Conservative Dentistry Journal Vol. 14 No. 1 January-June 2024; 11-14

Research Report

Differences of compressive strength between calcium carbonate from blood clam shells and calcium hydroxide as a candidate for pulp capping material

Widya Saraswati[1], Devi Eka Juniarti[1], Vita Lestari[2], Adioro Soetojo[1], Sri Kunarti[1], Febriastuti Cahyani[1], Ketut Suardita[3], Nabiela Rahardia[2]
[1]Department of Conservative Dentistry, Faculty of Dental Medicine, Universitas Airlangga, Surabaya, Indonesia
[2]Faculty of Dental Medicine, Universitas Airlangga, Surabaya, Indonesia
[3]Department of Conservative Dentistry, Faculty of Dentistry, Institut Ilmu Kesehatan Bhakti Wiyata, Kediri, Indonesia

ABSTRACT

Background: *Pulp capping is one of the treatments for reversible pulpitis and aims to maintain pulp vitality. This treatment requires a material that can protect the pulp with good biocompatibility. The physical and mechanical properties, bio interactivity and bioactivity of pulp capping materials are very important for the formation of reparative dentin. Calcium hydroxide ($Ca(OH)_2$) as the gold standard material in pulp capping treatment also has some disadvantages. Another alternative for pulp capping material is blood clam shell because it contains 98% calcium carbonate ($CaCO_3$), which is a compound with a bone-like structure and can induce pulp cell differentiation.* ***Objective:*** *To investigate and explain the difference in compressive strength between $CaCO_3$ from blood clam shells and $Ca(OH)_2$ as a candidate pulp capping material.* ***Methods:*** *This research is a laboratory experimental study with post test only control group design method. $Ca(OH)_2$ and $CaCO_3$ samples were formed with a mixture of powder and aquadest with 4x6 mm sample size. The samples were dried at room temperature and the compressive strength was measured using a universal testing machine (UTM).* ***Result:*** *There is a significant difference in compressive strength between $Ca(OH)_2$ and $CaCO_3$ blood clam shells in the Mann-Whitney test results ($p<0.05$).* ***Conclusion:*** *The results of the compressive strength test between the mixture of $Ca(OH)_2$ with aquadest in a ratio of 1:1 are greater than the mixture of $CaCO_3$ blood clam shells with aquadest in a ratio of 3:1 so that pure $CaCO_3$ blood clam shells with distilled water without other additives cannot be used as a candidate for capping pulp material.*

Keywords: *calcium carbonate, calcium hydroxide, blood clam shell, pulp capping, compressive strength.*

Correspondence: Widya Saraswati, Department of Conservative Dentistry, Faculty of Dental Medicine, Universitas Airlangga. Jl. Mayjen Prof. Dr. Moestopo No. 47, Surabaya 60312, Indonesia. Email:widya-s@fkg.unair.ac.id

INTRODUCTION

Basic Health Research in 2018 recorded the proportion of oral and dental problems at 57.6%, while only 10.2% received services from dental personnel. Pulp and periapex diseases are ranked 7th in outpatient diseases in Indonesia, recorded based on the Indonesian Health Data Profile in 2011.[1] Pulpitis is one of the dental and oral diseases whose prevalence is high enough to require attention. Untreated reversible pulpitis can progress to irreversible pulpitis and even pulp necrosis.[2]

Pulp capping is one of the treatments carried out in reversible pulpitis and aims to maintain pulp vitality.[3] Pulp capping treatment consists of two types, namely direct and indirect.[4] One of the pulp capping materials that can be used is calcium hydroxide ($Ca(OH)_2$). This material is favored by most dentists because it can accelerate the formation of tertiary dentin.[5] This treatment requires a material that can protect the pulp with good biocompatibility, which includes antibacterial, anti-inflammatory and other properties that can induce tissue healing and stimulate the formation of a dentinal bridge.[6]

Calcium hydroxide ($Ca(OH)_2$) is the gold standard material in pulp capping treatments and has been used since the early 1920s, due to its biocompatibility and ability to stimulate hard tissue formation as well as its antibacterial effect.[7] Although it is said that calcium hydroxide can promote tissue healing and repair, because the high pH can stimulate fibroblasts, migration to the injured area. However, it does not stimulate dentinogenesis well, because when it is used as a direct pulp capping material, calcium hydroxide particles are seen in the pulp cells, causing tunnel defects of the formed dentin bridge resulting porous dentin bridges.[8]

