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# The Retentive Strength of Laser-Sintered Cobalt-Chromium-Based Crowns Cemented by Glass Ionomer and Zinc Phosphate Cements after Pretreatment with a Desensitizing Paste Containing 8% Arginine and Calcium Carbonate

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**Abstract:** The effect of dentin pretreatment with desensitizing paste containing 8% arginine and calcium carbonate on the retention of laser-sintered cobalt-chromium (Co-Cr)-based crowns was examined. Forty molars were prepared using a standardized protocol. The Co-Cr crowns were produced using selective laser melting. The teeth were either pretreated with the desensitizing paste or not pretreated. After one week, each group was cemented with glass ionomer cement (GIC) or zinc phosphate cement (ZPC). Surface areas of the teeth were measured before cementation. After aging, the cemented crown-tooth assemblies were tested for retentive strength using a universal testing machine. The debonded surfaces of the teeth and crowns were examined at 2.7× magnification. Pretreating the dentin surfaces with the desensitizing paste before cementation with GIC or ZPC did not affect the retention of the Co-Cr crowns. The retention of the GIC group (6.04±1.10 MPa) was significantly higher than that of the ZPC group (2.75±1.25 MPa). The predominant failure mode for the ZPC and for the nontreated group of the GIC was adhesive cement-dentin; for the GIC-treated group, it was adhesive cement-crown. The desensitizing paste can be safely used to reduce postcementation sensitivity without reducing the retentive strength of Co-Cr crowns cemented with GIC or ZPC.

**Keywords:** desensitizing paste; dentin; retention; cements; cobalt-chromium

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## 1. Introduction

Dentin hypersensitivity following tooth preparation and cementation of fixed partial dentures (FPDs) has been a common phenomenon [1]. Postcementation complaints from patients have been received for 20 to 30% of crowns inserted [2], and this rate has remained at 6% and 3% after 2 and 3 years, respectively [3]. There are several explanations for this postoperative sensitivity. One outcome of aggressive tooth preparation is an increased number of opened and expanded dentinal tubules [4,5]. This condition is further aggravated by inadequate provisional restorations and removal of the smear layer due to acid etching induced by the cements [6]. Porcelain fused to metal (PFM) restorations, for example, are most commonly luted with zinc phosphate or glass ionomer cements (GICs), which are acidic in nature [7].

In an effort to control postoperative sensitivity, various desensitizing agents have been used to seal dentinal tubules before crown cementation; however, the literature is inconsistent regarding the effects of these agents on the retentive strength of FPDs. Sailer et al. [8,9] and Stawarczyk et al. [10,11] showed that glutaraldehyde/HEMA pretreatment and resin sealing of dentin following tooth preparation had a beneficial effect on the shear bond strength of self-adhesive resin cement. Other

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studies have reported that dentin desensitizing by means of glutaraldehyde-containing primers or dentin sealing by means of bonding agents did not affect the bond strength of the cements tested [12,13]. On the other hand, several studies have demonstrated that these agents decrease crown retention to some extent [14,15]. Aranha et al. [16] showed that specimens treated with dentin desensitizers (except Gluma) yielded significantly lower mean bond strengths than nontreated control specimens.

Recently, a new in-office Colgate Sensitive Pro-Relief Desensitizing Paste containing 8% arginine and calcium carbonate was shown to provide immediate and lasting relief from dentin hypersensitivity [17-21]. No significant difference in the bonding strength of composites to enamel or dentin pretreated with this desensitizing paste has been reported [22-24]. In addition, pretreating dentin surfaces with Pro-Relief Desensitizing Paste prior to cementation did not affect the retention of complete cast metal crowns luted with a glass ionomer cement (GIC) [25] or the retention of zirconium oxide crowns luted with a resin-modified GIC or a self-adhesive resin cement [26].

Recently, a new additive manufacturing technology operated by computer-aided design and computer-aided manufacturing (CAD/CAM), referred to as selective laser melting (SLM) technology, has been introduced for fabricating cobalt-chromium (Co-Cr) frameworks for PFM crowns. Co-Cr crowns produced with SLM exhibit a marginal and internal accuracy that is comparable to that of conventional production procedures but save time and facilitate laboratory procedures [27-29].

