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The physical and chemical properties of interim restorative materials, a comparative review of current products

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Abstract:

Objective: The aim of this study is to examine the physical properties of current interim restorative materials in a time dependent test.
Materials and Methods: The solubility (S), water sorption (WS) and compressive strength (CS) of IRM, Fuji triage, Ketac Silver, Cavit, and Telio CS Inlay were determined in accordance with the International Standards Organization. Two sets of specimens were made; one for compression testing and one for solubility. An initial mass (m1) was recorded, after submersion in water at 37°C (m2) was recorded. After 60 days, a final mass was recorded (m3) and sorption and solubility calculated. The compressive strength of the submerged materials was tested using an Instron machine at different time intervals. The data for CS was analyzed using t-tests in Prism 6 and S and WS data were analyzed with repeated measures ANOVA/Tukey ($\alpha=0.05$).
Results: When comparing materials to each other, Cavit was significantly different than the other materials in WS, S and CS. Results for the CS testing demonstrated that Cavit the lowest overall CS, while Fuji Triage demonstrated significantly higher compressive strength. Results for water sorption testing demonstrated that time did play a significant factor in water sorption after 30 days.
Conclusion: The null hypothesis was rejected, Cavit was significantly inferior in all categories, and Fuji Triage was significantly better in CS. Time does play a factor in interim restoration water sorption.

Introduction:

A major factor in non-surgical root canal success is the coronal restoration; a coronal seal from a permanent restoration is of utmost importance after endodontic treatment. [4,13] However, the role of the interim or temporary restoration in endodontic success may be overlooked by some practitioners.

An endodontic access cavity is created to properly access the pulp chamber. This access cavity is generally sealed with a temporary restoration during multi-treatment endodontic appointments, and often after completion of root canal therapy. The temporary or interim restorative material used to seal the access cavity is important to reduce the microbial load between appointments and to prevent bacterial contamination and reinfection of a root canal system after obturation. [7,9] In one survey lack of a sufficient temporary restoration was cited as the second most prevalent cause for post endodontic pain and endodontic failure.[2] In a meta-analysis looking at primary root canal success an adequate coronal restoration was listed as one of the major influences of success.[9]

Endodontics Colleagues of Excellence emphasizes placing a permanent restoration as soon as possible due to the risk of bacterial contamination through temporary restorations.[1] A study investigating the quality of the coronal restoration and the quality of endodontic treatment found that the success rate for a good restoration and endodontic therapy was 91%, compared to 71% in teeth with technically sound endodontic techniques and poor coronal restorations.[13] Clinical complications and time constraints make it difficult to place inter-appointment permanent restorations, and in certain cases, post endodontic obturation permanent restorations.[9]

Many studies have been carried out to determine what material is best suited for endodontic temporization, but few studies have looked at the physical properties of the materials in the oral environment over an extended period. Water sorption and water solubility are important properties of a material subject to a wet environment as they represent the degradation or loss of the material in an aqueous environment and the amount of water incorporated into a material over time.

The aim of this study is to examine the solubility (S), water sorption (WS), and compressive strength (CS) of current interim restorative materials in a time dependent test. The null hypothesis is that there will be no difference in solubility, water sorption or compressive strength in any of the tested materials.

Materials and Methods:

Solubility, water sorption, and compressive strength were performed on 5 materials in accordance to ISO-4049:2009.[6]
The following commercially available temporary materials were compared (1) Fuji Triage® (GC America, Alsip, IL), (2) Ketac™ Silver (3M, Saint Paul, MN), (3) IRM® (Dentsply Sirona, York, PA), (4) Telio CS Inlay (Ivoclar Vivadent, Amherst, NY), and (5) Cavit™(3M). The permanent restorative material Filtek Supreme (3M, Saint Paul, MN) was used as a control for comparison (see table 1).

