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Water sorption, solubility, expansion, and brushing abrasion of different temporary filling materials

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Purpose: To compare three different zinc oxide/calcium sulfate-based temporary filling materials [Cavit G (3M ESPE), i-Pro N (i-dental), Cavitimi (Imicryl)] regarding water sorption, solubility, expansion, and brushing abrasion.

Methods: Twelve cylindrically shaped samples (6 × 2 mm) were prepared from each material to determine water sorption, solubility, and expansion. The dry mass (m1) and diameter (d1) of the samples were measured after desiccation, followed by measurement of the saturated masses (m2) and diameters (d2) after 7 days of immersion in water, and then measurement of the dehydrated dry masses (m3). Using these values, the water sorption, solubility, and expansion of the materials were calculated. Ten cylindrically shaped samples (8 × 2 mm) were prepared to evaluate mass changes due to brushing abrasion and their masses were recorded before and after brushing. One-way analysis of variance and post hoc Tukey tests were used for statistical analysis.

Results: Significant differences were observed in the solubility ($p < 0.05$). Cavit G showed the highest solubility values, whereas Cavitimi exhibited the least. Mass loss and expansion values were significantly higher in Cavitimi ($p < 0.05$). Cavitimi showed the least water sorption ($p < 0.05$).

Conclusion: Cavitimi, a new temporary filling material, showed the highest mass loss and expansion, but the lowest values for solubility and water sorption. Cavit G exhibited the greatest solubility.

Keywords: Brushing abrasion, expansion, solubility, temporary filling materials, water sorption.

Introduction

Root canal treatments can be completed in single or multiple sessions. Single-session root canal treatments have advantages such as shorter treatment duration and greater comfort for the patient and clinician, but also limiting factors such as a cooperative patient, an experienced physician, and an environment without blood/exudate flow. Multiple visits are preferred when there is a persistent infection that cannot be eliminated by normal irrigation and require medicaments. The canals are temporarily sealed between the visits (1). However, deterioration of the physical/chemical properties of temporary fillers may lead to bacterial invasion and postoperative failure. This means that a treatment performed to achieve an antibacterial effect may result in the opposite and undesired situation (2).

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The most important factor in the deterioration of the physical/chemical properties of temporary fillers is the inability to withstand extreme conditions such as thermal changes. These thermal changes may cause microleakage due to the difference in the thermal expansion coefficient between the filling material and natural teeth (3). Occlusal forces and brushing abrasion can also negatively affect the sealing of temporary filling materials (4). Some studies reported that the sealing of temporary filling materials did not change significantly with thermal cycles alone, only when occlusal forces were applied in addition to temperature change (5,6). Moreover, since temporary filling materials are constantly exposed to saliva, dimensional changes due to water absorption, loss of retention, and staining may occur. These deteriorations in the material also provide a favorable environment for caries and periodontal disease (7). Filling materials may also show hygroscopic expansion and lead to fracture formation in the tooth (8).

An ideal temporary filling material should have the following characteristics: good marginal sealing, minimal porosity, dimensional stability, resistance to abrasion and compression, ease of application and removal, compatibility, and an aesthetic finish (9). Different materials have been developed to satisfy these properties. There are four types of temporary fillers that are generally used as follows: zinc oxide/calcium sulfate ($ZnO/CaSO_4$)-based, zinc oxide eugenol-based, glass ionomer, and resin-modified glass ionomer-based fillers. The high cost of glass ionomers, minimal working time, difficulty in distinguishing from dental tissue, and chemical bonds forming between the tooth and resin-modified glass ionomers limit its clinical use as a temporary filling material. Although $ZnO/CaSO_4$-based temporary fillers show low compressive strength, they have a high thermal expansion coefficient, which in turn provides an adequate seal when hardened (10). Zinc oxide eugenol-based temporary filling materials show a higher compressive strength than $ZnO/CaSO_4$-based materials, but can inhibit the polymerization of resin materials that are used for upper-restoration (11).

