]	resin based + petroleum jelly	titanium-metal alloy	32	yes	50	yes		12	yes			
	zinc oxide eugenol		36.6	yes	50	yes		12	yes			
	resin based		39.2	yes	50	yes		12	yes			
	zinc oxide noneugenol		40.8	yes	50	yes		12	yes			
	resin based		45.4	yes	50	yes		12	yes			
	zinc phosphate + petroleum jelly		147	yes	50	yes		12	yes			
	zinc phosphate		249.2	yes	50	yes		12	yes			

Pitta J, et al., [52]	resin based	titanium-PMMA	64.1	yes		yes						
	resin based		64.9	yes	50	yes						
	resin based		276.7	yes	30	yes						
	resin based		39.1	yes	30	yes						
	resin based		1146.5	yes		yes						
Pitta J, et al., [53]	resin based	titanium-PMMA	206.3			yes			yes			
	resin based		346.9			yes			yes			
	resin based		420			yes			yes			
	resin based		376.1			yes			yes			
Reddy SV, et al., [68]	zinc oxide eugenol	titanium-metal alloy	258.28	yes	50							
	zinc oxide eugenol		260.68	yes	50							
	zinc oxide eugenol		138.41	yes	50							
	zinc oxide eugenol		138.28	yes	50							
	resin based		184.86	yes	50							
	resin based		152.13	yes	50							
Rödiger M, et al., [25]	resin based	titanium-zirconia	101.1	yes	110	yes		4.31				
	resin based		311.7	yes	110	yes		6.79				
	resin based		447.9	yes	110	yes		4.31				
	resin based		478.7	yes	110	yes		6.79				
Rohr N, et al., [72]	glass ionomer	zirconia-zirconia	196	yes								
	resin based		43	yes								
	zinc oxide eugenol		127	yes								
	resin based		261	yes								
	resin based		253	yes								
	resin based		270	yes								
	resin based		226	yes								
	resin based		222	yes								
	resin based		238	yes								
	resin based		245	yes								
	resin based		318	yes								
	resin based		254	yes								
	resin based		605	yes								
	resin based		470	yes								
	resin based		257	yes								
	resin based		243	yes								
	resin based		269	yes								
	resin based		224	yes								
	resin based		363	yes								
	resin based		288	yes								
Rues S, et al., [54]	zinc oxide noneugenol	zirconia-zirconia	31	yes	50			4				
	methacrylate based		40	yes	50			4				
	resin based		436	yes	50			4				
	zinc phosphate		682	yes	50			4				

	glass ionomer		425	yes	50			4				
	zinc oxide noneugenol		17	yes	50	yes		4				
	methacrylate based		8	yes	50	yes		4				
	resin based		590	yes	50	yes		4				
	zinc phosphate		656	yes	50	yes		4				
	glass ionomer		522	yes	50	yes		4				
	zinc oxide noneugenol		107	yes	50			5.5				
	methacrylate based		41	yes	50			5.5				
	resin based		596	yes	50			5.5				
	zinc phosphate		477	yes	50			5.5				
	glass ionomer		570	yes	50			5.5				
	zinc oxide noneugenol		11	yes	50	yes		5.5				
	methacrylate based		13	yes	50	yes		5.5				
	resin based		689	yes	50	yes		5.5				
	zinc phosphate		915	yes	50	yes		5.5				
	glass ionomer		757	yes	50	yes		5.5				
Sadig wM, et al., [89]	zinc phosphate	titanium-titanium	380	yes	50			5.5				
	zinc phosphate		180	yes	50			5.5				
	zinc phosphate		260	yes	50			5.5				
	resin based		310	yes	50			5.5				
	resin based		470	yes	50			5.5				
	resin based		500	yes	50			5.5				
Safari S, et al., [61]	resin based	titanium-metal alloy	364.19	yes		yes		3		27.69	30	
	glass ionomer		154.02	yes		yes		3		27.69	30	
	zinc oxide eugenol		115.99	yes		yes		3		27.69	30	
	resin based		352.84	yes		yes		3		27.69	30	
	resin based		460.44	yes		yes		3		31.9	30	
	glass ionomer		243.68	yes		yes		3		31.9	30	
	zinc oxide eugenol		164.7	yes		yes		3		31.9	30	
	resin based		405.45	yes		yes		3		31.9	30	
Sahu N, et al., [82]	resin based	titanium-metal alloy	408.3	yes	110			8			25	
	resin based		159.9	yes	110			8			25	
	resin based		743.8	yes	110			8			25	
Schiessl C, et al., [55]	polycarboxylate	titanium-metal alloy	400	yes	50		4	6		33.12		
	polycarboxylate		430	yes	50		4	6		33.12		
	polycarboxylate		200	yes	50		4	6		33.12		
	zinc phosphate		270	yes	50		4	6		33.12		
	methacrylate based		80	yes	50		4	6		33.12		
	glass ionomer		180	yes	50		4	6		33.12		
	resin based		270	yes	50		4	6		33.12		
	zinc oxide noneugenol		130	yes	50		4	6		33.12		
	polycarboxylate		380	yes	50		6	6		33.12		

