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

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Abstract

Background: The present review presents the scientific state of the art in the field of cementation of crowns on implants. Because semipermanent cements have been specifically 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 in the retention 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 advantage of screw fixation primarily affects 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 avoid 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 (i.e., semipermanent cements) for the use on implants. They have become popular in recent years because they combine the advantages of reversibility 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 as 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] |                      |
|               |                                    | Breeding 1992 [17] |                      |
| Semipermanent | 50-200                             | Covey 2000 [37] | Medium to long term  |
|               |                                    | Di Felice 2007 [38] |                      |
|               |                                    | Dudley 2008 [23] |                      |
|               |                                    | Kaar 2006 [39] |                      |
| Definitive    | Polymeric 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%      |
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.
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 0.158** mm thickness and the 0.031** mm thickness significantly [41]. 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 (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 concavities 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 mm²). 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 mm² 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 Mehlo 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

### 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
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. Retrieval 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 | Particle size sandblasting (µm) | Thermocycling | Taper (°) | Abutment height (mm) | Chewing simulation | Abutment surface size (mm²) | Cement gap (mm) | Groove (abutment) |
|--------|--------|--------------------------|---------------|-------------------|-------------------------------|---------------|-----------|---------------------|------------------|------------------------|----------------|-----------------|
| Al Hamad KQ, et al., [62] | glass ionomer | titanium-metal alloy | 183.13 | yes | 8 | 6 |
| glass ionomer | 305.14 | yes | 50 | yes | 8 | 4 |
| glass ionomer | 239.95 | yes | 8 | 6 |
| glass ionomer | 523.71 | yes | 8 | 6 |
| zinc phosphate | 268.59 | yes | 8 | 4 |
| zinc phosphate | 418.69 | yes | 8 | 4 |
| zinc phosphate | 647.66 | yes | 8 | 6 |
| zinc phosphate | 700.93 | yes | 8 | 6 |
| zinc oxide eugenol | 65.53 | yes | 8 | 4 |
| zinc oxide eugenol | 139.79 | yes | 8 | 4 |
| zinc oxide eugenol | 73.48 | yes | 8 | 6 |
| zinc oxide eugenol | 207.09 | yes | 8 | 6 |
| zinc oxide eugenol + petroleum jelly | 9.86 | yes | 8 | 4 |
| zinc oxide eugenol + petroleum jelly | 42.09 | yes | 8 | 4 |
| zinc oxide eugenol + petroleum jelly | 17.36 | yes | 8 | 6 |
| zinc oxide eugenol + petroleum jelly | 48.27 | 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 Type                        | Study Reference    | Derafshi R, et al., [65] | Gultekin P, et al., [13] | Gumus HO, et al., [41] |
|----------------------------------|--------------------|--------------------------|--------------------------|------------------------|
| glass ionomer                    |                    | zinc oxide eugenol       | titanium-metal alloy      | zinc oxide eugenol     |
| resin based                      |                    | 46.88                    | 5.5                      | 31.64                  |
| resin based                      |                    | 46.31                    | 5.5                      | 31.64                  |
| resin based                      |                    | 65.3                     | 5.5                      | 31.64                  |
| resin based                      |                    | 62.25                    | 5.5                      | 31.64                  |
| Gumni MB, et al., [24]           |                    | zinc oxide eugenol       | titanium-metal alloy      | zinc oxide eugenol     |
| resin based                      |                    | 45.1                     | yes                      | 6                      |
| resin based                      |                    | 90.7                     | yes                      | 6                      |
| resin based                      |                    | 36.1                     | yes                      | 6                      |
| resin based                      |                    | 34.4                     | yes                      | 6                      |
| resin based                      |                    | 82.8                     | yes                      | 6                      |
| resin based                      |                    | 67.7                     | yes                      | 6                      |
| resin based                      |                    | 23.3                     | yes                      | 6                      |
| resin based                      |                    | 6.2                      | yes                      | 6                      |
| resin based                      |                    | 8.8                      | yes                      | 6                      |
| resin based                      |                    | 12.7                     | yes                      | 6                      |
| resin based                      |                    | 32.9                     | yes                      | 6                      |
| resin based                      |                    | 24.6                     | yes                      | 6                      |
| resin based                      |                    | 33.7                     | yes                      | 50                     |
| resin based                      |                    | 262.6                    | yes                      | 50                     |