No information has been found in the literature concerning the influence of pretreating dentin with 8.0% arginine and calcium carbonate desensitizing paste on the retentive strength of Co-Cr crowns produced by the SLM technology and cemented by zinc phosphate cement (ZPC) and glass ionomer cement (GIC), which are the most frequently used cements for luting metal-based restorations.

The aim of this in vitro study was to evaluate the effect of the pretreatment of dentin with Colgate Sensitive Pro-Relief Desensitizing Paste, which contains 8% arginine and calcium carbonate, on the retentive strength of SLM Co-Cr copings cemented by ZPC and GIC. The null hypotheses were as follows: (1) the retentive strength of the SLM Co-Cr copings cemented by ZPC and GIC to human extracted teeth would not be affected by the Colgate Sensitive Pro-Relief Desensitizing Paste, and (2) the retentive strength of the two cements is similar.

## 2. Results

The retentive strength (mean, SD) of the treated and untreated cementation groups are presented in Table 1. Pretreating the dentin surfaces with Colgate Sensitive Pro-Relief Desensitizing Paste prior to cementation with either GIC or ZPC did not affect the retentive strength of the Co-Cr copings ($p=0.780$). The retention obtained with Fuji I capsules (GIC) was significantly ($p=0.001$) higher than that obtained with Harvard Cement OptiCaps (ZPC). The interaction between cement and dentin treatment was not significant ($p=0.208$).

**Table 1.** Mean (SD) retentive strength (MPa) of the cobalt-chromium-based crown for all cementation groups.

| Cement Type | Treatment | Sample No. | Mean Retentive Value (MPa) | Standard Deviation |
|---|---|---|---|---|
| GIC | 1 | 10 | 6.39 | **1.06** |
| | 2 | 10 | 5.73 | **1.10** |
| | Total | 20 | 6.04 | **1.10** |
| ZPC | 1 | 10 | 2.39 | **0.99** |
| | 2 | 10 | 3.10 | **1.44** |
| | Total | 20 | 2.75 | **1.25** |
| Total | 1 | 20 | 4.29 | **2.27** |
| | 2 | 20 | 4.41 | **1.83** |
| | Total | 40 | 4.36 | **2.03** |

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Treatment:

1. Without pretreatment and with Colgate Sensitive Pro-Relief Desensitizing Paste (control)
2. With pretreatment and with Colgate Sensitive Pro-Relief Desensitizing Paste

Examination by magnifying glasses of the failure mode after the dislodgment of the crown revealed that for ZPC, the predominant failure mode was adhesive cement-dentin. In 85% of the surfaces, all (53%) or part (32%) of the surface of the crown was covered with cement, and the rest were detected on the dentin (Figure 1). This mode of failure was consistent regardless of whether the dentin was pretreated with Colgate Sensitive Pro-Relief Desensitizing Paste or not. In the GIC group, the predominant failure mode was adhesive cement-crown. In 62% of the surfaces, all (40%) or part (22%) of the surface of the dentin was covered with cement, and the rest were detected on the crown (Figure 1). This failure mode was inconsistent between the groups. In the nontreated group, more surfaces exhibited the adhesive cement-dentin mode of failure; in the treated group, more surfaces exhibited the adhesive cement-crown mode of failure (Figure 1). Cohesive cement failure was barely seen in all groups, while cohesive dentin failure did not occur.