Compressive Strength:

The materials were prepared and dispensed under room-temperature conditions of 23 ± 2°C and 50 ± 10% relative humidity and in accordance with the manufacturers' instructions. Test specimens of each material were created by packing the dental material into stainless steel molds (Ø=4mm, thickness =6mm) placed on a Mylar matrix strip-covered microscope slide. Immediately after the mold was completely filled, a second Mylar matrix strip and second slide were placed over the mold and manual pressure was applied to express excess material from the mold. The specimens were allowed to set at 37 ± 1°C and 10% humidity for 10 minutes longer than the manufacturer's recommended setting time to ensure materials were fully set.

Ten cylindrical specimens of each material were fabricated for each time frame, for a total of 50 specimens, stored in deionized water and kept at 37º C until the start of each test. Specimens were loaded until failure using Instron ELECTROPULS™ E 3000 with a 5000N load cell and at a cross-head speed of 0.5 mm/min to determine the CS of all specimens. CS tests were performed at 1, 7, 14, 30, and 45 days. The differences between each of the products were examined at each time-point using t-tests in Prism 6 (GraphPad Software, San Diego, CA). Significance was set at $p \leq 0.05$.

Solubility and water sorption:

The materials were prepared and dispensed under room-temperature conditions of 23 ± 2°C and 50 ± 10% relative humidity and in accordance with the manufacturers' instructions. Test specimens of each material were created by packing the dental material into stainless steel molds (Ø=15±1mm, thickness=1±0.1mm) placed on a Mylar matrix strip-covered microscope slide. The specimens were allowed to set at 37 ± 1°C and 10% humidity for 24 longer than the manufacturer's recommended setting time. The specimens dry mass (m_1± 0.1µg) was collected using a zeroed balance scale (Manufacturer name), and its volume (v±0.1mm) was calculated from its dimensions using a digital caliper (brand name). Next, the specimens were immersed in distilled water (37±1°C) until testing.

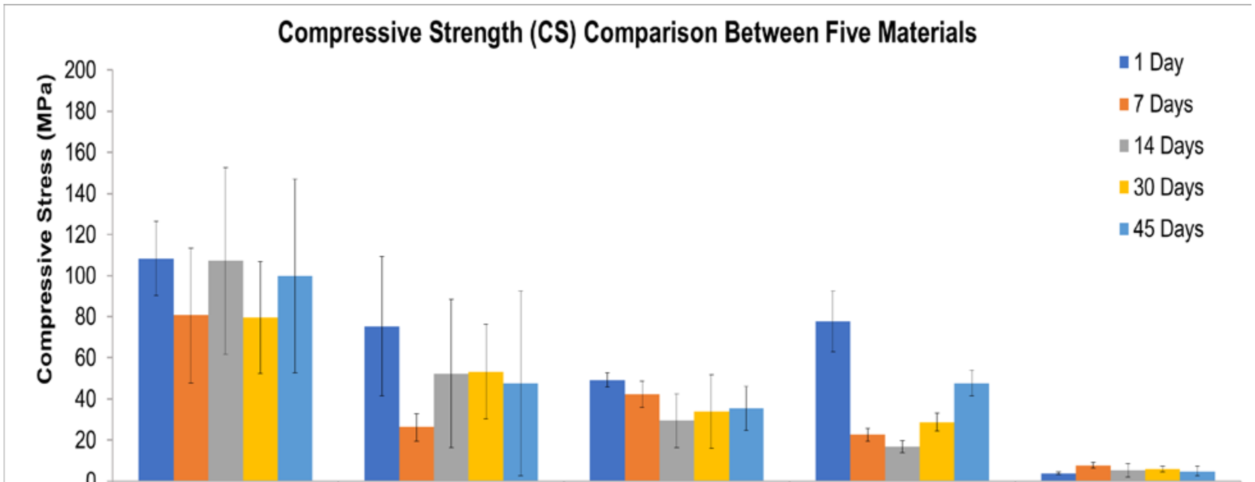
At 1 day, the specimens were removed from the distilled water, dabbed dry, re-weighed on the zeroed balance and that value was noted as (m_2). Specimens were then re-immersed in the individual 37±1°C distilled water containers. This process was repeated at 7, 14, 30, 45 days. After the 45-day data collection, specimens were desiccated at 23 ± 1°C until a constant mass was obtained (m_3). Fluid solubility (*Fsl*) was calculated with the equation $Fsl(\%) = \frac{m1-m3}{v}x100$ and water sorption (WS) was calculated with the equation $WS(\%) = \frac{m2-m3}{v}x100$.
Statistics: Data were analyzed with repeated measures ANOVA/Tukey (α=0.05).