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|                                | Retention (%) | Bonding Agent | Cementation Method | Study                          |
|--------------------------------|---------------|---------------|--------------------|--------------------------------|
| Glass ionomer                 | 75.7          | yes           | 50                 | Yes                            |
| Zinc oxide                    | 20.5          | yes           | 50                 | Yes                            |
| Zinc phosphate                | 258           | yes           | 50                 | Yes                            |
| Glass ionomer                 | 42.1          | yes           | 50                 | Yes                            |
| Jugdev J, et al., [85]         |               |               |                    |                                |
| Zinc oxide eugenol            | 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                   | 455.1         | yes           | 6                  | 5.7                            |
| Resin based                   | 565.52        | yes           | 6                  | 5.7                            |
| Resin based                   | 534.78        | yes           | 6                  | 5.7                            |
| Resin based                   | 678.6         | yes           | 6                  | 5.7                            |
| Kim Y, et al., [32]            |               |               |                    |                                |
| Calcium-hydroxide             | 48            |               |                    |                                |
| Calcium-hydroxide             | 58            |               |                    |                                |
| Calcium-hydroxide             | 52            |               |                    |                                |
| Zinc oxide                    | 39            |               |                    |                                |
| Zinc oxide                    | 53            |               |                    |                                |
| Zinc oxide                    | 40            |               |                    |                                |
| Zinc oxide eugenol            | 11            |               |                    |                                |
| Zinc oxide eugenol            | 20            |               |                    |                                |
| Zinc oxide eugenol            | 23            |               |                    |                                |
| Zinc oxide eugenol            | 10            |               |                    |                                |
| Zinc oxide eugenol            | 12            |               |                    |                                |
| Zinc oxide eugenol            | 14            |               |                    |                                |
| Kokubo Y, et al., [14]         |               |               |                    |                                |
| Polycarboxylate               | 300           | yes           | 8                  | 7.4                            |
| Polycarboxylate               | 120           | yes           | 8                  | 7.4                            |
| Polycarboxylate               | 250           | yes           | 8                  | 7.4                            |
| Polycarboxylate               | 275           | yes           | 8                  | 7.4                            |
| Polycarboxylate               | 60            | yes           | 8                  | 7.4                            |
| Polycarboxylate               | 40            | yes           | 8                  | 7.4                            |
| Polycarboxylate               | 50            | yes           | 8                  | 7.4                            |
| Polycarboxylate               | 20            | yes           | 8                  | 7.4                            |
| Zinc oxide eugenol            | 100           | yes           | 8                  | 7.4                            |
| Zinc oxide eugenol            | 60            | yes           | 8                  | 7.4                            |
| Zinc oxide eugenol            | 70            | yes           | 8                  | 7.4                            |
| Zinc oxide eugenol            | 70            | yes           | 8                  | 7.4                            |
| Zinc oxide eugenol            | 120           | yes           | 8                  | 7.4                            |
| Zinc oxide eugenol            | 10            | yes           | 8                  | 7.4                            |

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|                                      |                |        |    |        |        |        |
|--------------------------------------|----------------|--------|----|--------|--------|--------|
| Zinc oxide                          | 80             | yes    | 50 | 8      | 7.4    | 51.39  |
| Zinc oxide                          | 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 eugenol                  | Titanium-metal alloy | 170    | yes | 110   | yes    | 6      | 6      | 34.55  |
|--------------------------------------|----------------------|--------|-----|--------|--------|--------|--------|--------|
| Zinc phosphate                       | 362                  | yes    | 110 | yes    | 6      | 6      |        |        |
| Zinc oxide eugenol                  | 188                  | yes    | 110 | yes    | 6      | 6      |        |        |
| Zinc phosphate                       | 580                  | yes    | 110 | yes    | 6      | 6      |        |        |
| Zinc oxide eugenol                  | 204                  | yes    | 110 | yes    | 6      | 6      |        |        |
| Zinc phosphate                       | 549                  | yes    | 110 | yes    | 6      | 6      |        |        |
| Zinc oxide eugenol                  | 242                  | yes    | 110 | yes    | 6      | 6      |        |        |
| Zinc phosphate                       | 587                  | yes    | 110 | yes    | 6      | 6      |        |        |