	polycarboxylate		240	yes	50		6	6		33.12		
	polycarboxylate		200	yes	50		6	6		33.12		
	zinc phosphate		200	yes	50		6	6		33.12		
	methacrylate based		110	yes	50		6	6		33.12		
	glass ionomer		120	yes	50		6	6		33.12		
	resin based		230	yes	50		6	6		33.12		
	zinc oxide noneugenol		100	yes	50		6	6		33.12		
	polycarboxylate		320	yes	50		8	6		33.12		
	polycarboxylate		140	yes	50		8	6		33.12		
	polycarboxylate		140	yes	50		8	6		33.12		
	zinc phosphate		160	yes	50		8	6		33.12		
	polycarboxylate		80	yes	50		8	6		33.12		
	glass ionomer		100	yes	50		8	6		33.12		
	resin based		260	yes	50		8	6		33.12		
	zinc oxide noneugenol		90	yes	50		8	6		33.12		
	polycarboxylate		660	yes	50	yes	4	6		33.12		
	polycarboxylate		380	yes	50	yes	4	6		33.12		
	polycarboxylate		400	yes	50	yes	4	6		33.12		
	zinc phosphate		370	yes	50	yes	4	6		33.12		
	methacrylate based		5	yes	50	yes	4	6		33.12		
	glass ionomer		300	yes	50	yes	4	6		33.12		
	resin based		300	yes	50	yes	4	6		33.12		
	zinc oxide noneugenol		50	yes	50	yes	4	6		33.12		
	polycarboxylate		580	yes	50	yes	6	6		33.12		
	polycarboxylate		400	yes	50	yes	6	6		33.12		
	polycarboxylate		210	yes	50	yes	6	6		33.12		
	zinc phosphate		280	yes	50	yes	6	6		33.12		
	methacrylate based		5	yes	50	yes	6	6		33.12		
	glass ionomer		250	yes	50	yes	6	6		33.12		
	resin based		240	yes	50	yes	6	6		33.12		
	zinc oxide noneugenol		40	yes	50	yes	6	6		33.12		
	polycarboxylate		620	yes	50	yes	8	6		33.12		
	polycarboxylate		400	yes	50	yes	8	6		33.12		
	polycarboxylate		250	yes	50	yes	8	6		33.12		
	zinc phosphate		250	yes	50	yes	8	6		33.12		
	methacrylate based		5	yes	50	yes	8	6		33.12		
	glass ionomer		200	yes	50	yes	8	6		33.12		
	resin based		210	yes	50	yes	8	6		33.12		
	zinc oxide noneugenol		50	yes	50	yes	8	6		33.12		
	zinc phosphate		300	yes	50		4	6		33.12		
	glass ionomer		110	yes	50		4	6		33.12		
	zinc oxide noneugenol		100	yes	50		4	6		33.12		