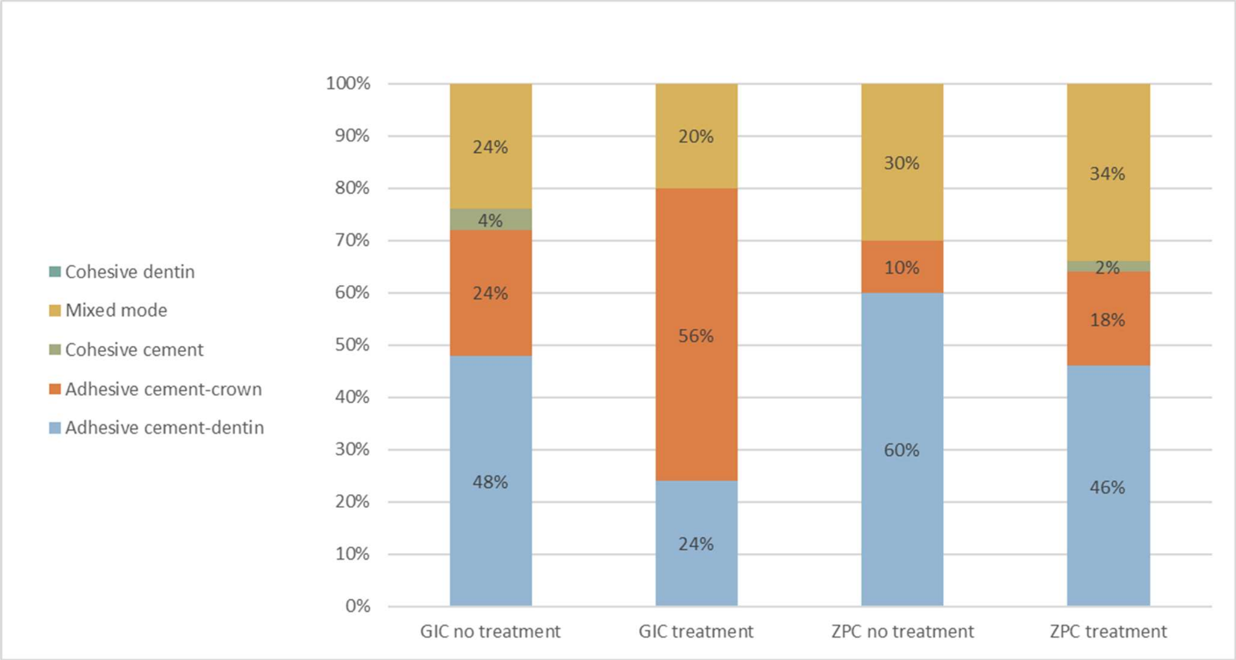


**Figure 1.** Distribution of failure modes (number of surfaces) for each cementation group.

Scanning electron microscopy (SEM) images of the dentin surfaces illustrating the various modes of failure are presented for the ZPC (Figure 2a-c) and GIC (Figure 3a, b) groups. Figure 2a-c illustrates the mixed mode of failure, whereas most of the dentin surface exhibits longitudinal striations of the bur, with a small part covered with the ZPC. This type of failure was consistent in the untreated (A,B) as well as the treated (C) ZPC groups.

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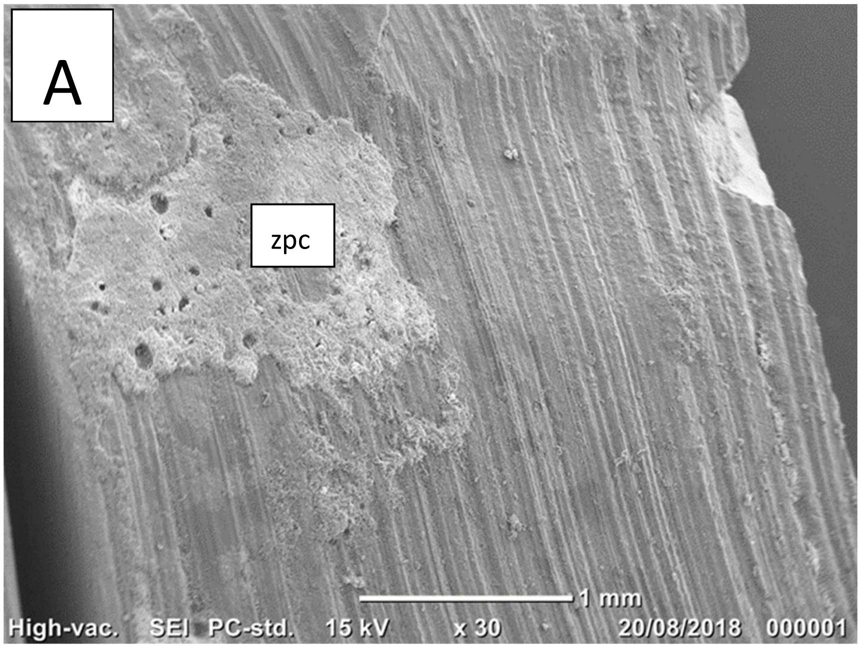


