



Marginal Adaptation of Eggshell Powder Coalesced Calcium Hydroxide Sealer Using SEM; An In-Vitro Study

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ABSTRACT:

Introduction: The synthesis and use of nanoparticles in dentistry has paved way for nanoscience in advanced dentistry. Eggshells are rich sources of calcium carbonate (94%) which can be used in synthesis of hydroxyapatite (HAp). Clinical studies have employed eggshell powder (ESP) either independently or in conjunction with other substances as agents for mineralizing teeth.

Objectives: This research sought to evaluate the marginal adaptability, interfacial layer of eggshell incorporated calcium hydroxide based sealer under scanning electron microscope (SEM).

Methods: Eggshell powder was produced through a calcination process, resulting in pure calcium oxide powder, free from pathogens. Egg shells were cleaned in sterile distilled water, boiled and dried to make a fine powder. This ESP was placed in furnace and obtained mass was observed under SEM. Thirty extracted permanent single rooted teeth were decoronated and instrumented by NeoEndo Flex (Neoendo Flex File, Orikam, Haryana, India) rotary file system. Derived ESP was then mixed with calcium hydroxide based sealer (Sybron Endo Kerr, USA). The modified sealer was used to obturate the teeth. The teeth were sectioned and examined under SEM for the marginal adaptability. An independent t-test and one-way analysis of variance were conducted, with subsequent Tukey's post hoc analysis applied.

Results: The results of this study state that the group B obturated with eggshell hydroxyapatite (ESH) modified sealer has lesser micro-gaps than group A. The control group A showed micro-gaps of larger dimensions than group B. The micro-gaps found in group B were greater in coronal section followed by middle and least in apical level contributing to lesser apical micro-leakage. The least derived particle size of novel ESH was 899 nm/0.899µm. the p value was less than 0.05 which is statistically significant for both the evaluated groups.

Conclusions: ESP, a naturally occurring and commonly accessible byproduct of the food industry, functions as an efficient source of calcium for dental applications. ESH sealer has shown better marginal adaptability to root dentin, which restores its potential to be used in evolving nano-dentistry.

1. Introduction

Science is undergoing a major transformation, leading humanity into a new era marked by breakthroughs in nanotechnology.¹ Nano-dentistry, like nanomedicine, aims for optimal oral health using nanomaterials and

biotechnological innovations, including tissue engineering and nano-robots.²

Endodontic therapy phases that include access opening, biomechanical preparation, obturation, post obturation restoration and anatomical complexities can affect the prognosis of tooth and may require specialized



techniques or materials.³ The choice of endodontic sealer significantly impacts the prognosis of root canal therapy, as some sealers are more susceptible to apical microleakage, which can lead to treatment failure.⁴ Current sealers struggle to bond effectively with dentin, leading to voids, microleakage and root canal failure.⁵

This highlights the demand for advance technologies like nanotechnology and improved endodontic materials to address these limitations and enhance treatment efficacy.⁶ Hydroxyapatite, a natural mineral in bones, makes up 30% to 70% of their mass. Its synthetic form is biocompatible and promotes osseointegration, making it an effective substitute for human bone in implants and prosthetics, leading to increased interest in its production and use.^{7,8} Hydroxyapatite can be produced synthetically in laboratory settings; however, it also occurs naturally in various biological materials such as seashells, marine. Eggshell powder (ESP), which is predominantly composed of calcium carbonate (98.2%), contains trace amounts of other minerals such as magnesium (0.9%) and phosphate (0.9%). Consequently, it is regarded as a significant source of calcium.⁹ Populous recent clinical studies have employed this substance either independently or in conjunction with other materials as a means of promoting tooth remineralization or facilitating bone repair.^{10,11,12}

The purpose of this study was to examine the marginal adaptability, interfacial layer, and enhanced bioactivity of a calcium hydroxide sealer that had been modified with ESH using scanning electron microscope (SEM), given the significant minerals found in the composition of eggshell (ES) and their established effectiveness in the regeneration of bone defects.

2. Material and Methodology

Commencement of the study was done after approval from Institutional ethical committee registered under number H-142/IECDYPDS/2025.

