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Evaluation of Solubility of Four Different Root Canal Sealers with Different Incubation Periods: A Comparative Study

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ABSTRACT

Aims of study: This study aims to evaluate and compare the solubility of four different sealer (Bioroot™ RCS, GuttaFlow Bioseal, EasySeal and Endofill) according to American National Standards Institute/American Dental Association (ANSI/ADA) Specification No. (57) and evaluate the effect of time on solubility of these sealers.

Materials and method: Six specimens for each incubation period were prepared using two split plastic ring molds (internal diameter of 20 mm, height of 1.5 mm). Each 2 specimens were weighted at once, stored in a preweighted glass petri dish with distilled water at 37 Cº, the specimens were removed either at (1 day, 3 days, 7 days,14 days and 30 days), after that water in the dish was evaporated and the dish was dried in desiccator and reweighted. Then solubility was calculated by using samples' weight loss (%). Then, the obtained data were analyzed statistically.

Results: Based on the results of One-way analysis of variance (ANOVA) and Post hoc Duncan's multiple range tests there was a significant difference in the Solubility at ($p \leq 0.001$) between the four tested sealers. The sequence for the solubility was: BioRoot ™ RCS > GuttaFlow Bioseal > Endofill > EasySeal. The solubility of all tested sealers had been increased with the time.

Conclusion: : According to different types of the sealers used in this study for assessing and comparing the solubility at different incubation periods. BioRoot ™ RCS had highest solubility, there was an increase in solubility of all tested sealers over the time.

Keywords: Root canal sealer, Solubility, Bioceramic-based sealer, Incubation periods.

I. INTRODUCTION

Endodontic therapy is a treatment sequence for a tooth with infected pulp which aims to eradicate infection and protecting the decontaminated tooth from subsequent microbial invasion. The removal of pulpal structures and their associations, subsequent shaping, cleaning and disinfection of canals, and obturation (filling) of the decontaminated canals are all part of endodontic therapy [1].

Endodontic sealer is an important component in root canal obturation, it is used to fill the space between the core material, such as gutta-percha (GP), and inner wall of the canal during the canal filling process in order to seal the root canals, trap remaining microbes, and also pack irregularities in the root canal [2]. According to the chemical constituents, the most common root canal sealers are zinc oxide eugenol, calcium hydroxide, glass ionomer, silicone, resin, and bioceramic-based [3].

If the sealer fails to function properly, microleakage may result in root canal treatment failure due to the clinically undetected passage of microorganisms, fluids, molecules, or ions between both the tooth and restorative material [4].

The solubility of endodontic sealing material also significant because material breakdown can impact the overall quality of endodontic therapy by releasing chemical compounds that may produce an inflammatory reaction at the periapical tissue [5]. Furthermore, root canal sealers should have low solubility rates in order to maintain sealing ability and/or prevent reinfection caused by the formation of gaps between the root canals and filling materials [6].

The aim of this study is to evaluate and compare the solubility of four different sealer (Bioroot ™ RCS, GuttaFlow Bioseal, EasySeal and Endofill) with different incubation periods according to (ANSI/ADA) Specification No.57/2006 for root canal sealing materials [7].

II. MATERIALS AND METHODS

Four different root canal sealers (Bioroot ™ RCS, GuttaFlow Bioseal, EasySeal and Endofill) were used in compliance with the manufacturer's instructions .

Table (1): Details of the root canal sealers used in the study

Endodontic sealer	Manufacturer	Composition	Setting time
BioRoot™ RCS	Septodont, Saint-Maur-des Fosses, France	Powder: tricalcium silicate, zirconium oxide, povidone Liquid: aqueous solution of calcium chloride and polycarboxylate	4 Hours
Endofill	Dentsply, Petrópolis Ind. e Com. Ltda, Riode Janeiro, Brazil	Zinc oxide, hydrogenated resin, bismuth subcarbonate, barium sulfate, sodium borate. Eugenol and oil of sweet almonds	2 Hours
EasySeal	Komet Dental -Gebr. Brasseler, Lemgo, Germany	Paste 1: 4-[-2-(4-hydroxyphenyl) propan-2-yl] phenol epichlorohydrine resin, alkylglycidyl ether, barium sulfate, tricalcium phosphate, diphenylolpropane-diglycidyl ether; Paste2: Polyalkoxyalkylamine copolymer,5-amino-1,3,3-trimethylcyclohexanmeth ylamine, aqua, barium sulfate, tricalcium phosphate, nanodispers silicone dioxide, polyhexamethylene biguanides-hydrochloride	15 Minutes
GuttaFlow Bioseal	Coltene/Whaledent Inc. Switzerland	Gutta-percha powder particles, polydimethylsiloxane, platinum catalyst, zirconium dioxide, calcium salicylate, Nano-silver particles, paraffin, coloring, bioactive glass ceramic	12-16 Minutes

Two split plastic ring molds with an internal diameter of 20 mm and a height of 1.5 mm as presented in (Figure 1) were used for specimen's preparation and placed on a glass plate. Tested

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materials were mixed according to the manufacturer's instructions and the mold was filled to slight excess. After that a second glass plate faced with a sheet of plastic was pressed on top of the sealer, then the glass plate carefully removed to leave a flat, uniform surface as shown in (Figure 2).