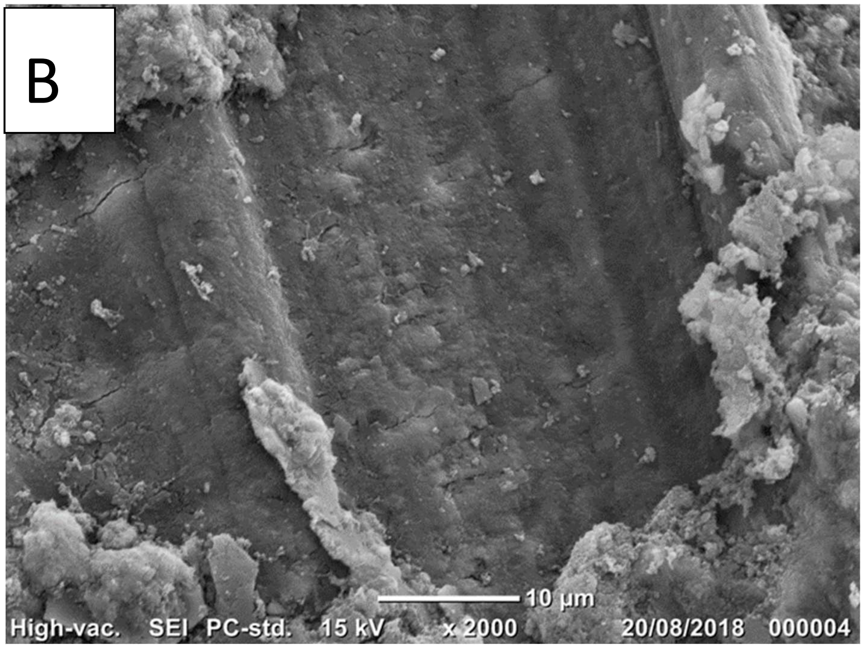

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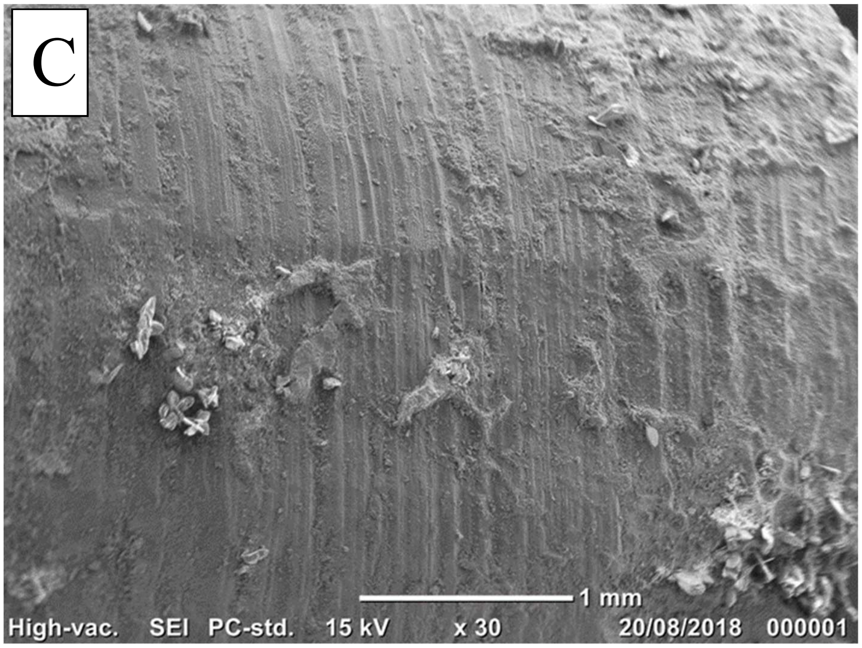
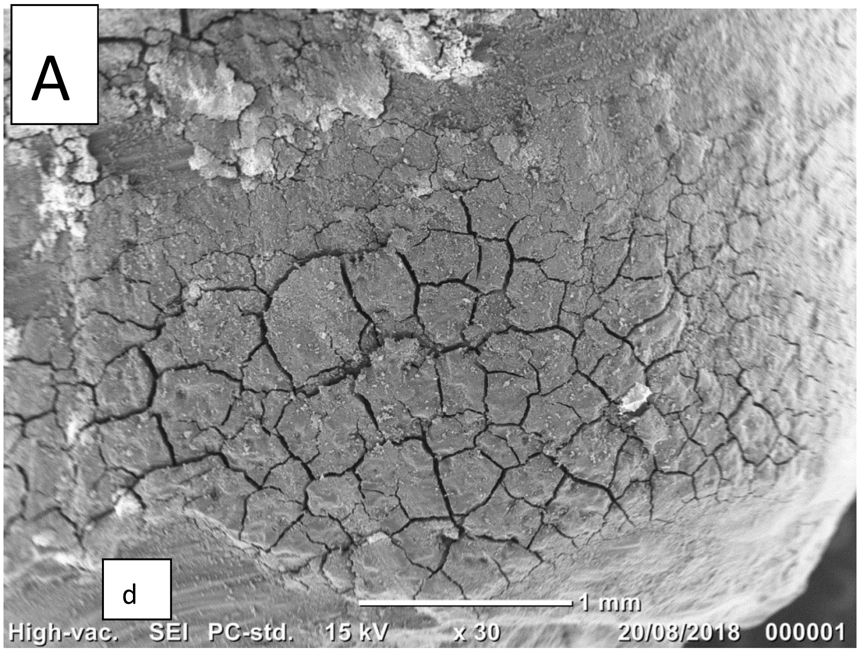