SPECIMEN PREPARATION:

Size of the sample was established using data supplied from G Power Version 3.19.2. The determination of the sample size was conducted through a statistical power analysis, considering effect size, the desired significance level, and expected result variability. The sample size was calculated to total 30 samples, with $n = 15$ each group, and alpha and beta significance levels established

at 0.05 and 0.2, respectively (i.e., power = 80%). Extracted human permanent teeth with single roots were used to acquire thirty roots. Teeth with mature apices, uncalcified canals, absence of root resorption, cracks, or fractures, and teeth with straight roots were included in this study. A radiographic examination, encompassing both buccolingual and mesiodistal perspectives, was conducted to verify the existence of a distinct single root canal in each tooth. They were decoronated at cemento-enamel junction standardizing the root length at 15 mm. The working length was established by placing a 15 K stainless steel file (Mani, India) into the root canal until the tip was observed extending past the apical foramen. By subtracting 1 mm from this measurement, the working length was determined. Biomechanical preparation was done by using (Neoendo Flex File, Orikam, Haryana, India) endodontic files to enlarge their canals at master apical size of #20.06. The settings for speed (RPM) and torque (N) adhered to the specifications provided by the instrument's manufacturer. The root canals then irrigated by 5.25% sodium hypochlorite and 17% EDTA utilizing a side-vented needle (30G, Orikam Healthcare Neoendo Side Vent Needle, India) to eliminate the smear layer followed by drying with paper points. All the thirty prepared tooth were distributed into two groups and obturated after grouping as follows.

GROUPING:

Group A – control group/ fifteen teeth were obturated with calcium hydroxide sealer without ESP.

Group B – fifteen teeth obturated with Eggshell hydroxyapatite (ESH) modified sealer group.

ESP PREPARATION:

Egg shell derived hydroxyapatite (ESH) was obtained with calcination process.¹³ Chicken eggs underwent a cleaning process using sterile distilled water, followed by a boiling treatment in a hot water bath at 100°C for period of 10 minutes to aid in the removal of their internal white membranes. Subsequently, the shells were dried, and the dehydrated material was finely ground into a consistent yellowish powder using sterile mortar pestle. The produced ESP underwent thermal processing through two calcination cycles in a muffle furnace (Thermolyne 47900, Model F4791; Kerper) at a temperature of 1000°C for about 1 hour, leading to the conversion of



calcium carbonate into calcium oxide. Calcium oxide was reacted with a 0.5 M solution of diammonium hydrogen phosphate, adhering to a stoichiometric ratio of $\text{Ca/p} = 1.67$, which resulted in the synthesis of hydroxyapatite (ESH). Calcination was performed in two cycles to achieve a finer particle size.

The ESH modified sealer was prepared by dispensing equal lengths of the base and catalyst from Sealapex (Sybron Endo Kerr, USA) and incorporating 0.5 grams of ESH. The components were then meticulously blended with the ESH powder until a homogeneous consistency was achieved, and the luting consistency was verified using a spatula. The obturated samples were then stored into a saline media for setting of the sealer material for a period of 7 days. All samples from Group A and Group B were later sectioned at the coronal, middle, and apical third levels. Segments approximately 2 mm thick were prepared using a low-speed, water-cooled diamond saw and a straight handpiece.

ROOT DENTIN INTERFACE ANALYSIS:

Each of the sectioned specimens underwent examination by (SEM) Make- FEI, Model – Quanta 200,

Specifications: Resolution: 3.0 nm resolution at 30 Kv, Magnification: 1000X

Accelerating Voltage: 200 V to 30 kV utilizing the low vacuum mode following gold coating with the SPI-module sputter coater allows for the evaluation of the interfacial layer and its marginal adaptability of group A & B.

STATISTICAL ANALYSIS:

Statistical analysis was accomplished using SPSS version 21.0 (SPSS Inc., released since 2015, IBM-SPSS Statics for Windows, version 21, Armonk, New York, IBM Corp.) The interfacial surface of the samples was estimated through a one-way analysis of variance, followed by Tukey's HSD post hoc test for evaluating the differences in three level sections of tooth (coronal, middle, apical). An independent t test was executed to compare the differences between group A and group B. The significance level was established at 0.05 ($P \leq 0.05$). A confidence level of 95% was adopted, along with a study power of 80%.