$ZnO/CaSO_4$-based temporary fillers contain 40%–60% zinc oxide and 1%–20% zinc sulfate monohydrate (10). The most widely used $ZnO/CaSO_4$-based temporary filling material is Cavit G (3M ESPE, Neuss, Germany) (12). Cavit G is the most preferred product for temporary restorations because of its good sealing, simple manipulation, and easy removal from the cavity (13). Cavitimi (Imicryl, Konya, Turkey) and i-Pro N (i-Dental, Siauliai, Lithuania) are gray and white $ZnO/CaSO_4$-based temporary filling materials, respectively. Studies on the physical/chemical properties of i-Pro N and Cavitimi are lacking.

The aim of this study was to evaluate and compare three different brands of $ZnO/CaSO_4$-based temporary fillers (Cavit G, i-Pro N, Cavitimi) in terms of water absorption, solubility, expansion, and brushing abrasion.

Materials and Methods

The commercial names and full contents of the $ZnO/CaSO_4$-based products used in this study are shown in Table 1.

Twelve cylindrically shaped samples with a diameter of 6 mm and a height of 2 mm were prepared from each material to evaluate water absorption, solubility, and expansion. All samples were kept in glass containers containing silica gel at 37°C until a stable dry mass was obtained. Mass measurements were made in 24-hour periods to determine the stable dry mass. Initially, the dry mass (m1) was recorded when the samples did not show a mass variation of more than 0.1 mg throughout the measurements. The samples were then examined under a stereomicroscope. For each sample, 12 different diameter measurements were made at 15° angles, and the average of these values was noted as the initial diameter (d1) for each sample. Afterwards, the samples were immersed in distilled water and incubated at 37 °C for 7 days. Following this 7-day period, the samples were removed from the water and measured at 1-minute intervals until they reached a stable mass. Following confirmation that the mass of the samples did not change more than 0.1 mg in a single minute, this measured mass was recorded as the mass (m2) saturated with water. Subsequently, the samples were examined again under a stereomicroscope to measure their expansion and diameter. The measured values were recorded as diameter (d2) post-expansion. The samples were finally dried at 37°C and their masses were determined on a precision scale in 24-hour

Table 1. Contents, manufacturers, and batch numbers of the materials used in the study

Material	Contents	Manufacturer	Batch Number
Cavit G	Zinc Oxide, Talc, Ethylene Bis (Oxyethylene) Diacetate, Zinc Sulfate, Polyvinyl Acetate, Calcium Salt, Hydrate	3M ESPE	4136911
i-Pro N	Zinc Oxide, Calcium Sulfate	i-dental	050211
Cavitimi	Zinc oxide, Calcium Sulfate, Calcium Fluoride, Aroma	Imicryl	20031

periods with no more than 0.1 mg variation and recorded as dehydrated dry mass (m3). Mass measurements were made using an analytical balance (Radwag PS 510.R1), which has an accuracy of ±0.1 mg. Using the formula for water absorption of materials *(m2 – m3)/V,* solubility was calculated *(m1 – m3)/V*. Volume *(V)* was calculated using the formula $\pi.r^2.h$. The *r* and *h* variables represent the radius and height of the sample, respectively. The expansion was calculated with the percentage of changes in the diameter formula *[((d2 – d1) / d1) x 100]*.

To determine the mass loss caused by brushing abrasion, 10 cylindrically shaped samples with a diameter of 8 mm and a height of 2 mm were prepared from each material and incubated at 37 °C until a stable mass was obtained. The masses of the samples were measured in 24-hour intervals to ensure their stabilization. After confirming that mass variation did not exceed 0.1 mg, the prebrushing masses (m1) of the samples were recorded and the samples were then placed in a brushing simulator for abrasion testing. The samples were brushed with a medium-hard bristled brush at a speed of 30 mm/s with 250 back-and-forth strokes using toothpaste and distilled water. Following this, the samples were removed from the device and kept in a 37 °C incubator until a stable mass was obtained, which was then recorded as the post-brushing mass (m2). The loss of mass due to brushing was calculated by subtracting m2 from m1. The brushing design is shown in Figure 1.