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     |
| Material Type          | Study Insert   | Study Reference | Number | Retention Rate | Melt Temperature | Degree of Dispersion |
|------------------------|----------------|-----------------|--------|----------------|------------------|---------------------|
| Polycarboxylate        | Mehl et al., [46] |                  | 105    | 5              | 37.2             | 50                  |
| Resin Based            | Nagasawa et al., [67] |               | 49.09  | 5              | 33.95            | 50                  |
| Zinc Oxide Eugenol     | Naumova et al., [47] |                | 20.0   | 5              | 37.2             | 50                  |

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| Material                  | Bond Strength | Bond Type | Setting Time | Bonding Time | Bonding Agent |
|--------------------------|---------------|-----------|--------------|--------------|---------------|
| 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            | 228.1         | 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 | 181.9 | Yes | Yes | 6 | 5.5 |
| 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            |
| Ongthiemak, 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 | Yes | 12 | Yes | 147 | Yes | 50 | Yes |
| Zinc Phosphate           | 249.2         | Yes       | 50           | Yes          | 12            | Yes           |
| Study (et al.) | Material Type | Bonding Material | Bonding Surface | Bonding Area | Retention (N) | Bonding Success | Details |
|--------------|--------------|-----------------|-----------------|--------------|---------------|----------------|---------|
| Pitta J, et al. [52] | Resin | Titanium-PMMA | Yes | Resin | 64.1 | Yes | Yes |
| | Resin | 64.9 | Yes | Resin | 50 | Yes | |
| | Resin | 276.7 | Yes | Resin | 30 | Yes | |
| | Resin | 39.1 | Yes | Resin | 30 | Yes | |
| | Resin | 1146.5 | Yes | Resin | | Yes | |
| Pitta J, et al. [53] | Resin | Titanium-PMMA | Yes | Resin | 206.3 | Yes | Yes |
| | Resin | 346.9 | Yes | Resin | | Yes | |
| | Resin | 420 | Yes | Resin | | Yes | |
| | Resin | 376.1 | Yes | Resin | | Yes | |
| Reddy SV, et al. [68] | Resin | Titanium-Metal Alloy | Yes | Resin | 258.28 | Yes | 50 |
| | Resin | 260.68 | Yes | Resin | 50 | | |
| | Resin | 138.41 | Yes | Resin | 50 | | |
| | Resin | 138.28 | Yes | Resin | 50 | | |
| | Resin | 184.86 | Yes | Resin | 50 | | |
| | Resin | 152.13 | Yes | Resin | 50 | | |
| Rödiger M, et al. [25] | Resin | Titanium-Zirconia | Yes | Resin | 101.1 | Yes | 110 |
| | Resin | 311.7 | Yes | Resin | 110 | Yes | 6.79 |
| | Resin | 447.9 | Yes | Resin | 110 | Yes | 6.79 |
| | Resin | 478.7 | Yes | Resin | 110 | Yes | 6.79 |
| Rohr N, et al. [72] | Resin | Zirconia-Zirconia | Yes | Resin | 196 | Yes | |
| | Resin | 43 | Yes | Resin | | | |
| | Resin | 127 | Yes | Resin | | | |
| | Resin | 261 | Yes | Resin | | | |
| | Resin | 253 | Yes | Resin | | | |
| | Resin | 270 | Yes | Resin | | | |
| | Resin | 226 | Yes | Resin | | | |
| | Resin | 222 | Yes | Resin | | | |
| | Resin | 238 | Yes | Resin | | | |
| | Resin | 245 | Yes | Resin | | | |
| | Resin | 318 | Yes | Resin | | | |
| | Resin | 254 | Yes | Resin | | | |
| | Resin | 605 | Yes | Resin | | | |
| | Resin | 470 | Yes | Resin | | | |
| | Resin | 257 | Yes | Resin | | | |
| | Resin | 243 | Yes | Resin | | | |
| | Resin | 269 | Yes | Resin | | | |
| | Resin | 224 | Yes | Resin | | | |
| | Resin | 363 | Yes | Resin | | | |
| | Resin | 288 | Yes | Resin | | | |
| Rües S, et al. [54] | Resin | Zirconia-Zirconia | Yes | Resin | 31 | Yes | 50 |
| | Resin | 40 | Yes | Resin | 50 | | 4 |
| | Resin | 436 | Yes | Resin | 50 | | 4 |
| | Resin | 682 | Yes | Resin | 50 | | 4 |
| Material Type                  | Study                          | Retention Rate | Bond Strength | Tensile Strength | Hertz | Debond Strength |
|-------------------------------|-------------------------------|----------------|---------------|------------------|-------|-----------------|
| Glass Ionomer                 | Safari S, et al., [61]         | 364.19         | yes           | yes              | 3     | 27.69           |
| Resin Based                   | Sadig wM, et al., [89]         | 380            | yes           | yes              | 5.5   |                 |
| Zinc Phosphate                | Ziegler S, et al., [49]        | 180            | yes           | yes              | 5.5   |                 |
| Resin-Based Titanium-Alloy    | Ziegler S, et al., [49]        | 310            | yes           | yes              | 5.5   |                 |
| Resin-Based titanium-Alloy    | Ziegler S, et al., [49]        | 470            | yes           | yes              | 5.5   |                 |
| Resin-Based titanium-Alloy    | Ziegler S, et al., [49]        | 500            | yes           | yes              | 5.5   |                 |
| Polycarboxylate               | Schiessl C, et al., [55]       | 408.3          | yes           | yes              | 8     | 25              |
| Polycarboxylate               | Sahu N, et al., [82]           | 405.45         | yes           | yes              | 3     | 31.9            |