	resin based		250	yes	50		4	6		33.12		
	zinc phosphate		210	yes	50		6	6		33.12		
	glass ionomer		100	yes	50		6	6		33.12		
	zinc oxide noneugenol		110	yes	50		6	6		33.12		
	resin based		270	yes	50		6	6		33.12		
	zinc phosphate		180	yes	50		8	6		33.12		
	glass ionomer		90	yes	50		8	6		33.12		
	zinc oxide noneugenol		80	yes	50		8	6		33.12		
	resin based		260	yes	50		8	6		33.12		
	zinc phosphate		280	yes	50	yes	4	6		33.12		
	glass ionomer		300	yes	50	yes	4	6		33.12		
	zinc oxide noneugenol		70	yes	50	yes	4	6		33.12		
	resin based		320	yes	50	yes	4	6		33.12		
	zinc phosphate		230	yes	50	yes	6	6		33.12		
	glass ionomer		180	yes	50	yes	6	6		33.12		
	zinc oxide noneugenol		50	yes	50	yes	6	6		33.12		
	resin based		290	yes	50	yes	6	6		33.12		
	zinc phosphate		250	yes	50	yes	8	6		33.12		
	glass ionomer		190	yes	50	yes	8	6		33.12		
	zinc oxide noneugenol		40	yes	50	yes	8	6		33.12		
	resin based		280	yes	50	yes	8	6		33.12		
	zinc phosphate		380	yes	120		4	6		33.12		
	glass ionomer		210	yes	120		4	6		33.12		
	zinc oxide noneugenol		90	yes	120		4	6		33.12		
	resin based		260	yes	120		4	6		33.12		
	zinc phosphate		350	yes	120		6	6		33.12		
	glass ionomer		190	yes	120		6	6		33.12		
	zinc oxide noneugenol		110	yes	120		6	6		33.12		
	resin based		210	yes	120		6	6		33.12		
	zinc phosphate		340	yes	120		8	6		33.12		
	glass ionomer		160	yes	120		8	6		33.12		
	zinc oxide noneugenol		100	yes	120		8	6		33.12		
	resin based		220	yes	120		8	6		33.12		
	zinc phosphate		350	yes	120		4	6		33.12		
	glass ionomer		220	yes	120		4	6		33.12		
	zinc oxide noneugenol		40	yes	120		4	6		33.12		
	resin based		260	yes	120		4	6		33.12		
	zinc phosphate		280	yes	120		6	6		33.12		
	glass ionomer		220	yes	120		6	6		33.12		
	zinc oxide noneugenol		40	yes	120		6	6		33.12		
	resin based		210	yes	120		6	6		33.12		
	zinc phosphate		280	yes	120		8	6		33.12		

	glass ionomer		210	yes	120		8	6		33.12		
	zinc oxide noneugenol		20	yes	120		8	6		33.12		
	resin based		220	yes	120		8	6		33.12		
	polycarboxylate		150	yes	50		4	6		33.12		
	polycarboxylate		220	yes	50		4	6		33.12		
	polycarboxylate		225	yes	50		4	6		33.12		
	polycarboxylate		100	yes	50		6	6		33.12		
	polycarboxylate		75	yes	50		6	6		33.12		
	polycarboxylate		160	yes	50		6	6		33.12		
	polycarboxylate		110	yes	50		8	6		33.12		
	polycarboxylate		80	yes	50		8	6		33.12		
	polycarboxylate		160	yes	50		8	6		33.12		
	polycarboxylate		140	yes	50	yes	4	6		33.12		
	polycarboxylate		290	yes	50	yes	4	6		33.12		
	polycarboxylate		330	yes	50	yes	4	6		33.12		
	polycarboxylate		225	yes	50	yes	6	6		33.12		
	polycarboxylate		240	yes	50	yes	6	6		33.12		
	polycarboxylate		225	yes	50	yes	6	6		33.12		
	polycarboxylate		60	yes	50	yes	8	6		33.12		
	polycarboxylate		350	yes	50	yes	8	6		33.12		
	polycarboxylate		225	yes	50	yes	8	6		33.12		
	polycarboxylate		380	yes	50		4	6		33.12		
	polycarboxylate		400	yes	50		4	6		33.12		
	polycarboxylate		220	yes	50		4	6		33.12		
	polycarboxylate		375	yes	50		6	6		33.12		
	polycarboxylate		230	yes	50		6	6		33.12		
	polycarboxylate		210	yes	50		6	6		33.12		
	polycarboxylate		300	yes	50		8	6		33.12		
	polycarboxylate		90	yes	50		8	6		33.12		
	polycarboxylate		100	yes	50		8	6		33.12		
	polycarboxylate		610	yes	50	yes	4	6		33.12		
	polycarboxylate		375	yes	50	yes	4	6		33.12		
	polycarboxylate		390	yes	50	yes	4	6		33.12		
	polycarboxylate		520	yes	50	yes	6	6		33.12		
	polycarboxylate		380	yes	50	yes	6	6		33.12		
	polycarboxylate		220	yes	50	yes	6	6		33.12		
	polycarboxylate		610	yes	50	yes	8	6		33.12		
	polycarboxylate		390	yes	50	yes	8	6		33.12		
	polycarboxylate		220	yes	50	yes	8	6		33.12		
	polycarboxylate		470	yes	50		4	6		33.12		
	polycarboxylate		375	yes	50		4	6		33.12		
	polycarboxylate		220	yes	50		4	6		33.12		
	polycarboxylate		520	yes	50		6	6		33.12		