3. Results

SEM images of scanned samples are as shown below

Figure 1a: Micro-gap observed in coronal section of control group A by SEM

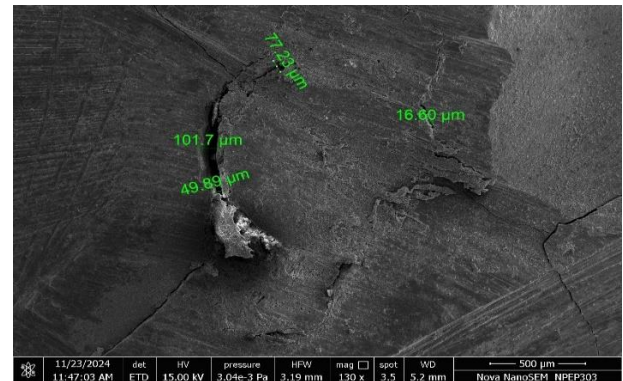


Figure 1b: Micro-gap observed in coronal section of experimental group B

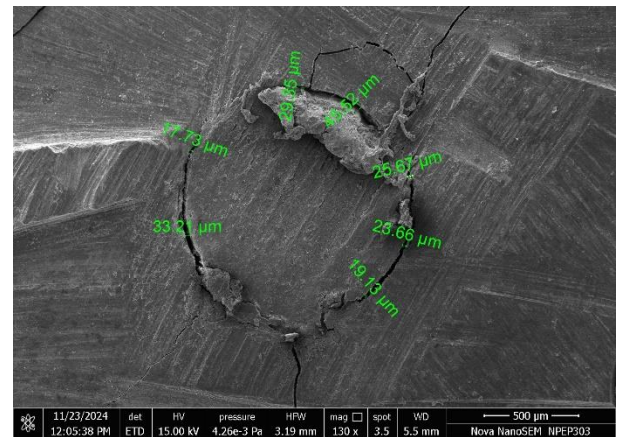
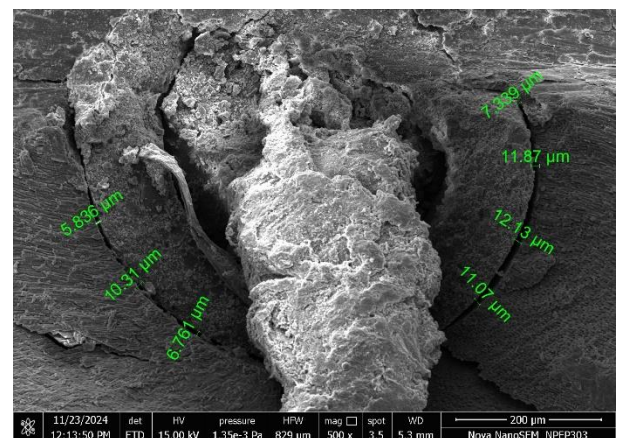


Figure 1c: Micro-gap at apical section of group B showing least dimensional micro-gap





Comparison of interfacial surface between root dentin and sealer illustrated greater micro-gaps in Group-A than Group B. The interfacial layer is distinctly observable; however, there exists a micro-gap between the Group A sealer material and the root dentin. The control group/Group A showed highest mean of micro-gap at value 74.65µm in contrast to experimental group/Group B with mean 54.16µm. The results of the marginal gap analysis for Group A and Group B stated a statistically significant difference among groups examined [Table 1].

Table 1: Comparison of control group and experiment group with mean Marginal gap in um by independent t test

Group	n	Mean	S D	SE	t-value	P-value
Control group	15	74.6	27.0	6.9	2.1382	0.0414
Experiment group	15	54.2	25.5	6.6		

Group B teeth obturated with ESH sealer showed presence of micro-gaps, where greater micro-gaps were present at the coronal level followed by middle and apical third as explained in [Table 2].