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| Material Type          | Code | Setting | Viscosity | Shrinkage | Tensile Strength (N) |
|-----------------------|------|---------|-----------|-----------|---------------------|
| Polycarboxylate       | 240  | yes     | 50        | 6         | 6                   |
| Polycarboxylate       | 200  | yes     | 50        | 6         | 6                   |
| Zinc phosphate        | 200  | yes     | 50        | 6         | 6                   |
| Zinc phosphate        | 160  | yes     | 50        | 6         | 6                   |
| Polycarboxylate       | 140  | yes     | 50        | 6         | 6                   |
| Glass ionomer         | 120  | yes     | 50        | 6         | 6                   |
| Resin based           | 230  | yes     | 50        | 6         | 6                   |
| Zinc oxide noneugenol | 320  | yes     | 50        | 8         | 6                   |
| Polycarboxylate       | 320  | yes     | 50        | 8         | 6                   |
| Polycarboxylate       | 140  | yes     | 50        | 8         | 6                   |
| Polycarboxylate       | 140  | yes     | 50        | 8         | 6                   |
| Zinc phosphate        | 80   | yes     | 50        | 8         | 6                   |
| Glass ionomer         | 100  | yes     | 50        | 8         | 6                   |
| Resin based           | 260  | yes     | 50        | 8         | 6                   |
| Zinc oxide noneugenol | 90   | yes     | 50        | 8         | 6                   |
| Polycarboxylate       | 660  | yes     | 50        | yes       | 4                   |
| Polycarboxylate       | 380  | yes     | 50        | yes       | 4                   |
| Polycarboxylate       | 400  | yes     | 50        | yes       | 4                   |
| Zinc phosphate        | 370  | yes     | 50        | yes       | 4                   |
| Methacrylate-based    | 5    | yes     | 50        | yes       | 4                   |
| Glass ionomer         | 300  | yes     | 50        | yes       | 4                   |
| Resin based           | 300  | yes     | 50        | yes       | 4                   |
| Zinc oxide noneugenol | 50   | yes     | 50        | yes       | 4                   |
| Polycarboxylate       | 580  | yes     | 50        | yes       | 6                   |
| Polycarboxylate       | 400  | yes     | 50        | yes       | 6                   |
| Polycarboxylate       | 210  | yes     | 50        | yes       | 6                   |
| Zinc phosphate        | 280  | yes     | 50        | yes       | 6                   |
| Methacrylate-based    | 5    | yes     | 50        | yes       | 6                   |
| Glass ionomer         | 250  | yes     | 50        | yes       | 6                   |
| Resin based           | 240  | yes     | 50        | yes       | 6                   |
| Zinc oxide noneugenol | 40   | yes     | 50        | yes       | 6                   |
| Polycarboxylate       | 620  | yes     | 50        | yes       | 8                   |
| Polycarboxylate       | 400  | yes     | 50        | yes       | 8                   |
| Polycarboxylate       | 250  | yes     | 50        | yes       | 8                   |
| Zinc phosphate        | 250  | yes     | 50        | yes       | 8                   |
| Methacrylate-based    | 5    | yes     | 50        | yes       | 8                   |
| Glass ionomer         | 200  | yes     | 50        | yes       | 8                   |
| Resin based           | 210  | yes     | 50        | yes       | 8                   |
| Zinc oxide noneugenol | 50   | yes     | 50        | yes       | 8                   |
| Zinc phosphate        | 300  | yes     | 50        | yes       | 4                   |
| Glass ionomer         | 110  | yes     | 50        | yes       | 4                   |
| Zinc oxide noneugenol | 100  | yes     | 50        | yes       | 4                   |