Table 1: Materials compared with manufacturer information

Category	Glass ionomer	Glass ionomer + metal	Zinc oxide and eugenol	Self-Adhesive Temporary Composite	Zinc oxide/ calcium sulfate
Brand Name	Fuji Triage	Ketac Silver	IRM	Telio CS inlay material	Cavit W
Manufacturer	GC	3M ESPE	DENTSPLY	Ivoclar	3M ESPE
Ingredients (from Manufacture)	Alumino-silicate glass, polybasic carboxylic acid, water, tartaric acid	Alumino-silicate glass, silver, titanium dioxide, copoylmer of acrylic acid, water, tartaric acid	zinc oxide, PMMA powder, eugenol	dimethacrylate-based, silicon dioxide fillers	zinc oxide, calcium sulfate, zinc sulfate, polyvinyl acetate polyvinyl, choloride acetate, tri ethanolamine
Set time	2 min 30 sec, recommend not to adjust with a bur until 4 minutes	5 minutes after activation	set time 5 min	Light cured increments of 4mm for 10sec	avoid chewing for 2 hours after application
Manufacturer suggested time of use in mouth	manufacturer does not provide this information	manufacturer does not provide this information	less than one year	no more than 6 weeks	manufacturer does not provide this information

Results:

Results for the CS testing demonstrated that Cavit was significantly different than the other groups, showing the lowest overall CS. Fuji triage demonstrated significantly higher compressive strength tests (see Figure 1). All other materials were not significantly different from one another. Time was not a significant factor in the CS tests.



	Fuji	Ketac Silver	IRM	Telio	Cavit
1 Day	108.373	75.348	49.168	77.701	3.881
7 Days	80.582	26.206	42.224	22.496	7.716
14 Days	107.204	52.261	29.493	16.857	5.241
30 Days	79.668	53.167	33.860	28.756	5.835
45 Days	99.856	47.602	35.383	47.747	4.862

Figure 1: Compressive Strength

When comparing water sorption and solubility Cavit was again a significant outlier (see Figure 2 and 3). In this study Cavit both absorbed water and lost substance or material into the water significantly more than the other materials. Results for water sorption testing demonstrated that time did play a significant factor in water sorption. This study demonstrated that 30 days was the critical time in which water sorption changes were observed. The 30 day and 45-day samples of all materials showed significantly more water sorption than the previous time frames (see figure 3).