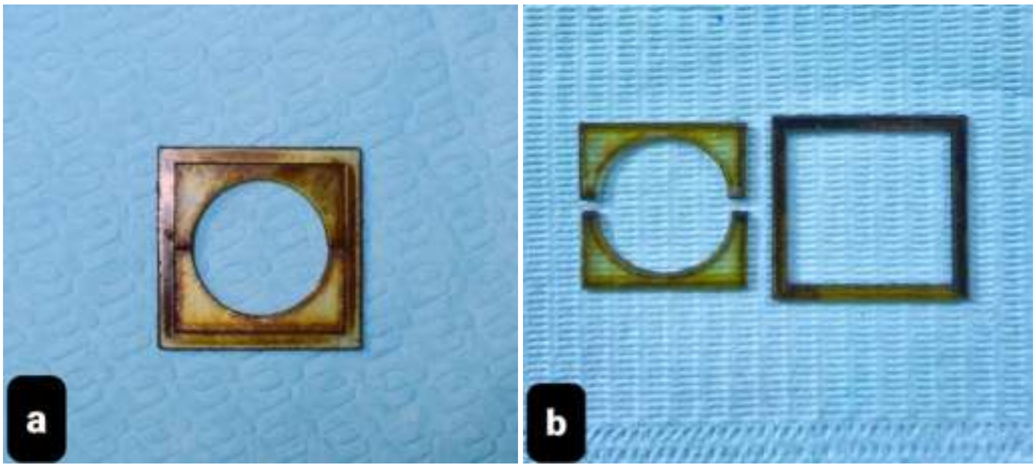

Figure (1): a: Closed two split plastic ring mold   b: Opened two split plastic ring mold.

Figure (2): Two split ring mold filled with the tested sealer.

The filled mold was placed in the incubator a temperature of 37 ˚C for a period of time 50% longer than the setting time stated by the manufacturer. Then the mold was removed and the mass of the two specimens (m_1+m_2) was determined at once to the nearest 0.001 g using electronic balance measuring device (Figure 3).

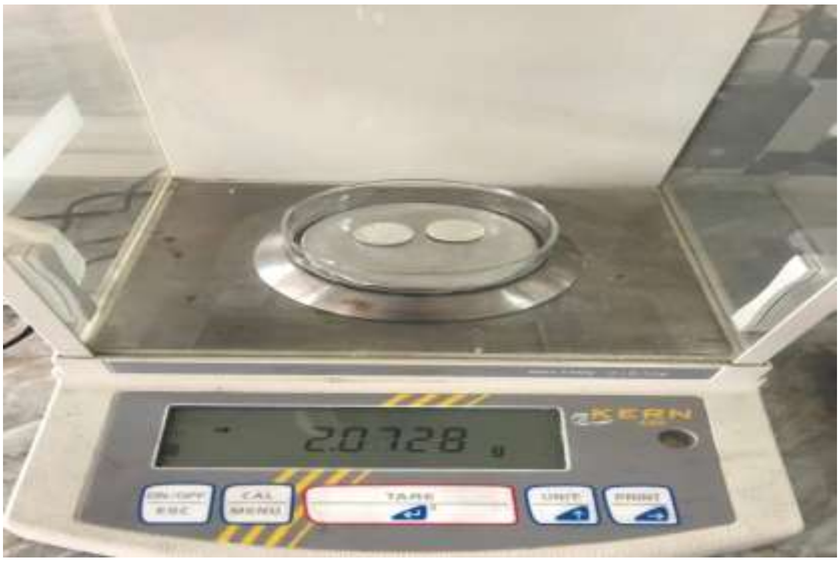

Figure (3): Electronic balance measuring the weight of the tow specimens.

Two such specimens were placed in the glass Petri dish (having a diameter of approximately 90 mm with a minimum volume of 70 ml and of known mass to the nearest 0.001g), such that the surfaces do not touch and the sealer remains undisturbed in the dish. 50 ml of distilled water was added and the dish was covered. The Petri dish and contents were placed at (37) ºC in the incubator, then the specimens were removed by a tweezer either at (1 day,3 days ,7 days ,14 days and 30 days), washed with 3 ml of fresh distilled water, allowing the washings to drain back into the Petri dish. Then the specimens were discarded. The water was evaporated from the dish without boiling, until obtain constant mass, the dish was cooled in desiccator containing silica gel to room temperature before each weighing (accurate to the nearest 0.001 g).