**Figure 2a-c** (ZPC group). Scanning electron microscopy image of the untreated (a,b) and treated (c) dentin surfaces after failure illustrating the mixed mode of failure but with majority to adhesive cement-dentin , whereas most of the dentin surface exhibits longitudinal striations of the bur, with only a small part covered with cement (zpc). This type of failure with predominant adhesive cement-dentin was typical of the ZPC group.



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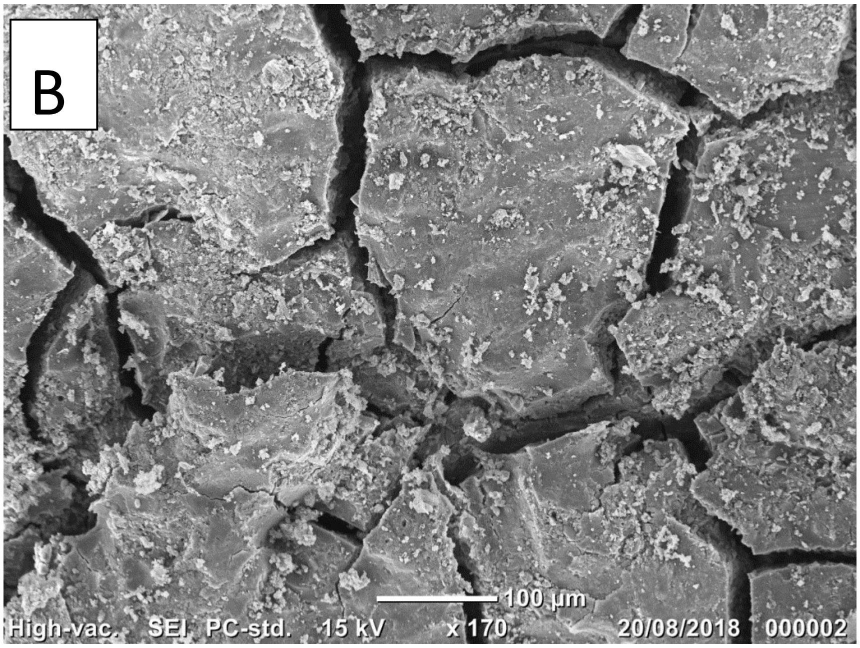


**Figure 3a,b** (GIC group). Scanning electron microscopy images of the treated dentin surface after failure. (**a**) Most of the dentin surface is covered with cement (×30), and only a small part of the dentin is exposed (d), demonstrating the striations of the bur. (**b**) At greater magnification (×170), a craze lines in the cement layer caused by the dehydration process is evident.