Calcium carbonate ($CaCO_3$) is an important component in biological systems that can be found in the shells of marine organisms, pearls, and egg shells.[9] The large production of mussels in Indonesia will certainly produce a large amount of mussel shells as well. Blood clams (*Anadara granosa*) are biota that are often found in Southeast Asian countries, especially Indonesia. Indonesian people generally only consume the meat and then the shells will be discarded into natural waste or utilized as handicrafts, even though the shells of blood clams have a high $CaCO_3$ composition, which is as much as 98%.[10]

High concentration of $CaCO_3$, good anti-inflammatory and biocompatibility properties, similarity of bone and tooth structure in both organic and inorganic composition, good strength and stability in wet dentine can make *Anadara granosa* an alternative material to induce reparative dentin formation in the pulp capping process.[11] In addition to being biocompatible and having the ability to induce reparative dentin formation, pulp capping materials have other physical and mechanical requirements. These include tensile strength, compressive strength, shear strength, and flexural strength.[12] The mechanical properties of pulp capping materials can affect their resistance to fracture during placement of the final restoration material or when supporting overlying restorations over time.[13]

Pulp capping materials require a minimum compressive strength of 1.2 MPa. The durability of a material is measured by its compressive strength.[14] The importance of measuring the compressive strength of a pulp capping material is to test its ability to withstand the pressure from condensation of the overlying restoration material.[15] Sufficient compressive strength will allow the pulp capping material to remain in position despite the force of the operative procedure.[13] The compressive strength parameter is an indirect measurement of material bonding. It is an important property that affects clinical performance and has a role in the treatment of perforations where the material is directly exposed to occlusal forces.[16]

MATERIALS AND METHODS

The research conducted has obtained permission from the Health Research Ethical Clearance Commission, Faculty of Dentistry, Universitas Airlangga with Ethical Number 1245/HRECC.FODM/XI/2023. The type of research conducted was laboratory experimental research with a post-test only control group design to determine the difference in compressive strength of $CaCO_3$ blood clam shells (*Anadara granosa*) compared to $Ca(OH)_2$ as a candidate for pulp capping material. This study used $CaCO_3$ blood clam shells in powder dosage form obtained from the Faculty of Metallurgical Materials, Sepuluh November Institute of Technology and $Ca(OH)_2$ powder (hydroxido calsio P.A). The research sample was divided into 2 groups, the first group was a mixture of $Ca(OH)_2$ powder and sterile distilled water with a ratio of 1:1, according to the manufacturer's rules. The second group was a mixture of blood clam shell $CaCO_3$ powder and sterile distilled water with a ratio of 3:1, which is the optimal ratio because it has the best setting time.11 Each mixture was then molded into a cylindrical mold with a diameter of 4 mm and a height of 6 mm.

The instrument in the compressive strength test used in this study is Universal Testing Machine (UTM) to measure the maximum value of an object in receiving a vertical compressive load before the object is destroyed. The sample is placed in the center of the pressing tool with the position of the vertical axis of the sample perpendicular to the flat plane. The UTM is turned on and the pressing part will move slowly with a pressure of 1kN and a speed of 1 mm/minute until it is destroyed. After the sample is destroyed, the number indicated on the computer connected to the UTM)is recorded and the results in kgF are converted into Newtons and then divided by the cross-sectional area to obtain the compressive strength in Mega Pascal.[17]

RESULTS

Compressive strength tests of bloodshell CaCO3 and $Ca(OH)_2$ were conducted. A higher compressive strength value indicates an increase in the compressive strength of a dental material. The average data of the compressive strength test results for each group can be seen in Table 1.

Based on the Table 1, it is known that the average compressive strength of the $Ca(OH)_2$ group is higher than the average of the $CaCO_3$ group. Furthermore, the standard deviation of the $Ca(OH)_2$ group is greater than the standard deviation of the CaCO3 group, which means that the variance of the $Ca(OH)_2$ group data is more diverse. The data of the research results are displayed using graphs which can be seen in Figures 1, 2, and Table 2.

The data obtained in each group was tested for normality of data distribution using the Sahpiro-Wilk test, because the amount of data in each group was less than 50 and the data homogeneity test using Levene's Test. Based on the results of the normality test, it is known that the p-value for the compressive strength data of the $Ca(OH)_2$ group and the $CaCO_3$ group is 0.530 and 0.992, respectively, this p-value price is greater than the significance level of 0.05. This means that the assumption of normality is met.