Table 2: Summary of Marginal gap in um in three sections [coronal, middle, apical]

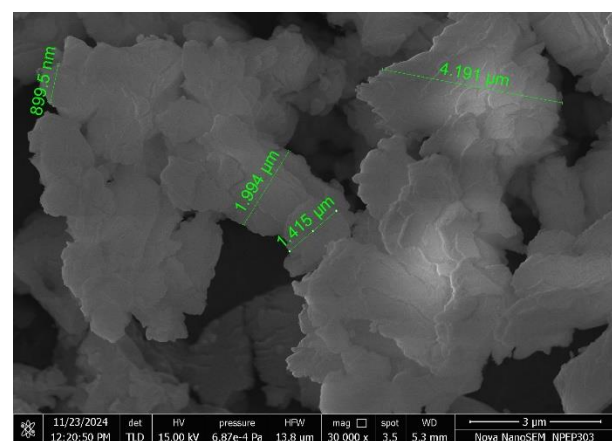
Sections	Mean	Std. Dev	Std.Err.	95% CI for mean	
				Lower	Upper
Coronal third	66.34	25.89	4.73	56.67	76.00
Middle third	20.09	8.21	1.50	17.03	23.16
Apical third	5.34	1.77	0.32	4.68	6.00

The least amount of micro-gaps were seen at the apical third of teeth. Previous studies have proved the presence or absence of micro-gaps, whereas in this study we were

able to derive the dimensions of the micro- gaps. The maximum micro-gap present in coronal section was 66.34 µm and the least was observed in apical third at 5.34 µm.

SEM also revealed the nature and particle size of hydroxyapatite formed from eggshell powder (ESH) as illustrated in [Figure 2]

Figure 2: ESH derived with least particle size of 0.899 µm.



4. Discussion

The obturation, is an essential component of effective root canal treatment (RCT). A three-dimensional obturation with comprehensive coronal, lateral, and apical sealing is essential for enduring success.¹⁴ Endodontics has come long way from traditional sealers to present day bioceramic sealers and nano-particles impregnated materials. Early sealers were adaptations of zinc oxide–eugenol (ZOE) cements derived from Grossman or Rickert’s formula, which gained widespread use globally.^{15,16} The sealing capabilities of zinc oxide eugenol sealers are less effective than those of other sealers, primarily due to the higher solubility of the ZOE sealer, resulting in weak adhesion between gutta-percha and ZOE.¹⁶ Sealers that are free of eugenol, help reduce any potential harmful effects linked to it. These are typically referred to as non-eugenol sealers. Resin sealers, which are eugenol-free, provide remarkable adhesion to the canal walls namely epoxy resin-based sealers (AH Plus) and methacrylate resin-based sealers [RealSeal/Epiphany, EndoREZ, Hydron].¹⁷ They show excellent adhesion and low cytotoxicity, however have elicited an initial inflammatory response, which may lead



to allergic and mutagenic reactions.¹⁸ The development of sealers gradually branched out to more biocompatible and economic sealers. This transition led to introduction of bioceramic sealers and MTA based sealers.¹⁶ The end product of bioceramic sealers and MTA based sealers is calcium hydroxide as a result of hydration process.¹⁹ Hydroxyapatite is precipitated concurrently with the calcium silicate hydrate phase, resulting in an intricate structure that enhances the strength of the set cement.²⁰ Amalgamation of both calcium ions and hydroxyapatite crystals was the primary intention of our study that highlights the future potential of ESH sealer in endodontics. SEM method was used in this study as it is the most effective method to evaluate the surface morphology and penetration of sealer in dentinal tubule.