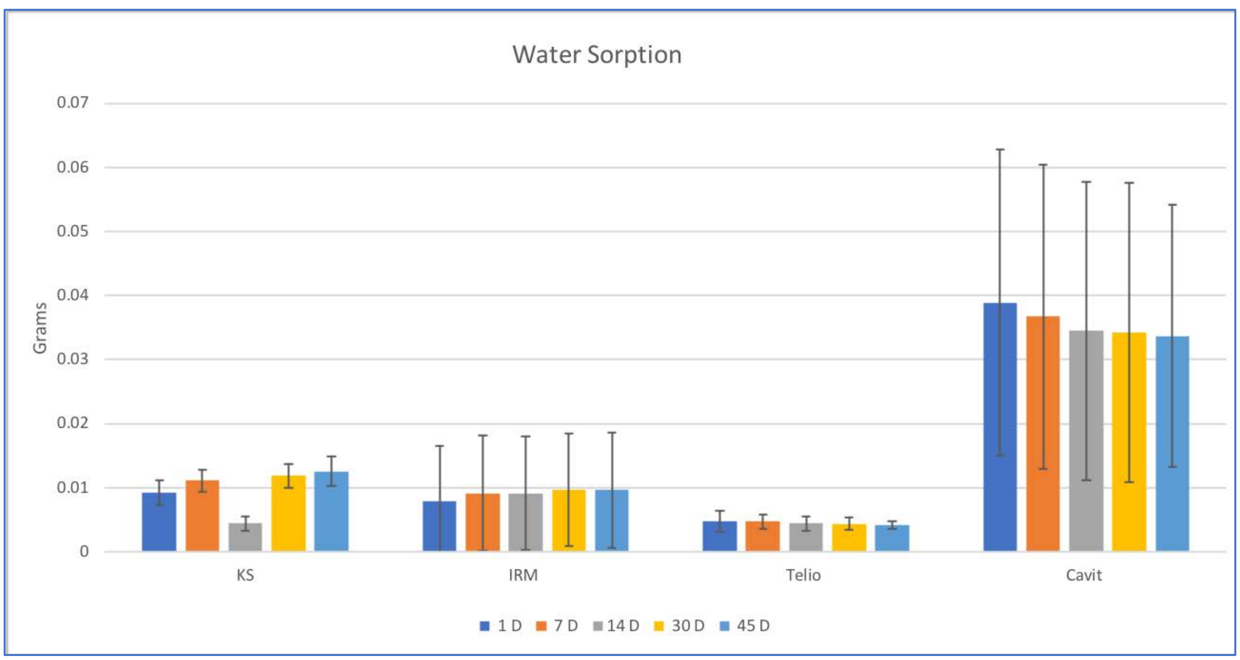


Figure 2: Water Sorption

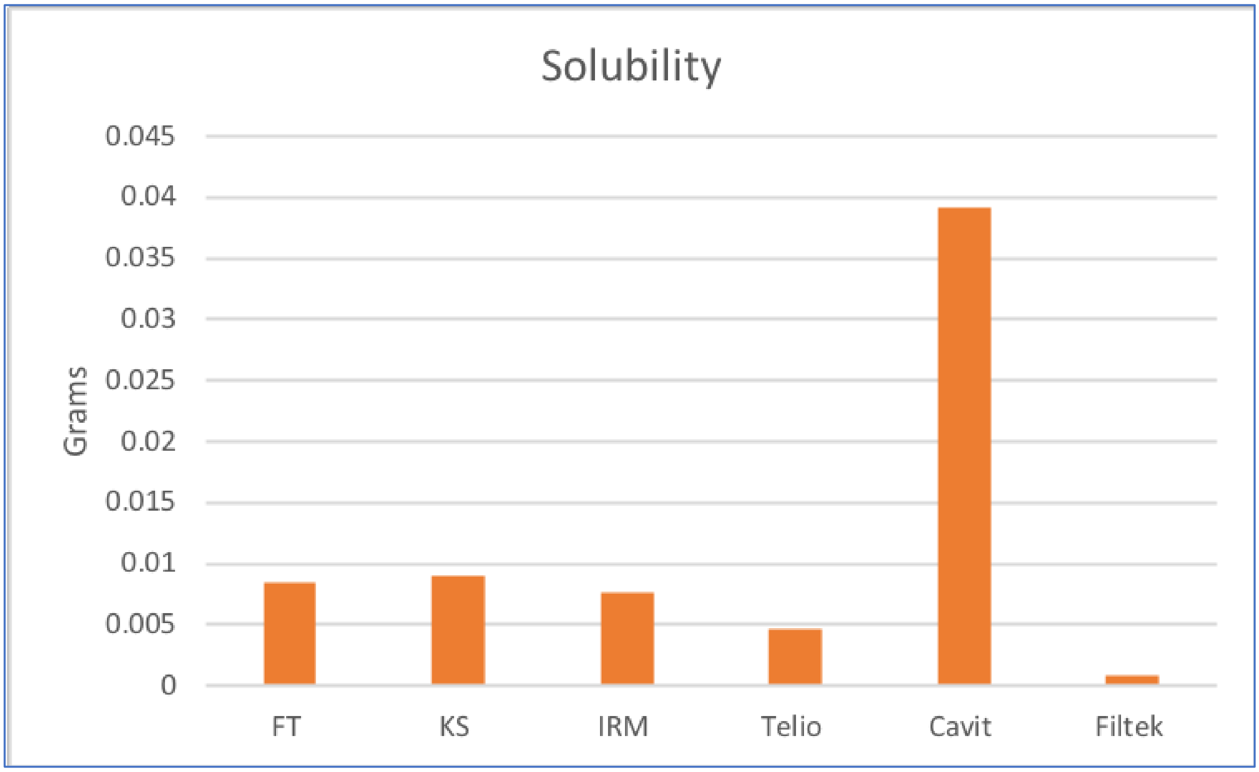


Figure 3: Overall Solubility

Discussion:
While an ideal interim restorative material for endodontic therapy may not currently exist, based on Naom's guideline for an ideal restoration, a material's physical and chemical properties may influence a provider's interim restorative material decision. [9]

Water sorption is the amount of water absorbed into the body of the material and solubility is the amount of the substance that will dissolve into a solvent over time. Compressive strength is useful for comparing materials that are weak in tension.[7,12] All three physical properties might indicate how a material will perform in the oral environment under the daily functions of mastication.

Cavit demonstrated the least desirable properties among the interim materials in all tested categories (WS, S, CS). Time was a factor in the overall performance of all materials tested, and the critical timeframe for the majority of the materials was 30 days. This was similar to a 2013 study that found none of the temporary materials could withstand leakage in a 30 day test.[3] This finding confirms that temporary restorations should be used for very short periods of time and a permanent restoration should be placed at the earliest possible date.[1,5] Of the materials tested, Fuji Triage had the best performance for compressive strength. Therefore, it may be a better temporary material in areas of heavy mastication.

IRM and cavit are commonly used as endodontic temporaries due to their ease in placement and removal,[15] but these materials fall short of ideal. In one microleakage study it was found that IRM's eugenol content may prevent bacterial penetration but not marginal leakage of fluid, and in the 21-day study the pulp chamber was completely filled with dye, representing leakage. In the same study, Cavit had little marginal leakage but absorbed