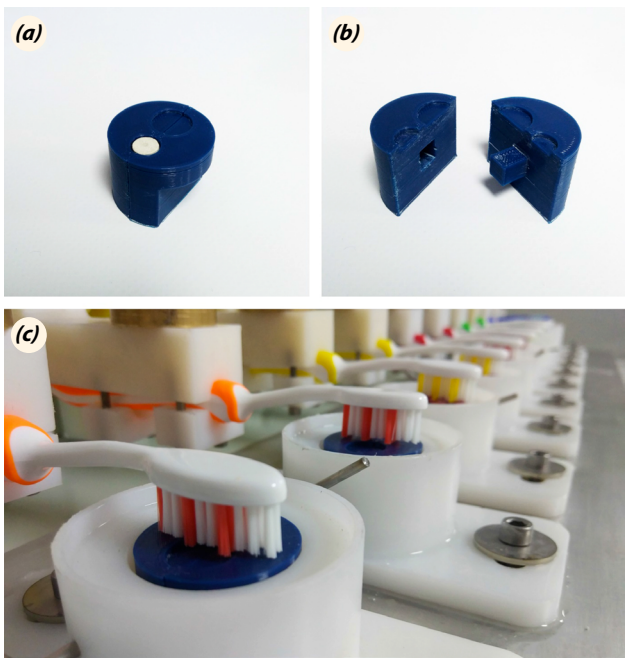

Fig. 1. Brushing design. **(a, b)** Apparatus in which the samples were placed. Note that a key lock system is used to avoid damaging the sample. **(c)** Position of the samples and brush placed in the brushing simulator.

Statistical Analysis

For statistical analysis, the IBM SPSS Statistics for Windows version 22.0 (IBM Corp., Armonk, NY, USA) program was used. Normal distribution of data was confirmed using the Shapiro–Wilks test. The data were subjected to one-way analysis of variance and posthoc Tukey tests. Significance was determined as $p< 0.05$.

Results

Cavit G (366.94 µg/mm³) and i-Pro N (353.67 µg/mm³) showed higher values of water absorption, while Cavitimi (206.31 µg/mm³) had the lowest values (Fig. 2). There was no significant difference in water absorption between Cavit G and i-Pro N ($p> 0.05$).

In terms of solubility, a significant difference was found between the three materials ($p< 0.05$). From the highest to the lowest, solubility values were noted as the solubility of Cavit G (274.1 µg/mm³), followed by that of i-Pro N (150.31 µg/mm³) and Cavitimi (73.68 µg/mm³), respectively (Fig. 3).

The percentage of diameter change (expansion) values of the materials were examined, with no significant dif-

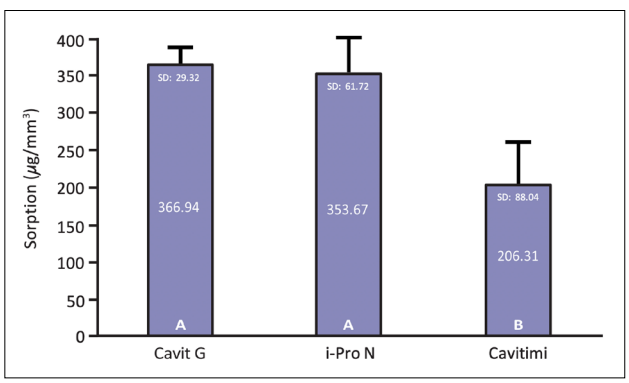

Fig. 2. Water absorption values of the materials used in the study. Distinct letters indicate statistical differences among the materials ($p< 0.05$).