The results of present study show lesser micro-gaps in Group B (ESH modified sealer) with the mean micro-gap in coronal being 54.16 μm which is much lesser than Group -A. The contents of calcium hydroxide sealer leach out calcium ions as a byproduct that coalesce with calcium oxide of eggshells which eventually produce novel hydroxyapatite by releasing calcium ions during hydrolysis, which may interact with external phosphate ions in bodily fluids.²³ Mony et al. assessed the remineralization capabilities of enamel surface lesions using a solution of chicken eggshell powder (CESP) and found that the elevated pH, combined with abundant bioavailable calcium in eggshell solution, may enhance the remineralization process.²² The formation of hydroxyapatite improves chemical adhesion between dentin and the ESH sealer and promotes dentin remineralization, this may have been a factor in presence of least micro-gaps in ESH modified group.²³ In control group of calcium hydroxide sealer, samples showed presence of greater micro-gaps as compared to group B of ESH. Camps et al., (2015) has stated that the dentinal tubules of extracted teeth are dehydrated, this lack of moisture might adversely affected the setting reaction of calcium hydroxide sealers leading to micro-gaps formation.²⁴

Sealapex sealer contains a base with calcium oxide, zinc oxide, sulfonamides and silica, and catalyst with bismuth trioxide, PMMA resin, methyl salicylate, titanium dioxide, silica, pigments and isobutyl salicylate.^{21,22,23} The variations in constituents probably implied a crucial role in influencing the outcomes noted in this study. The primary components of eggshells consist of minerals,

which account for 95.1%, proteins in 3.3%, and water comprising 1.6%. Calcium serves as the predominant mineral, making up 37.3% of the total weight, primarily in crystalline form. The calcium present is predominantly calcium carbonate (CaCO_3) in 93.6%, followed by calcium triphosphate in 0.8%.²¹ Calcium ions enhance the expression of bone-related proteins via calcium channels, and increased calcium levels can activate adenosine triphosphate (ATP), essential for mineralization.²¹ The calcium silicate sealers are monomer free that reduces the shrinkage after setting. This monomer free property of calcium silicate sealers may have contributed to deeper penetration and reduction of micro-gap formation in ESH group.

There exists a relationship among marginal adaptation and the sealing capability at the dentine/material interface of the sealer material, which shall influence their clinical success rate. Results of the current study revealed that in group B the least micro-gap was at apical level followed by middle and coronal third. Increasing the penetration depth of sealers in dentinal tubules may have a positive impact on prognosis of root canal treatment. According to the study findings greater penetration of ESH sealer was noted in apical third of teeth leading to least measured micro-gap. The average micro-gap calculated at apical third was 5.34 μm . This can be accounted to remarkable physical properties of the calcium silicate-based sealers, such as flow, low film thickness, and dimensional stability.²⁵ Additionally, the alkaline nature of byproducts from calcium silicate-based sealers may have modified the structure of dentin collagen fibres, facilitating sealer penetration.²⁶

Dentin surface energies differ among the coronal, middle, and apical regions, and difficulties in completely removing the smear layer from the apical area may hinder sealer penetration in apical area.²⁷ This study contradicts our observations where lesser micro-gaps are seen in apical third section than coronal and middle levels. This study involved the preparation of root canals using standard irrigation protocol assisted by ultrasonic activation, which in turn lead to better cleaning of apical thirds and elimination of smear layer. The penetration depth of ESH sealer can also be a consequence of proper cleaning and shaping of the apical third. Eggshell derived hydroxyapatite has mineral composition similar to root dentin and cementum which leads to a formation of close contact with root dentin, minimizing the micro-gap



formation.^{28,29} Calcium silicate sealers show the presence of 'bio-mineralisation' property when in interaction with dentinal fluid that can be associated with the less micro-gap formation in ESH group and at three different levels of tooth. All the forementioned reasons support the results seen in this study where apical third shows least micro-gap.

In present study we were able to derive the dimensions of ESH derived particles to finer size. N.A.S Mohd et al. (2020) has derived ESH particle size of 8.44 μm , we were able to derive it [0.899 μm]/ 899 nm in size. The finer particle size can be a result of two cycles of calcination performed for ESH formation. The lesser the particle size the more the adhesion of ESH to root dentin and lesser will be the micro-gaps. Lowenthal et al. (1996) states Eggshell derived hydroxyapatite pulp capping agent show, less inflammatory infiltrate at end of 3 months and calcific bridge formation is thicker in ESP pulp capping agents than with the negative controls. Results of this study are analogous to the studies conducted in support of ESH derived sealers.