the dye in to the body of the material. [17] This data is similar to the findings of the current study, where Cavit absorbed water into the body of the material almost immediately. Cavit was affected by the constant aqueous environment and was disseminated into the solvent. A shortcoming of the current study is the thickness of the tested discs in S and WS tests. In a previous study it was found that a minimum thickness of 3.5mm of Cavit is necessary to prevent leakage.[16] The ISO standards used in the current study are those designed for permanent restorations,[6] and do not take into account the differences between temporary and permanent restorations. To date there is not an ISO standard test for interim restorative materials.

The handling sensitivity of these materials demonstrate the importance of permanent restoration placement to prevent leakage. [1,4,5,10,13] The investigators in this study found it difficult to achieve consistent results when preparing molds from all categories tested. Multiple molds were rejected due to catastrophic voids or air bubbles due to the technique sensitivity of the materials; and some molds subject to testing still had noticeable defects which may have affected test results. These findings were also noted in a previous study examining the leakage of Cavit. In that study, inconsistencies of Cavit observed under electron microscopy led to increased leakage.[16] The handling inconsistencies of the materials are a potential limitation of this study and should be considered when conducting future studies of interim endodontic restorations.

Conclusion:

In conclusion, the null hypothesis was rejected because Cavit performed significantly worse with respect to water sorption, solubility, and compressive strength compared to all other interim materials tested. Fuji Triage was significantly better in compressive strength than all other materials tested.

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