Based on the homogeneity test results, the p-value is 0.001, this price is smaller than the significance level of 0.05. This means that the compressive strength data between the $CaCO_3$ group and the $Ca(OH)_2$ group have inhomogeneous data variances. After performing the prerequisite tests of normality and homogeneity, it was found that the data did not meet the assumption of homogeneity. Thus, hypothesis testing cannot be done using the Independent Sample T-test but using the Mann-Whitney test. The basis for decision

Table 1. Number of samples, mean, and standard deviation of compressive strength

Group	N	Mean	Std Deviation
Group 1	16	3.214 MPa	1.172
Group 2	16	0.673 MPa	0.192

Descriptions: Group 1: Mixture of $Ca(OH)_2$ powder and distilled water in a ratio of 1:1. Group 2: Mixture of $CaCO_3$ powder and distilled water with a ratio of 3:1

CDJ (eISSN: 2722-8045; pISSN: 2087-1848) is open access under CC-BY license. Available at: https://e-journal.unair.ac.id/CDJ
DOI: https://doi.org/10.20473/cdj.v14i1.2024.11-14

making in the Mann-Whitney test can be done through a probability approach, the significance used is α=0.05. The basis for decision making is to look at the probability number, provided that if the p-value> 0.05 then H_0 is accepted, if the p-value <0.05 then H_0 is rejected. Based on the results obtained, it can be said that H_0 is rejected and H_1 is accepted, which indicates that the results of the study are not in accordance with the initial hypothesis and there is a significant difference in compressive strength between the $Ca(OH)_2$ group and the $CaCO_3$ group.

Table 2. Average and results of compressive tests for each sample group

Sample	$CaCO_3$	$Ca(OH)_2$
1	0.662112927 Mpa	1.227578714 Mpa
2	0.382810402 Mpa	4.473817931 Mpa
3	0.588458615 Mpa	4.930901138 Mpa
4	0.807585049 Mpa	3.566208773 Mpa
5	0.576863 Mpa	3.182446883 Mpa
6	0.725610848 Mpa	1.991707838 Mpa
7	0.793715123 Mpa	3.318440018 Mpa
8	0.918802058 MPa	3.414610658 Mpa
9	0.288080289 Mpa	1.189115242 Mpa
10	0.679264334 Mpa	4.277919408 Mpa
11	0.478948644 Mpa	2.735244528 Mpa
12	0.773334392 Mpa	4.778773815 Mpa
13	0.590007166 MPa	2.86018128 Mpa
14	0.641346462 Mpa	4.42328376 Mpa
15	0.819289505 Mpa	2.455690783 Mpa
16	1.036962383 Mpa	2.597918711 Mpa
Average	0.67269945 Mpa	3.213989968 Mpa

DISCUSSION

The results of this study can be proven by the underlying causes of the majority of several studies on the physical and mechanical properties of a material that uses a combination of blood clam shells and $CaCO_3$ content inside. There are several factors that cause the compressive strength of $CaCO_3$ blood clam shells to be smaller than $Ca(OH)_2$ in the results of this study, including the concentration factor of using $CaCO_3$ powder blood clam shells, From several previous studies, it can be concluded that the more concentration of $CaCO_3$ powder blood clam shells used will produce lower compressive strength test values, and the use of blood clam shell powder with a composition of 100% is not effective, therefore other additives are needed to complement and obtain higher compressive strength test values.[15,17]

In addition to the concentration factor, the temperature factor also affects the compressive strength value. There is previous research that states the addition of blood clam shells as a substitute is very influential with certain mixture variations and the higher the temperature level, the higher the compressive strength value, because in that study the sample with room temperature treatment got the lowest compressive strength value compared to other temperature variations, while in this study the sample was only treated at room temperature. The third factor is particle size, the particle size used in this study is micro, while nano particles have the advantage of increasing the compressive strength value. $CaCO_3$ nano particles act as micropore fillers so that they will have much smaller pores so that the bonding structure will be denser and will increase the compressive strength value, the use of nano particle size makes it possible

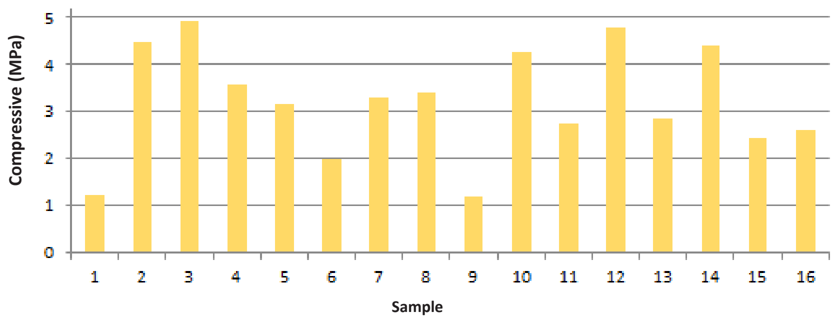

Figure 1. Compressive strength values of $Ca(OH)_2$.