However, the study was performed in an ex-vivo setting that might affect the results in further in-vivo studies. The derivation of ESH is sourced from animal which might be a limiting factor in acceptability to certain patients in future. The characterization of ESH can be done using more advanced technologies in further studies. The side-effects of such ESH sealers need to be studied for guided clinical purposes and more research is advocated in near future.

5. Conclusion:

Within the boundaries of this research study, it can be stated that the ESH sealer enhances the marginal adaptation of sealer to root dentin. Incorporation of ESH reduces the apical microleakage due to better adaptation. SEM analysis further validated the sealers performance by characterizing the hydroxyapatite particle morphology derived from eggshell powder. In conclusion, the quantitative reduction of micro-gaps achieved with the ESH sealer suggests meaningful progress toward enhancing the quality of endodontic sealers, with potential implications for improving treatment success rates in clinical endodontics. This study is one bi-directional model which can be incorporated in routine dentistry to enhance the root

canal treatment and give patients the benefits of advancements in nanotechnology.

References

1. Murdoch-Kinch, C. A.; McLean, M. E. Minimally invasive dentistry. *J. Am. Dent. Assoc.* 2003, 134, 87–95.
2. Peacock, J. M.; Orchardson, R. Effects of potassium ions on action potential conduction in A- and C-fibers of rat spinal nerves. *J. Dent. Res.* 1995, 74, 634–641.
3. Dadresanfar, B.; Rotstein, I. Outcome of endodontic treatment: The most cited publications. *J. Endod.* 2021, 47, 1865–1874.
4. Rai, K.; Mandhotra, P.; Sharma, N.; Patil, L.; Sharma, A.; Singh, S. In vitro assessment of apical microleakage of teeth sealed with three different root canal sealers: A comparative study. *J. Pharm. Bioallied Sci.* 2021, 13, 375–378.
5. Sudan, P. S.; Samson, E. P.; Kukreja, M. K.; Khan, M.; Misurya, R.; Ismail, P. M. S. A comparative evaluation of apical leakage using three root canal sealants: An in vitro study. *J. Contemp. Dent. Pract.* 2018, 19, 955–958.
6. Fontana, C. E.; Dos Santos, B. A.; Campos, M. C.; de Lima, S. G.; da Silva, V. C.; Gonçalves, A. D.; de Moura, J. D.; Rocha, D. G.; Pinheiro, S. L.; Bueno, C. S. Evaluation of the apical sealing of an eggshell hydroxyapatite-based sealer. *J. Clin. Exp. Dent.* 2023, 15, 895–903.
7. Yunoki, S.; Ikoma, T.; Tsuchiya, A.; Monkawa, A.; Ohta, K.; Sotome, S.; Shinomiya, K.; Tanaka, J. Fabrication and mechanical and tissue ingrowth properties of unidirectionally porous hydroxyapatite/collagen composite. *J. Biomed. Mater. Res., Part B* 2007, 80, 166–173.
8. Ning, L.; Malmström, H.; Ren, Y. F. Porous collagen-hydroxyapatite scaffolds with mesenchymal stem cells for bone regeneration. *J. Oral Implantol.* 2015, 41, 45–49.
9. King'ori, A. M. A review of the uses of poultry eggshells and shell membranes. *Int. J. Poult. Sci.* 2011, 10, 908–912.