The difference between the final mass of the Petri dish (M_2) and its original mass (M_1) was recorded to the nearest 0.001 g, as the amount of material removed from the specimens. This difference in mass was recorded, calculated as a percentage of the original combined mass of the two specimens (m_1+m_2). This test was carried out twice more for each time and recorded the mean value for each period as the solubility of the material. The following formula was used to measure the percentage of solubility:

Solubility =

M_1 = Original mass of the Petri dish
M_2 = Final mass of the Petri dish
m1+m2= Original combined mass of the two specimens

Statistical Analysis

The data were analyzed using the Statistical Package for the Social Sciences (IBM.SPSS) software, version 25. The level of significance was chosen at $p \leq 0.001$. Following normality testing, the following tests have been carried out:

- One-way analysis of variance (ANOVA) test was used to find if there is a significant difference in the solubility) between the different tested root canal sealers at ($p \leq 0.001$).
- The means were compared using Post hoc Duncan's multiple range test to determine which groups gave the highest solubility.

Ⅲ. RESULTS

The results of analysis of variance (One-Way ANOVA) for the solubility of the tested endodontic sealers at different time intervals and for the solubility of different tested endodontic sealers within same time showed there is a significant difference in the solubility of these sealers. Based on the results of Duncan's multiple range test "$P \leq 0.001$" , the solubility of BioRoot™ RCS was significantly greater than other tested sealers and EasySeal revealed significantly the lowest solubility at all tested times.

While GuttaFlow Bioseal and Endofill had solubility ranging between BioRoot™ RCS and EasySeal with a significant difference between them except at 24hr. GuttaFlow Bioseal had a higher solubility than Endofill at 3,7,14 days, but the solubility of Endofill became greater than GuttaFlow Bioseal at 30 days (vertical analysis which referred in the table with small letters). The results also showed that the solubility of all the

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tested sealers increased significantly with time (horizontal analysis which was referred in the table with capital letters) (Table 2, Figure 4).

Table (2): Duncan's Multiple Range Test of the solubility of different types of the tested sealers.

Material	**Metric**	**1 day**	**3 days**	**7 days**	**14 days**	**30 days**
BioRoot™ RCS	Mean	13.105 *E **a	16.542 D a	18.972 C a	19.731 B a	19.991 A a
	***N	3	3	3	3	3
	Std. Deviation	.00462	.00300	.00404	.00306	.00265
GuttaFlow Bioseal	Mean	1.527 E B	2.042 D b	2.572 C b	2.631 B b	2.699 A c
	N	3	3	3	3	3
	Std. Deviation	.00351	.00513	.00557	.00252	.00200
EasySeal	Mean	.690 E C	.983 D d	1.275 C d	1.433 B d	1.874 A d
	N	3	3	3	3	3
	Std. Deviation	.00208	.00351	.00153	.00252	.00265
Endofill	Mean	1.528 E B	1.914 D c	2.354 C c	2.503 B c	2.837 A b
	N	3	3	3	3	3
	Std. Deviation	.00153 `	.00300	.00252	.00252	.00208

*Capital letters (horizontal analysis) means solubility of the tested endodontic sealer at different time intervals, different letters mean there is a significant difference.

**Small letters (vertical analysis) indicate solubility of different tested endodontic sealers within same time, different letters mean there is a significant difference.
***N means number of samples.

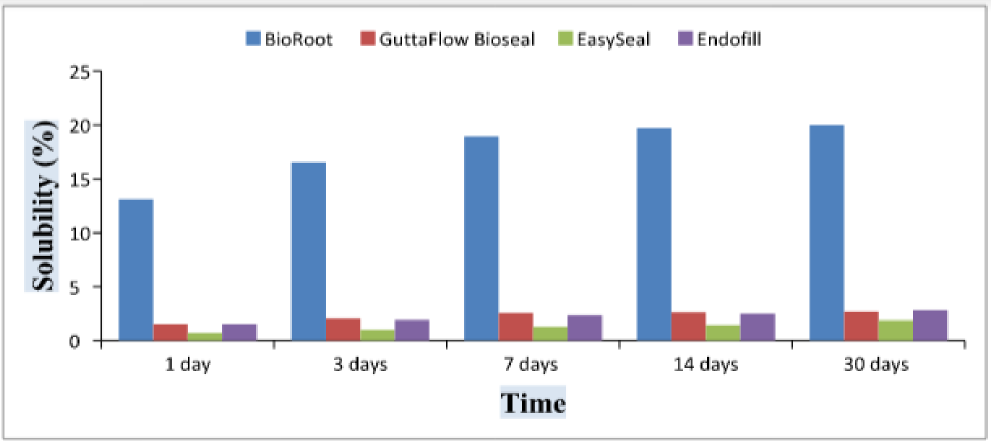

Figure (4): Histogram for the solubility of tested root canal sealers.