Figure 3a,b illustrates the adhesive crown cement mode of failure, with most of the dentin surface covered with cement. This mode of failure was typical of the treated GIC group

## 3. Discussion

Colgate Sensitive Pro-Relief Desensitizing Paste contains arginine, bicarbonate and calcium carbonate and is highly effective in occluding dentin tubules, as was previously demonstrated by confocal laser scanning microscopy (CLSM) and SEM [30]. This paste has been shown to physically plug and seal exposed dentin tubules and to effectively provide dentin hypersensitivity relief [31], which has been reported to last for up to 28 days and to reduce the postpreparation and postcementation sensitivity of vital teeth that serve as abutments for FPDs; however, this treatment may be advocated only if retentive strength is not affected [20].

In the current study, the retention of cobalt-chromium-based (Co-Cr) copings was tested one week after dentin pretreatment with Pro-Relief Desensitizing Paste in order to resemble a period of reevaluation prior to final cementation. The luting agents used in this study were GIC and ZPC. Both cements are associated with postcementation sensitivity, which can last for a week [32]. GIC and ZPC are popular choices for luting metal-based restorations. GIC relies on both the mechanical retention to surface irregularities and the chelation to calcium in the tooth structure, while ZPC relies only on mechanical retention to both dentin and crown surfaces [33,34].

The current results support the first null hypothesis of the study, implying that pretreatment with Colgate Sensitive Pro-Relief Desensitizing Paste would have no effect on the retentive strength of SLM Co-Cr crown copings cemented to human extracted teeth with GIC or ZPC. Our results are in agreement with those of another study that demonstrated that pretreating dentin surfaces with Pro-Relief Desensitizing Paste prior to cementation did not affect the retention of complete cast metal crowns luted with GIC [25]. Moreover, in the aforementioned study, pretreatment with Pro-Relief showed the best retention of complete cast metal crowns compared to all other dentin desensitizers tested. Pilo et al. [26] showed the same results with zirconium oxide (Y-TZP) crowns luted with either resin-modified glass ionomer cement (RMGIC) or self-adhesive resin cement (SARC).

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Our second null hypothesis was rejected because the retentive strength of GIC was significantly higher than that of ZPC. This conclusion is in accordance with a previous study of Wiskott et al. [35] demonstrating that crowns luted with resin composite cement and GIC were more resistant to dynamic lateral loading than those luted using ZPC. On the other hand, Gorodovsky et al. [36] reported no significant difference between the retention of zinc phosphate and that of glass ionomer. A review of the research of different cements did not reveal a consistent conclusion about the retentive strength of GIC in comparison with that of ZPC. Some studies showed a higher retentive strength for ZPC, and others reported a higher retentive strength for GIC; some showed no significant difference between the two cements [33]. However, it should be noted that all the aforementioned ZPC studies used the classic Harvard Cement normal setting, whereas in the current study, the newer Harvard Cement OptiCaps was used. The latter is the capsulated version intended to overcome mistakes in mixing and dosing. It has been shown that Vickers hardness increases with more powder with a rise in mean values following an exponential curve ranging between 34 and 66 MPa [37]. Comparison studies between hand-mixed and capsulated ZPC have not been reported yet.

The lack of effect on the retentive strength of ZPC from Colgate Sensitive Pro-Relief Desensitizing Paste with 8% arginine and calcium carbonate was also verified by an absence of change in failure mode, which was mainly adhesive cement-dentin. This finding implies that all or most of the crown was covered by ZPC, probably due to surface irregularities of the intaglio of the Co-Cr copings. In the GIC group, the predominant failure mode was adhesive cement-crown. This finding implies that all or most of the dentin was covered by GIC, probably due to the chemical interaction between the dentin surface and the chelating calcium ions. Although the Colgate Sensitive Pro-Relief Desensitizing Paste did not affect the retentive strength, the failure mode varied between the groups; in the nontreated group, most of the cement remained on the crown, while in the treated group, most of the dentin was covered with cement. These differences might be explained by chelation between the polyalkenoic chains in GIC and the calcium carbonate contained in the Colgate Sensitive Pro-Relief Desensitizing Paste, which physically plugs and seals exposed dentin tubules.