10. Neunzehn, J.; Szuwart, T.; Wiesmann, H. P. Eggshells as natural calcium carbonate source in combination with hyaluronan as beneficial additives for bone graft materials, an in vitro study. *Head Face Med.* 2015, 11, 12.
11. Haghgoo, R.; Mehran, M.; Ahmadvand, M.; Ahmadvand, M. J. Remineralization effect of eggshell versus nano-hydroxyapatite on caries-like lesions in permanent teeth (in vitro). *J. Int. Oral Health* 2016, 8, 435–439.
12. Arias, J. L.; Fernandez, M. S. Biomimetic processes through the study of mineralized shells. *Mater. Charact.* 2003, 50, 189–195.
13. Allam, G.; Abd El-Geleel, O. Evaluating the mechanical properties, and calcium and fluoride release of glass-ionomer cement modified with chicken eggshell powder. *Dent. J. (Basel)* 2018, 6, 40.
14. Darcey, J.; Roudsari, R. V.; Jawad, S.; Taylor, C.; Hunter, M. Modern endodontic principles. Part 5: Obturation. *Dent. Update* 2016, 43, 114–120, 123–126.
15. Hammad, M.; Qualtrough, A.; Silikas, N. Evaluation of root canal obturation: A three-dimensional in vitro study. *J. Endod.* 2009, 35, 541–544.
16. Tyagi, S.; Tyagi, P.; Mishra, P. Evolution of root canal sealers: An insight story. *Eur. J. Gen. Dent.* 2013, 2, 199.
17. Komabayashi, T.; Colmenar, D.; Cvach, N.; Bhat, A.; Primus, C.; Imai, Y. Comprehensive review of current endodontic sealers. *Dent. Mater. J.* 2020, 39, 703–720.
18. Al-Hiyasat, A. S.; Tayyar, M.; Darmani, H. Cytotoxicity evaluation of various resin-based root canal sealers. *Int. Endod. J.* 2010, 43, 148–153.
19. Aprillia, I.; Usman, M.; Asrianti, D. Comparison of calcium ion release from MTA-Angelus® and Biodentine®. *J. Phys. Conf. Ser.* 2018, 1073, 052008.
20. Yang, Q.; Troczynski, T.; Liu, D. M. Influence of apatite seeds on synthesis of calcium phosphate cement. *Biomaterials* 2002, 23, 2751–2760.
21. Reddy, S. P.; Prasad, M. G.; Radhakrishna, A. N.; Sandeep, R. V.; Divya, D. V.; Santosh Kumar, K. V. K. Clinical comparison of eggshell derived calcium hydroxyapatite with Dycal® as indirect pulp capping agents in primary molars. *Pesqui. Bras. Odontopediatria Clin. Integr.* 2020, 20.
22. Mony, B.; Ebenezar, A. V.; Ghani, M. F.; Narayanan, A.; S, A.; Mohan, A. G. Effect of chicken egg shell powder solution on early enamel carious lesions: An in vitro preliminary study. *J. Clin. Diagn. Res.* 2015, 9, 30–32.
23. Sarkar, N. K.; Caicedo, R.; Ritwik, P.; Moiseyeva, R.; Kawashima, I. Physicochemical basis of the biologic properties of mineral trioxide aggregate. *J. Endod.* 2005, 31, 97–100.
24. Wang, J. S.; Bai, W.; Wang, Y.; Liang, Y. H. Effect of different dentin moisture on the push-out strength of bioceramic root canal sealer. *J. Dent. Sci.* 2023, 18, 129–134.
25. Kharouf, N.; Arntz, Y.; Eid, A.; Zghal, J.; Sauro, S.; Haikel, Y.; Mancino, D. Physicochemical and antibacterial properties of novel, premixed calcium silicate-based sealer compared to powder-liquid bioceramic sealer. *J. Clin. Med.* 2020, 9, 3096.
26. Xuereb, M.; Vella, P.; Damidot, D.; Sammut, C. V.; Camilleri, J. In situ assessment of the setting of tricalcium silicate-based sealers using a dentin pressure model. *J. Endod.* 2015, 41, 111–124.
27. Nair, U.; Kosco, P.; Pillai, C. Comparative evaluation of three different irrigation activation on debris removal from root canal systems. *Internet J. Dent. Sci.* 2009, 9.
28. Neunzehn, J.; Szuwart, T.; Wiesmann, H. P. Eggshells as natural calcium carbonate source in combination with hyaluronan as beneficial additives for bone graft materials, an in vitro study. *Head Face Med.* 2015, 11, 12.
29. Gandolfi, M. G.; Siboni, F.; Prati, C. Chemical-physical properties of TheraCal, a novel light-curable MTA-like material for pulp capping. *Int. Endod. J.* 2012, 45, 571–579.