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| 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 |
| Material          | Temperature | Bonding | Setting Time | Retraction (mm) |
|-------------------|-------------|---------|--------------|-----------------|
| Glass ionomer     | 210         | yes     | 120          | 8               |
| Zinc oxide        | 20          | yes     | 120          | 8               |
| Resin based       | 220         | yes     | 120          | 8               |
| Polycarboxylate   | 150         | yes     | 50           | 4               |
| Polycarboxylate   | 220         | yes     | 50           | 4               |
| Polycarboxylate   | 225         | yes     | 50           | 4               |
| Polycarboxylate   | 100         | yes     | 50           | 6               |
| Polycarboxylate   | 75          | yes     | 50           | 6               |
| Polycarboxylate   | 160         | yes     | 50           | 6               |
| Polycarboxylate   | 110         | yes     | 50           | 8               |
| Polycarboxylate   | 80          | yes     | 50           | 8               |
| Polycarboxylate   | 160         | yes     | 50           | 8               |
| Polycarboxylate   | 140         | yes     | 50           | 4               |
| Polycarboxylate   | 290         | yes     | 50           | 4               |
| Polycarboxylate   | 330         | yes     | 50           | 4               |
| Polycarboxylate   | 225         | yes     | 50           | 6               |
| Polycarboxylate   | 240         | yes     | 50           | 6               |
| Polycarboxylate   | 225         | yes     | 50           | 6               |
| Polycarboxylate   | 60          | yes     | 50           | 8               |
| Polycarboxylate   | 350         | yes     | 50           | 8               |
| Polycarboxylate   | 225         | yes     | 50           | 8               |
| Polycarboxylate   | 380         | yes     | 50           | 4               |
| Polycarboxylate   | 400         | yes     | 50           | 4               |
| Polycarboxylate   | 220         | yes     | 50           | 4               |
| Polycarboxylate   | 375         | yes     | 50           | 6               |
| Polycarboxylate   | 230         | yes     | 50           | 6               |
| Polycarboxylate   | 210         | yes     | 50           | 6               |
| Polycarboxylate   | 300         | yes     | 50           | 8               |
| Polycarboxylate   | 90          | yes     | 50           | 8               |
| Polycarboxylate   | 100         | yes     | 50           | 8               |
| Polycarboxylate   | 610         | yes     | 50           | 4               |
| Polycarboxylate   | 375         | yes     | 50           | 4               |
| Polycarboxylate   | 390         | yes     | 50           | 4               |
| Polycarboxylate   | 520         | yes     | 50           | 6               |
| Polycarboxylate   | 380         | yes     | 50           | 6               |
| Polycarboxylate   | 220         | yes     | 50           | 6               |
| Polycarboxylate   | 610         | yes     | 50           | 8               |
| Polycarboxylate   | 390         | yes     | 50           | 8               |
| Polycarboxylate   | 220         | yes     | 50           | 8               |
| Polycarboxylate   | 470         | yes     | 50           | 4               |
| Polycarboxylate   | 375         | yes     | 50           | 4               |
| Polycarboxylate   | 220         | yes     | 50           | 4               |
| Polycarboxylate   | 520         | yes     | 50           | 6               |

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|       |       |       |       |       |       |
|-------|-------|-------|-------|-------|-------|
| 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 | 4 | 6 | 33.12 |
| polycarboxylate | 350 | yes | 50 | 4 | 6 | 33.12 |
| polycarboxylate | 330 | yes | 50 | 4 | 6 | 33.12 |
| polycarboxylate | 520 | yes | 50 | 6 | 6 | 33.12 |
| polycarboxylate | 230 | yes | 50 | 6 | 6 | 33.12 |
| polycarboxylate | 250 | yes | 50 | 6 | 6 | 33.12 |
| polycarboxylate | 580 | yes | 50 | 8 | 6 | 33.12 |
| polycarboxylate | 360 | yes | 50 | 8 | 6 | 33.12 |
| polycarboxylate | 220 | yes | 50 | 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 | 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 |

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