	polycarboxylate		330	yes	50		6	6		33.12		
	polycarboxylate		280	yes	50		6	6		33.12		
	polycarboxylate		400	yes	50		8	6		33.12		
	polycarboxylate		300	yes	50		8	6		33.12		
	polycarboxylate		225	yes	50		8	6		33.12		
	polycarboxylate		610	yes	50	yes	4	6		33.12		
	polycarboxylate		350	yes	50	yes	4	6		33.12		
	polycarboxylate		330	yes	50	yes	4	6		33.12		
	polycarboxylate		520	yes	50	yes	6	6		33.12		
	polycarboxylate		230	yes	50	yes	6	6		33.12		
	polycarboxylate		250	yes	50	yes	6	6		33.12		
	polycarboxylate		580	yes	50	yes	8	6		33.12		
	polycarboxylate		360	yes	50	yes	8	6		33.12		
	polycarboxylate		220	yes	50	yes	8	6		33.12		
Sheets JL, et al., [66]	zinc oxide eugenol	titanium-metal alloy	117.8	yes	50		3	6.38				
	polycarboxylate		358.6	yes	50		3	6.38				
	resin based + petroleum jelly		130.8	yes	50		3	6.38				
	resin based		172.4	yes	50		3	6.38				
	resin based + KY jelly		31.6	yes	50		3	6.38				
	resin based		131.6	yes	50		3	6.38				
	resin based		41.2	yes	50		3	6.38				
	zinc phosphate		171.8	yes	50		3	6.38				
	glass ionomer		167.8	yes	50		3	6.38				
	glass ionomer		147.5	yes	50		3	6.38				
	polycarboxylate		158.8	yes	50		3	6.38				
Guler U, et al., [9]	zinc oxide eugenol	titanium-zirconia	6.52			yes						
	zinc phosphate		83.09			yes						
	resin based		251.18			yes						
	zinc oxide eugenol		17.82			yes						
	zinc phosphate		116.41			yes						
	resin based		248.72			yes						

References

1. Thoma DS, Wolleb K, Bienz SP, Wiedemeier D, Hämmerle CHF, et al. (2018) Early histological, microbiological, radiological, and clinical response to cemented and screw-retained all-ceramic single crowns. Clin Oral Implants Res 29: 996-1006.
2. Duyck J, Naert I (2002) Influence of prosthesis fit and the effect of a luting system on the prosthetic connection preload: an *in vitro* study. Int J Prosthodont15: 389-396.
3. Mehl C, Harder S, Steiner M, Vollrath O, Kern M (2013) Influence of cement film thickness on the retention of implant-retained crowns. J Prosthodont 22: 618-625.
4. Mehl C, Harder S, Wolfart M, Kern M, Wolfart S (2008) Retrievability of implant-retained crowns following cementation. Clin Oral Implants Res 19: 1304-1311.
5. Torrado E, Ercoli C, Al Mardini M, Graser GN, Tallents RH, et al. (2004) A comparison of the porcelain fracture resistance of screw-retained and cement-retained implant-supported metal-ceramic crowns. J Prosthet Dent 91: 532-537.
6. Sailer I, Muhlemann S, Zwahlen M, Hammerle CH, Schneider D (2012) Cemented and screw-retained implant reconstructions: a systematic review of the survival and complication rates. Clin Oral Implants Res 23: S163-S201.

7. Chee W, Felton DA, Johnson PF, Sullivan DY (1999) Cemented *versus* screw-retained implant prostheses: which is better? Int J Oral Maxillofac Implants 14: 137-141.

8. Assenza B, Scarano A, Leghissa G, Carusi G, Thams U, et al. (2005) Screw- *vs* cement-implant-retained restorations: an experimental study in the Beagle. Part 1. Screw and abutment loosening. J Oral Implantol 31: 242-246.

9. Guler U, Budak Y, Queiroz JRC, Ozcan M (2017) Dislodgement Resistance of Zirconia Copings Cemented onto Zirconia and Titanium Abutments. Implant Dent 26: 510-515.

10. Wolfart M, Wolfart S, Kern M (2006) Retention forces and seating discrepancies of implant-retained castings after cementation. Int J Oral Maxillofac Implants 21: 519-525.

11. Montenegro AC, Machado AN, Depes Gouvea CV (2008) Tensile strength of cementing agents on the CeraOne system of dental prosthesis on implants. Implant Dent 17: 451-460.