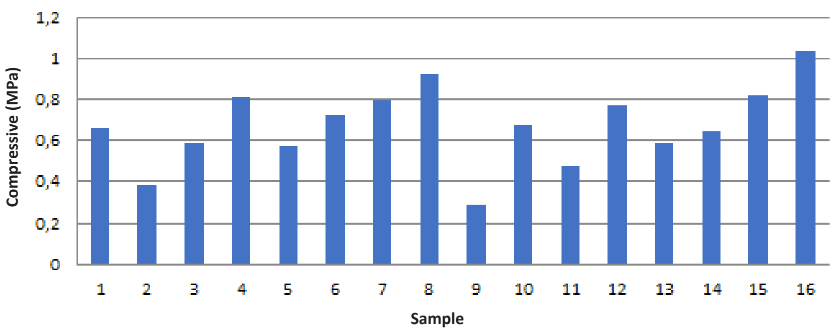

Figure 2. Compressive strength values of blood clam shell $CaCO_3$.

DOI: https://doi.org/10.20473/cdj.v14i1.2024.11-14

to create identical products with better structure and without changing the chemical content of the material.[15,17]

The fourth factor is the stirring time, the more $CaCO_3$ is added and the longer the stirring time, the more $CaCO_3$ is decomposed so as to produce more CO_2 gas which causes pores and results in the compressive strength test value decreasing. In this study, no special determination was made to determine the stirring time.[18] The decrease and increase in compressive strength test values occurred due to the reaction of the content contained in blood clam shell powder, namely calcium contained in $CaCO_3$ which can produce heat energy so that the use of added ingredients and blood clam shell powder complements with the appropriate percentage can increase the compressive strength value. However, excessive use causes hydration and brittleness, thereby reducing compressive strength. In addition, the MgO (Magnesium Oxide) compound present in blood clam shells has the property of expanding easily when mixed with water. So the use of excess blood clam shell powder can cause the process to expand and break easily (expansion). The effect of blood clam shell $CaCO_3$ powder material can increase compressive strength if it acts as an added material, which certainly requires other additives to be used as a material. Bloodshell $CaCO_3$ can reduce compressive strength if it acts as a complement.[13]

There are differences between natural materials (blood clam shells) and synthetic material hydroxido calsio P.A ($Ca(OH)_2$) used in this research in terms of physical and mechanical properties. Synthetic materials have higher strength to be able to increase the compressive strength of natural materials, the addition of additive materials is needed in order to increase the physical and mechanical strength better. Although the compressive strength value of $CaCO_3$ blood clam shell is lower than $Ca(OH)_2$ and does not meet the compressive strength standard for pulp capping of 1.2 MPa, $CaCO_3$ blood clam shell still needs to be explored further because it has better biological properties than $Ca(OH)_2$ (toxicity, solubility, porosity, stimulus of dentinogenesis process) so it is necessary to further investigate the ability of $CaCO_3$ when added with other additives to increase its compressive strength. The additives can be propolis, propylene glycol, combined with $Ca(OH)_2$, and $CaCO_3$ in hydroxyapatite or nano form. However, these additives must also have antitoxic properties to be used as pulp capping material additives.[19,20]

In conclusion, the compressive strength of bloodshell $CaCO_3$ with a p:w ratio of 3:1 was lower than that of $Ca(OH)_2$ with a p:w ratio of 1:1. The mixture of pure blood clam shell $CaCO_3$ with distilled water without other additives is not effective as a candidate for pulp capping material.