IV. DISCUSSION

The conventional solubility test was performed by measuring the difference in mass before and after immersing the materials in distilled water for 24 hrs; however, materials may disintegrate when stored for an extended period of time [8]. Furthermore, a 24hr period may not provide information on material behavior over the time. Therefore, in the present study, different time intervals were used in order to evaluate the solubility of the material.

Although all sealers showed some solubility, BioRoot™ RCS exhibited the highest solubility in all tested immersion periods, the high solubility of this sealer might be explained as the result of the hydrophilic nanosized particles that increase its surface area and allow more liquid molecules to come in contact with the sealer. Furthermore, the long setting of these sealers can also explain the high values of solubility**.** The high values of solubility in distilled water of the set BioRoot™ RCS are associated with significant Ca^{2+} and OH^{-} release, which dissolves leaving voids. Therefore, the increase in BioRoot™ RCS solubility over the time may be explained by the leaching of calcium ions over a time [9]. This coincides with the results of Poggio et al., (2017); Colombo et al., (2018); Abu Zeid et al., (2022)[10-12].

For BioRoot™ RCS the given solubility values were contradictory. A previous study done by Prullage et al., (2016) in which the solubility of BioRoot RCS was in the same range with Urban et al., (2018) that contrast the results of the present study [13,14]. The variation between the results of various researches on solubility could be related to differences in methodology utilized, such as the method used to assess the solubility (by suspending the samples or just immersion in distalled water) or method utilized to dry the samples after having submittted them to solubility testing [14].

Also, the immersion solution affects on the solubility value of the material, BioRoot™ RCS showed less solubility when immersed in phosphate-buffered saline (PBS) than when immersed in distilled water [15].

The second highest solubility value was for the GuttaFlow Bioseal that attributed to the fact that silicone-based sealers contain gutta-percha in their chemical composition, which may increase the size of the polymer cavities of the polydimethylsiloxane and oils. Larger pore cavities provide a more open molecular structure over a time and allow greater water absorption to a certain limit. Also, the hygroscopic capacity of the calcium silicate which present in GuttaFlow Bioseal may result in the highest accumulation of water between the polymer's chains. Also, it may be due to the leakage of Ca^{2+}, so that, high values of solubility in water may correlated with high Ca^{2+} and OH^{-} release [16].

The results of the study of Camargo et al., (2017) coincide with the results of the present study, which found that the solubility of the GuttaFlow Bioseal is higher when compared with epoxy resin based endodontic sealer [17].

The solubility of ZOE-based sealer (Endofill) was lesser than BioRoot™ RCS and GuttaFlow Bioseal sealer. The cause of solubility could be due to the sealers matrix continuously leaking eugenol, decomposing the balance between the matrix and eugenol. Because sodium borate is very soluble, its presence in Endofill contributes in increasing sealers´ solubility. The hardened zinc eugenolate's hydrolysis reaction also contributes to its solubility [18].

The findings of this study are in agreement with the results of Schäfer et al., (2003); Fadhil and Al-Hashimi, (2015); and Torres et al., (2019)[19-21].

The lowest solubility values were observed for EasySeal, this could be due to the crossed links in its resin polymers, which promoted low solubility [22]. Because epoxy resin-based endodontic sealers are hydrophobic and do not absorb water, their porosity and solubility values are generally lower than those of tricalcium silicate-containing materials [9, 23].

The findings of the present study regarding the solubility of EasySeal were in agreement with the findings of Prüllage et al., (2016) and Poggio et al., (2017)[13,10]. While the results of Sonntag et al., (2015) showed the solubility of EasySeal after one day immersion exceeded even the solubility of EasySeal after 30 days immersion in the present study and which disagree with the results of the current study [24]. This difference may be due to discrepancy or modification in the methods used. The solubility of all tested sealers were increased over the time due to increase in above mentioned causes of solubility of each sealer.

V. CONCLUSION

According to the results of this study with its limitations, BioRoot ™ RCS had the highest solubility rate and EasySeal had the least solubility rate while GuttaFlow Bioseal and EasySeal ranged between them with the higher rate for GuttaFlow Bioseal. Also, there was an increase in solubility of all tested sealers over the time.

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