12. Nejatidanesh F, Savabi O, Ebrahimi M, Savabi G (2012) Retentiveness of implant-supported metal copings using different luting agents. Dent Res J (Isfahan) 9: 13-18.

13. Gultekin P, Gultekin BA, Aydin M, Yalcin S (2013) Cement selection for implant-supported crowns fabricated with different luting space settings. J Prosthodont 22: 112-119.

14. Kokubo Y, Kano T, Tsumita M, Sakurai S, Itayama A, et al. (2010) Retention of zirconia copings on zirconia implant abutments cemented with provisional luting agents. J Oral Rehabil 37: 48-53.

15. Heinemann F, Mundt T, Biffar R (2006) Retrospective evaluation of temporary cemented, tooth and implant supported fixed partial dentures. J Craniomaxillofac Surg 34: S86-S90.

16. Pan YH, Ramp LC, Lin CK, Liu PR (2006) Comparison of 7 luting protocols and their effect on the retention and marginal leakage of a cement-retained dental implant restoration. Int J Oral Maxillofac Implants 21: 587-592.

17. Breeding LC, Dixon DL, Bogacki MT, Tietge JD (1992) Use of luting agents with an implant system: Part I. J Prosthet Dent 68: 737-741.

18. Hebel KS, Gajjar RC (1997) Cement-retained *versus* screw-retained implant restorations: achieving optimal occlusion and esthetics in implant dentistry. J Prosthet Dent 77: 28-35.

19. Ekfeldt A, Carlsson GE, Borjesson G (1994) Clinical evaluation of single-tooth restorations supported by osseointegrated implants: a retrospective study. Int J Oral Maxillofac Implants 9: 179-183.

20. Akca K, Iplikcioglu H, Cehreli MC (2002) Comparison of uniaxial resistance forces of cements used with implant-supported crowns. Int J Oral Maxillofac Implants17: 536-542.

21. Hill EE (2007) Dental cements for definitive luting: a review and practical clinical considerations. Dent Clin North Am 51: 643-658.

22. Ramp MH, Dixon DL, Ramp LC, Breeding LC, Barber LL (1999) Tensile bond strengths of provisional luting agents used with an implant system. J Prosthet Dent 81: 510-514.

23. Dudley JE, Richards LC, Abbott JR (2008) Retention of cast crown copings cemented to implant abutments. Aust Dent J 53: 332-339.

24. Guncu MB, Cakan U, Canay S (2011) Comparison of 3 luting agents on retention of implant-supported crowns on 2 different abutments. Implant Dent 20: 349-353.

25. Rodiger M, Rinke S, Ehret-Kleinau F, Pohlmeyer F, et al. (2014) Evaluation of removal forces of implant-supported zirconia copings depending on abutment geometry, luting agent and cleaning method during re-cementation. J Adv Prosthodont 6: 233-240.

26. Parisay I, Khazaei Y (2018) Evaluation of retentive strength of four luting cements with stainless steel crowns in primary molars: An *in vitro* study. Dent Res J (Isfahan) 15: 201-207.

27. Habib B, von Fraunhofer JA, Driscoll CF (2005) Comparison of two luting agents used for the retention of cast dowel and cores. J Prosthodont 14: 164-169.

28. Passon C, Lambert RH, Lambert RL, Newman S (1992) The effect of multiple layers of die-spacer on crown retention. Oper Dent 17: 42-49.

29. Campbell SD (1990) Comparison of conventional paint-on die spacers and those used with the all-ceramic restorations. J Prosthet Dent 63: 151-155.

30. Emtiaz S, Goldstein G (1997) Effect of die spacers on precementation space of complete-coverage restorations. Int J Prosthodont 10: 131-135.

31. Webb EL, Murray HV, Holland GA, Taylor DF (1983) Effects of preparation relief and flow channels on seating full coverage castings during cementation. J Prosthet Dent 49: 777-780.

32. Kim Y, Yamashita J, Shotwell JL, Chong KH, Wang HL (2006) The comparison of provisional luting agents and abutment surface roughness on the retention of provisional implant-supported crowns. J Prosthet Dent 95: 450-455.

33. Jorgensen KD (1955) The relationship between retention and convergence angle in cemented veneer crowns. Acta Odontol Scand 13: 35-40.

34. Gilboe DB, Teteruck WR (1974) Fundamentals of extracoronal tooth preparation. Part I. Retention and resistance form. J Prosthet Dent 32: 651-656.