This is an in vitro study; hence, the subjective desensitizing effect of the Colgate Sensitive Pro-Relief Desensitizing Paste with 8% arginine and calcium carbonate on vital teeth prepared for FPD must be validated in clinical studies before being recommended for use.

**4. Materials and methods**

The study sample comprised forty freshly extracted, caries-free, intact molars that were extracted for periodontal reasons (age range 40-60). Approval from the Ethical Committee of Tel Aviv University was obtained (#21-08-16) and all individuals signed an informed consent.

The teeth were stored in a germ-free 0.1% thymol tap water solution at room temperature for a maximum of 2 weeks until experimentation. Each tooth was suspended in the middle of an aluminum ring and was mounted 2 mm apical to the cementoenamel junction (CEJ) in poly(methyl methacrylate) resin (Quick resin, Ivoclar, Schaan, Liechtenstein) after notching the roots for retention purposes. The mounted teeth were stored in tap water at room temperature at all times.

A standardized protocol yielding an axial height of 5 mm and a 10° taper was followed for preparation. The occlusal surface was sectioned perpendicular to the long axis with a water-cooled precision saw (Isomet Plus, Buehler, IL, USA). A 0.4-mm, 360° chamfer finish line located 1 mm above the CEJ with a 10° taper preparation was obtained by a rigidly secured, high-speed handpiece equipped with a diamond bur (C1-Strauss, Ra'anana, Israel) mounted on a custom-designed, surveyor-like apparatus (Figure 4). A new diamond bur was used for each tooth.

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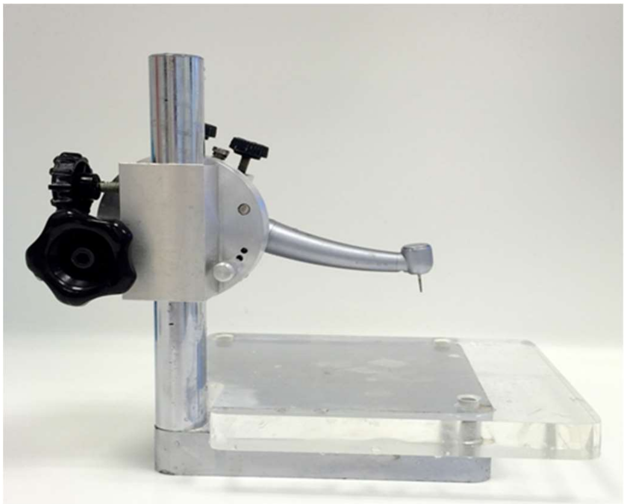

**Figure 4.** Surveyor-like apparatus for standardized preparation of mounted extracted teeth.

The prepared teeth were digitally scanned by a laboratory scanner (Series 7, Dental Wing, Letourneux, Montreal, Canada) operated by blue light and equipped with 5 axes of rotation, and STL files were obtained. Forty Co-Cr copings were produced using an SLM system (Eosint M 280, EOS, Krailling, Germany) at a commercial dental laboratory (MS Systems, Or Yehuda, Israel). The CAD-CAM Co-Cr cores were 1.0 mm thick with a 50 μm virtual cement spacer layer and were designed with an occlusal loop (4-mm outer diameter and 2-mm inner diameter) extending coronally from the occlusal surface to facilitate tensile loading (Figure 5a) [38]. The 40 prepared teeth were randomly assigned to two groups (2 × 20). In the first group, the dentin surfaces were pretreated with Colgate Sensitive Pro-Relief Desensitizing Paste using prophy cups under light pressure according to the manufacturer's recommendations. In the second group, which served as the control group, the dentin surfaces were not pretreated. The Co-Cr copings were placed on each tooth, which was then stored at 37°C under 100% humidity for 1 week, resembling a period of reevaluation prior to final cementation. In each group, two luting cements were evaluated (2 × 10): a GIC (GC Fuji I Capsule, GC, Tokyo, Japan) and a ZPC (Harvard Cem OptiCaps, Harvard Dental International, GmbH). Prior to cementation, the areas of the axial and occlusal surfaces of each prepared tooth were measured as previously described [38]. The cements were used according to the manufacturer's recommendations. Each crown was cemented to its tooth in a standardized manner under a constant load of 50 N (Force gauge, FG 20, Lutron, Taiwan) for 10 min and allowed to set for 24 h