REFERENCES

1. Kementerian Kesehatan RI. Hasil Riset Kesehatan Dasar (Riskesdas) 2018. Jakarta: Badan Penelitian dan Pengembangan Kesehatan Kementerian RI. 2018;2(1):21-3.
2. Kartinawanti, A. T., & Asy'ari, A. K. Penyakit Pulpa Dan Perawatan Saluran Akar Satu Kali Kunjungan. JIKG (Jurnal Ilmu Kedokteran Gigi). 2021;4(2): 64-72.
3. Garg, N., & Garg, A. Textbook of operative dentistry. 3ed Edition. Boydell & Brewer Ltd. 2013; 3(2): 246-61.
4. Kurniasari, A. Efektivitas Pasta Biji Kopi Robusta (Coffea Robusta) Sebagai Bahan Direct Pulp Capping Terhadap Jumlah Sel Makrofag Dan Sel Limfosit Pulpa Gigi. 2018;1(2):72-8
5. Sulastri, S. Dental Material: Bahan Ajar Keperawatan Gigi. 2017;2(1):54-9
6. Kumala, Y. R., Rachmawati, D., & Hersanto, K.. Stimulasi Dentin Reparatif Direct Pulp Capping Menggunakan Ekstrak Ikan Teri (Stolephorus sp). 2017:1-9.
7. Zakaria, M. N., Cahyanto, A., & El-Ghannam, A. Calcium release and physical properties of modified carbonate apatite cement as pulp capping agent in dental application. Biomaterials Research. 2018;22(1):1-6.
8. Marpaung, Y. A. Analisis Kemampuan Nacre dalam Ekspresi TGF-β1 Menginduksi Dentin Tertier (In Vivo). 2019:78-84.
9. Al-Omari, M.M.H., Rashid, I.S., Qinna, N.A., Jaber, A.M., Dan Badwan, A.A. Calcium Carbonate. Profiles Of Drug Substances, Excipients, And Related Methodology. ISSN 2016; 1871-5125.41:31-132
10. Santoso, P. Studi Penangkapan Kerang Darah (Anadara granosa) Menuju Pengembangan Study of cockles (Anadara granosa) fishery towards the development of its aquaculture in Sub-District Kupang Tengah, District Kupang. 2022;2(1):46-9.
11. Saraswati, W., Dhaniar, N., Wahjuningrum, D. A., Nuraini, N., & Bhardwaj, A. The Effect of Exposure Calcium Carbonat from Blood Cockle (Anadara Granosa) Shells to the Expression of the NF-κβ on Dentin Pulp Complex. Journal of International Dental and Medical Research. 2021;14(2):549-553.
12. Anusavice KJ, Shen C, Rawls HR. Philip's Science of Dental Material. 12th ed.St. Louis:Elsevier. 2013:178.
13. Nielsen MJ, Casey JA, VanderWelee LA, Vandewalle KS. Mechanical properties of new dental pulp-capping materials. Gen. Dent. 2016;64(1):44-8.
14. Cooper, P. R., Holder, M. J., & Smith, A. J. Inflammation and regeneration in the dentin-pulp complex: a double-edged sword. Journal of Endodontics. 2014;40(4):46-51.
15. Camilleri J. Evaluation of the phyysical properties of an endodontic Portland cement incorporating alternative radiopacifiers used as root-end filling material. Int Endod J. 2010;43:231-40.
16. Vanja Opačić Galić, Zoran Stamenić, Violeta Petrović, Vukoman Jokanović, Slavoljub Živković. 2018. Compressive strength of calcium silicate-based cement. Serbian Dental Journal, vol. 65, No 1, pp : 7-10
17. Goel M, Bala S, Sachdeva G, Schweta. Comperative Evaluation Of MTA, Calcium Hydroxide And Portland Cement As A Root End Filling Materials : A Comprehensive Review. Indian Journal of Dental Sciences. 2011;3(5):83–8.
18. Ekariadi, I., Zulaida, Y.M., Suryana. Pengaruh Penambahan Caco3 Dari Limbah Cangkang Dan Waktu Pengadukan Pada Pembuatan Alluminium Foam Menggunakan Metode Melt Route. *Jurnal Rekayasa Mesin Teknik Maetalurgi*. 2023:409-420.
19. Widjiastuti I, Setyabudi , Mudjiono M, Setyowati E. Compressive Strength Test on Calcium Hydroxide with Propolis Combination. Conservative Dentistry Journal Vol.9 No. 2019:28-32.
20. Zhang T, Jin J, Yang S, Li G, Jiang J. Effect of Hydrogen Bonding on the Compressive Strength of Dihydroxypoly(p-phenylenebenzobisoxazole) Fibers. ACS Applied Materials & Interfaces. 2009;1(10):2123–25.