35. Botega DM, Mesquita MF, Henriques GE, Vaz LG (2004) Retention force and fatigue strength of overdenture attachment systems. J Oral Rehabil 31: 884-889.

36. Lehmann KM, Arnim F (1976) Studies on the retention capability of push-button attachments. SSO Schweiz Monatsschr Zahnheilkd 86: 521-530.

37. Covey DA, Kent DK, St Germain HA Jr, Koka S (2000) Effects of abutment size and luting cement type on the uniaxial retention force of implant-supported crowns. J Prosthet Dent 83: 344-348.

38. Di Felice R, Rappelli G, Camaioni E, Cattani M, Meyer JM, et al. (2007) Cementable implant crowns composed of cast superstructure frameworks luted to electroformed primary copings: an *in vitro* retention study. Clin Oral Implants Res 18: 108-113.

39. Kaar D, Oshida Y, Andres CJ, Barco MT, Platt JA (2006) The effect of fatigue damage on the force required to remove a restoration in a cement-retained implant system. J Prosthodont 15: 289-294.

40. Pan YH, Lin CK (2005) The effect of luting agents on the retention of dental implant-supported crowns. Chang Gung Med J 28: 403-410.

41. Gumus HO, Kurtulus IL, Kuru E (2018) Evaluation and comparison of the film thicknesses of six temporary cements before and after thermal cycling. Niger J Clin Pract 21: 1656-1661.

42. Kurt M, Kulunk T, Ural C, Kulunk S, Danisman S, et al. (2013) The effect of different surface treatments on cement-retained implant-supported restorations. J Oral Implantol 39: 44-51.

43. Lennartz A, Dohmen A, Bishti S, Fischer H, Wolfart S (2018) Retrievability of implant-supported zirconia restorations cemented on zirconia abutments. J Prosthet Dent 120: 740-746.

44. Lewinstein I, Block L, Lehr Z, Ormianer Z, Matalon S (2011) An *in vitro* assessment of circumferential grooves on the retention of cement-retained implant-supported crowns. J Prosthet Dent 106: 367-372.

45. Mehl C, Harder S, Schwarz D, Steiner M, Vollrath O, et al. (2012) *In vitro* influence of ultrasonic stress, removal force preload and thermocycling on the retrievability of implant-retained crowns. Clin Oral Implants Res 23: 930-937.

46. Mehl C, Ali S, El Bahra S, Harder S, Vollrath O, et al. (2016) Is There a Correlation Between Tensile Strength and Retrievability of Cemented Implant-Retained Crowns Using Artificial Aging? Int J Prosthodont 29: 83-90.

47. Naumova EA, Roth F, Geis B, Baulig C, Arnold WH, et al. (2018) Influence of Luting Materials on the Retention of Cemented Implant-Supported Crowns: An *In vitro* Study. Materials (Basel) 11: 1853.

48. Nejatidanesh F, Savabi O, Savabi G, Razavi M (2018) Effect of cleaning methods on retentive values of saliva-contaminated implant-supported zirconia copings. Clin Oral Implants Res 29: 530-536.

49. Nejatidanesh F, Savabi O, Shahtoosi M (2013) Retention of implant-supported zirconium oxide ceramic restorations using different luting agents. Clin Oral Implants Res 24: 20-24.

50. Pan YH, Ramp LC, Lin CK, Liu PR (2007) Retention and leakage of implant-supported restorations luted with provisional cement: a pilot study. J Oral Rehabil 34: 206-212.

51. Pitta J, Bijelic-Donova J, Burkhardt F, Fehmer V, Narhi T, et al. (2020) Temporary Implant-Supported Single Crowns Using Titanium Base Abutments: An *In vitro* Study on Bonding Stability and Pull-out Forces. Int J Prosthodont 33: 546-552.

52. Pitta J, Burkhardt F, Mekki M, Fehmer V, Mojon P, et al. (2020) Effect of airborne-particle abrasion of a titanium base abutment on the stability of the bonded interface and retention forces of crowns after artificial aging. J Prosthet Dent 126: 214-221.

53. Rohr N, Balmer M, Muller JA, Martin S, Fischer J (2019) Chewing simulation of zirconia implant supported restorations. J Prosthodont Res 63: 361-367.

54. Rues S, Fugina M, Rammelsberg P, Kappel S (2017) Cemented Single Crown Retention on Dental Implants: An *In vitro* Study. Int J Prosthodont 30: 133-135.