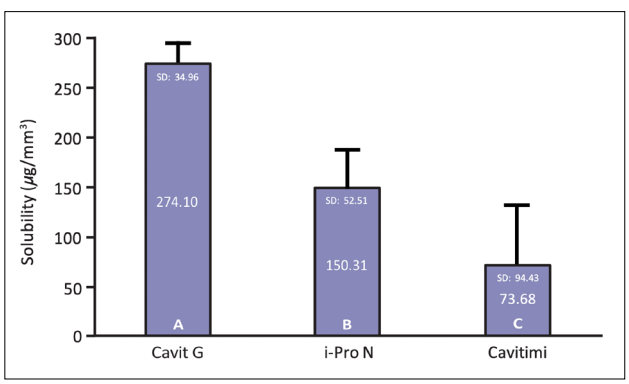

Fig. 3. Solubility values of the materials used in the study. Distinct letters indicate statistical differences among the materials ($p< 0.05$).

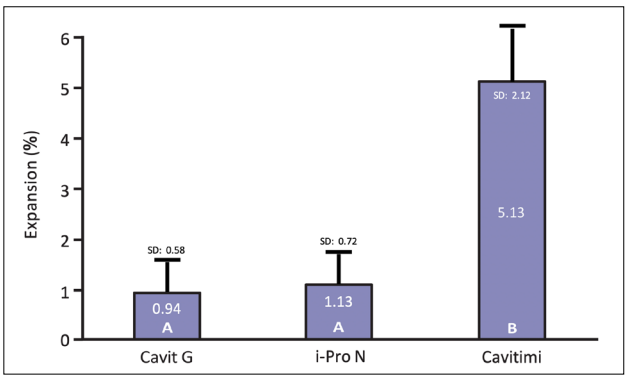

Fig. 4. Expansion (percentage of changes in diameter) values of the materials used in the study. Distinct letters indicate statistical differences among the materials ($p< 0.05$).

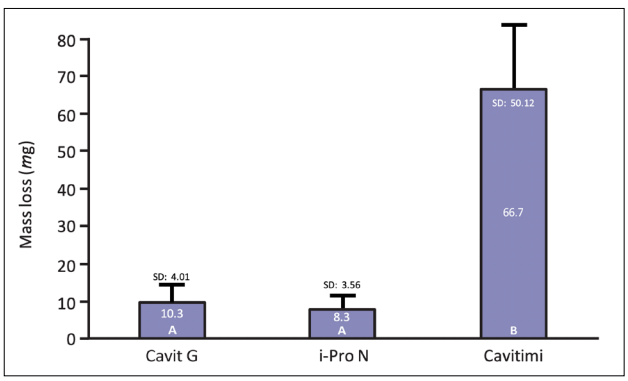

Fig. 5. Mass loss values of the materials used in the study after brushing. Distinct letters indicate statistical differences among materials ($p< 0.05$).

ference found between Cavit G (0.94%) and i-Pro N (1.13%). Cavitimi (5.13%) had the highest expansion values ($p< 0.05$) (Fig. 4).

The highest mass loss values due to brushing abrasion were observed in the Cavitimi (66.7 mg) group ($p< 0.05$). No significant difference was found between Cavit G and i-Pro N ($p> 0.05$) (Fig. 5).

Discussion

This study was conducted to evaluate and compare different commercial forms of $ZnO/CaSO_4$-based temporary fillers (Cavit G, 3M ESPE; i-Pro N, i-dental; Cavitimi, Imicryl) in terms of water absorption, solubility, expansion, and brushing abrasion. While there are many studies comparing different types of temporary fillers, none pertain to comparing commercial forms of $ZnO/CaSO_4$-based temporary fillers.

There are no studies conducted with Cavitimi and i-Pro N in the literature, while there are studies examining the water absorption, solubility, and mass loss of Cavit (7,14). The water absorption and solubility data on Cavit in these studies (7,14) support our study results. Although we used the same method as that of some studies (13,14) to calculate mass loss, this parameter could not be compared with other studies since mass loss is not a percentage value.

Mass loss values and volumes of the materials were accepted as the criterion in calculating water absorption and solubility data (15,16). Cavit G and i-Pro N showed the greatest absorption of water while Cavitimi showed the least.