(A)

(B)

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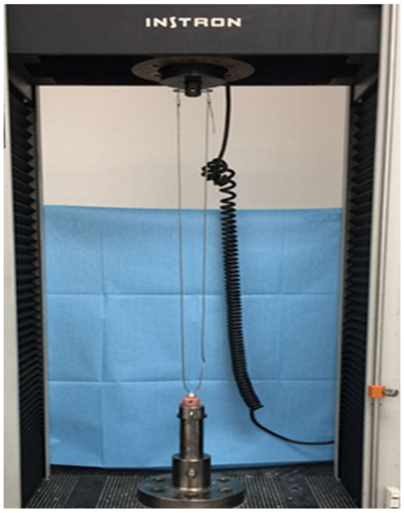


**Figure 5** (**a**). Co-Cr coping showing the design of the occlusal surface to enable postcementation removal with (**b**). Metal cable connecting the coping and the universal testing machine.

The cemented crown-tooth assemblies were stored in tap water at 37°C for two weeks, followed by thermal cycling between water temperatures of 5°C and 55°C for 5000 cycles with a 10-s dwell time (Y. Manes, TA, Israel). After thermal cycling, the crown-tooth assemblies were subjected to dislodgment forces through a 1.2-mm diameter metal cable entangled through the occlusal loop along the apico-occlusal axis using a universal testing machine (Instron, Model 4502, Instron Corp., Buckinghamshire, UK) at a crosshead speed of 1 mm/min (Figure 5b) until failure. The force at dislodgment was recorded and divided by the total surface area of each prepared sample to yield the retention value (Pa).

The debonded surfaces of the teeth and crowns were examined with magnifying glasses at 2.7× magnification (Orascoptic, Middleton, WI, USA). Each surface of the dentin-crown interface was analyzed separately (five surfaces per tooth). Failure was classified based on the criteria presented in Table 2

**Table 2.** Classification of failure criteria.

| Classification | Description | Criteria |
|---|---|---|
| 1 | Cement principally on crown surface | Adhesive cement-dentin |
| 2 | Cement principally on dentin surface | Adhesive cement-crown |
| 3 | Cement equally distributed on dentin & crown surfaces | Cohesive cement |
| 4 | Mixed mode | Adhesive & cohesive cement |
| 5 | Fracture of the tooth | Cohesive dentin |

A separate analysis was performed for each matched Co-Cr tooth surface (buccal, lingual, mesial, distal and occlusal). For each category, the number of surfaces was counted and presented as a percentage of all the surfaces for the specific cement.

To analyze the dentin surfaces, the debonded surfaces of some teeth representing different failure categories from each group were examined under an SEM (Quantum 2000) in high vacuum mode following gold sputter-coating. The acquisition conditions were as follows: 25 kV, 90 μA and 40–1000× magnification

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### *4.1. Statistical Analysis*

Retentive strength was evaluated using two-way analysis of variance (ANOVA) with repeated measures; cement (n = 2) and pretreatment (n = 2) were the independent variables. The level of significance was 0.05

## 5. Conclusions

An 8.0% arginine and calcium carbonate in-house desensitizing paste can be safely used on dentin to reduce postcementation sensitivity without compromising the retention of SLM Co-Cr crowns cemented with either ZPC or GIC.

**Author Contributions:** Conceptualization, Rafael Pilo and Shifra Levartovsky; Investigation, Sharon Agar; Methodology, Rafael Pilo and Shifra Levartovsky; Supervision, Shifra Levartovsky; Writing – original draft, Rafael Pilo and Shifra Levartovsky; Writing – review & editing, Rafael Pilo.

**Conflicts of Interest:** The authors do not have any financial interest in the companies whose materials are included in this article. Neither of the authors has any conflict of interest related to this manuscript.

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