55. Schiessl C, Schaefer L, Winter C, Fuerst J, Rosentritt M, et al. (2013) Factors determining the retentiveness of luting agents used with metal- and ceramic-based implant components. Clin Oral Investig 17: 1179-1190.

56. Sellers K, Powers JM, Kiat-Amnuay S (2017) Retentive strength of implant-supported CAD-CAM lithium disilicate crowns on zirconia custom abutments using 6 different cements. J Prosthet Dent 117: 247-252.

57. Ongthiemsak C, Mekayarajjananonth T, Winkler S, Boberick KG (2005)The effect of compressive cyclic loading on retention of a temporary cement used with implants. J Oral Implantol 31: 115-120.

58. Alvarez-Arenal A, Gonzalez-Gonzalez I, Pines-Hueso J, deLlanos-Lanchares H, del Rio Highsmith J (2016) The Effect of Compressive Cyclic Loading on the Retention of Cast Single Crowns Cemented to Implant Abutments. Int J Prosthodont 29: 80-82.

59. Carnaggio TV, Conrad R, Engelmeier RL, Gerngross P, Paravina R, et al. (2012) Retention of CAD/CAM all-ceramic crowns on prefabricated implant abutments: an *in vitro* comparative study of luting agents and abutment surface area. J Prosthodont 21: 523-528.

60. Bresciano M, Schierano G, Manzella C, Screti A, Bignardi C, et al. (2005) Retention of luting agents on implant abutments of different height and taper. Clin Oral Implants Res16: 594-598.

61. Safari S, Hosseini Ghavam F, Amini P, Yaghmaei K (2018) Effects of abutment diameter, luting agent type, and re-cementation on the retention of implant-supported CAD/CAM metal copings over short abutments. J Adv Prosthodont 10: 1-7.

62. Al Hamad KQ, Al Rashdan BA, Abu-Sitta EH (2011) The effects of height and surface roughness of abutments and the type of cement on bond strength of cement-retained implant restorations. Clin Oral Implants Res 22: 638-644.

63. Abbo B, Razzoog ME, Vivas J, Sierraalta M (2008) Resistance to dislodgement of zirconia copings cemented onto titanium abutments of different heights. J Prosthet Dent 99: 25-29.

64. Rodiger M, Kloss J, Gersdorff N, Burgers R, Rinke S (2018) Removal forces of adhesively and self-adhesively luted implant-supported zirconia copings depend on abutment geometry. J Mech Behav Biomed Mater 87: 119-123.

65. Derafshi R, Ahangari AH, Torabi K, Farzin M (2015) Evaluation of the Effect of Axial Wall Modification and Coping Design on the Retention of Cement-retained Implant-supported Crowns. J Dent Res Dent Clin Dent Prospects9: 35-39.

66. Sheets JL, Wilcox C, Wilwerding T (2008) Cement selection for cement-retained crown technique with dental implants. J Prosthodont 17: 92-96.

67. Nagasawa Y, Hibino Y, Nakajima H (2014) Retention of crowns cemented on implant abutments with temporary cements. Dent Mater J 33: 835-844.

68. Reddy SV, Reddy MS, Reddy CR, Pithani P, R SK, et al. (2015) The influence of implant abutment surface roughness and the type of cement on retention of implant supported crowns. J Clin Diagn Res 9: ZC05- ZC07.

69. Woelber JP, Ratka-Krueger P, Vach K, Frisch E (2016) Decementation Rates and the Peri-Implant Tissue Status of Implant-Supported Fixed Restorations Retained *via* Zinc Oxide Cement: A Retrospective 10-23-Year Study. Clin Implant Dent Relat Res 18: 917-925.

70. Sorrentino R, Galasso L, Tete S, De Simone G, Zarone F (2012) Clinical evaluation of 209 all-ceramic single crowns cemented on natural and implant-supported abutments with different luting agents: a 6-year retrospective study. Clin Implant Dent Relat Res 14: 184-197.

71. Lopes ACO, Machado CM, Bonjardim LR, Bergamo ETP, Ramalho IS, et al. (2019) The Effect of CAD/CAM Crown Material and Cement Type on Retention to Implant Abutments. J Prosthodont 28: e552-e556.

72. Rohr N, Brunner S, Martin S, Fischer J (2018) Influence of cement type and ceramic primer on retention of polymer-infiltrated ceramic crowns to a one-piece zirconia implant. J Prosthet Dent 119: 138-145.

73. Mehl C, Harder S, Shahriari A, Steiner M, Kern M (2012) Influence of abutment height and thermocycling on retrievability of cemented implant-supported crowns. Int J Oral Maxillofac Implants 27: 1106-1115.