Water absorption plays a critical role in the hardening of hydrophilic materials. The material expands due to hygroscopicity and a good seal forms between the tooth and the material (11,17). However, some studies have reported that the solubility of the material increases as the absorbed water creates gaps in the material (14,16). In this study, similar results were found when comparing the water absorption and solubility values of these materials. Thus, our study results are supported by the other studies.

Expansion values of the materials were obtained by calculating the percentage of changes in diameter (18). Twelve different diameter measurements for each sample analyzed under a stereomicroscope were conducted in a simulated environment with an accuracy of 0.04 mm. While Cavitimi showed the greatest expansion, Cavit G and i-Pro N were less expansive materials with similar values. The additional components in the materials are not the same and this may lead to the difference in expansion values. All three materials contain zinc oxide and calcium sulfate. Cavitimi contains calcium fluoride as an additional component, while Cavit G contains materials such as polyvinyl acetate and hydrate (Table 1).

According to the findings of our study, it may seem contradictory that Cavitimi, which shows positive values in terms of water absorption, is the material that exhibits the greatest expansion. However, considering that Cavitimi is the material that dissolves the least and loses the most mass with brush abrasion, we can conclude that the expansion of Cavitimi may be a superficial expansion, and not directly linked to water absorption. The fact that it is the material with the highest brushing abrasion confirms the superficial expansion of Cavitimi. Similarly, Sidhu et al. (19) reported the "self-healing effect," according to which minimal expansion and even contraction can be observed as the absorbed water causes a sealing effect on the internal cracks of the materials (18). Cavitimi may not display the "self-healing" effect because there may be less water penetration, which is limited to superficial expansion.

It has been reported that calcium fluoride added to the filling materials may cause deterioration of the mechanical properties of the material (20). In a study evaluating fluorine-releasing composites, it was shown that calcium

carbonates, which are formed by the deterioration of these materials, expand the material (21). High expansion properties of Cavitimi may also be related to its calcium fluoride content.

The effects of water absorption, solubility, expansion, or brushing abrasion on the deterioration of materials are undeniable. However, the deterioration of the microstructure of the materials has been reported to be a cause of water absorption, and not expansion, swelling, or softening of the material (16,22).

The materials tested in this study were placed in a brushing simulator to determine mass loss due to brushing abrasion. Cavit G and i-Pro N showed similar mass loss, while Cavitimi was the material that lost the most mass. This can be attributed to Cavitimi exhibiting superficial expansion and the brushing forces having a heavier impact on the superficial layer of the material.

Wiegand et al. (23) reported that the average force applied with a manual toothbrush is 1.6 N. The annual number of contacts on one surface of the tooth is believed to be around 10,000 (24,25). Considering an individual brushing their teeth for 2 minutes twice a day and the number of strokes and forces that would be applied in a weekly period while brushing, the brushing simulator was operated with a brush head weight of 200 gr (1.9 N) in 250 back-and-forth strokes; back-and-forth strokes are preferred because the temporary filling materials used between root canal treatment sessions are located on the occlusal surface of the tooth.

According to the manufacturers, $ZnO/CaSO_4$-based temporary filling materials show their optimum properties within a period of approximately one week. Calcium hydroxide, a prominent intracanal medicament, also exhibits penetration of its hydroxyl ions deep into tooth dentin within a 7-day period while showing its maximum effectiveness in 3–4 weeks (26). These reasons are the dictation of the generally accepted 1-week interval between the sessions in root canal treatment. In our study, a 7-day period for brushing was simulated and the samples were kept in water for 7 days to calculate the water absorption values.

Conclusion

Cavitimi, a new temporary filling material, exhibits the greatest values in terms of mass loss and expansion, and showed the lowest values for solubility and water absorption. Cavit G exhibited the highest solubility value. It is not possible to choose the best or worst materials regarding every parameter, which is why clinicians should evaluate their positive and negative features and choose the appropriate material by considering the clinical reflections of these features. Manufacturers, on the other hand, should improve the deficiencies of these materials, and should be cautious in improvement of properties that may antagonize and lead to deterioration in other properties. In such dilemmas, attention should be given to the development of the feature in the material that will provide the most advantage in clinical use.

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