74. Schierano G, Manzella C, Menicucci G, Parrotta A, Zanetti EM, et al. (2016) *In vitro* standardization of two different removal devices in cemented implant prosthesis. Clin Oral Implants Res 27: 1026-1030.

75. Saghiri MA, Asatourian A, Garcia-Godoy F, Gutmann JL, Sheibani N (2013) The impact of thermocycling process on the dislodgement force of different endodontic cements. Biomed Res Int.

76. Enkling N, Ueda T, Gholami H, Bayer S, Katsoulis J, et al. (2014) Precision of fit and retention force of cast non-precious-crowns on standard titanium implant-abutment with different design and height. Clin Oral Implants Res 25: 451-457.

77. Liang T, Hu X, Zhu L, Pan X, Zhou Y, et al. (2016) Comparative *in vitro* study of cementing techniques for implant-supported restorations. J Prosthet Dent 116: 59-66.

78. Worni A, Gholami H, Marchand L, Katsoulis J, Mericske-Stern R, et al. (2015) Retrievability of implant-supported crowns when using three different cements: a controlled clinical trial. Int J Prosthodont 28: 22-29.

79. Sadighpour L, Geramipanah F, Fazel A, Allahdadi M, Kharazifard MJ (2018) Effect of Selected Luting Agents on the Retention of CAD/CAM Zirconia Crowns Under Cyclic Environmental Pressure. J Dent (Tehran) 15: 97-105.

80. Cano-Batalla J, Soliva-Garriga J, Campillo-Funollet M, Munoz-Viveros CA, Giner-Tarrida L (2012) Influence of abutment height and surface roughness on *in vitro* retention of three luting agents. Int J Oral Maxillofac Implants 27: 36-41.

81. Ajay R, Suma K, Ali SA, Kumar Sivakumar JS, Rakshagan V, et al. (2017) Effect of Surface Modifications on the Retention of Cement-retained Implant Crowns under Fatigue Loads: An *In vitro* Study. J Pharm Bioallied Sci 9: S154-S160.

82. Sahu N, Lakshmi N, Azhagarasan NS, Agnihotri Y, Rajan M, et al. (2014) Comparison of the effect of implant abutment surface modifications on retention of implant-supported restoration with a polymer based cement. J Clin Diagn Res 8: 239-242.

83. Kilicarslan MA, Ozkan P (2013) Evaluation of retention of cemented laser-sintered crowns on unmodified straight narrow implant abutments. Int J Oral Maxillofac Implants 28: 381-387.

84. Weyhrauch M, Igiel C, Wentaschek S, Pabst AM, Scheller H, et al. (2014) Retentive strength of monolithic all-ceramic crowns on implant abutments. Int J Comput Dent 17: 135-144.

85. Jugdev J, Borzabadi-Farahani A, Lynch E (2014) The effect of air abrasion of metal implant abutments on the tensile bond strength of three luting agents used to cement implant superstructures: an *in vitro* study. Int J Oral Maxillofac Implants 29: 784-790.

86. T P Bergamo E, Zahoui A, Luri Amorin Ikejiri L, Marun M, Peixoto da Silva K, et al. (2020) Retention of zirconia crowns to Ti-base abutments: effect of luting protocol, abutment treatment and autoclave sterilization. J Prosthodont Res 65: 171-175.

87. Ebert A, Hedderich J, Kern M (2007) Retention of zirconia ceramic copings bonded to titanium abutments. Int J Oral Maxillofac Implants 22: 921-927.

88. Rappelli G, Corso M, Coccia E, Camaioni E, Di Felice R, et al. (2008) *In vitro* retentive strength of metal superstructures cemented to solid abutments. Minerva Stomatol 57: 95-101.

89. Sadig WM, Al Harbi MW (2007) Effects of surface conditioning on the retentiveness of titanium crowns over short implant abutments. Implant Dent 16: 387-396.

90. Sailer I, Sailer T, Stawarczyk B, Jung RE, Hammerle CH (2009) *In vitro* study of the influence of the type of connection on the fracture load of zirconia abutments with internal and external implant-abutment connections. Int J Oral Maxillofac Implants 24: 850-858.

91. de Campos TN, Adachi LK, Miashiro K, Yoshida H, Shinkai RS, et al. (2010) Effect of surface topography of implant abutments on retention of cemented single-tooth crowns. Int J Periodontics Restorative Dent 30: 409-413.