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EFFECT OF MAULI BANANA STEM EXTRACT-CA(OH)$_2$ COMBINATION ON WATER SOLUBILITY AND ABSORPTION AS A POTENTIAL PULP CAPPING MATERIAL

Agung Satria Wardhana[1)*], Dewi Puspitasari[1)], Debby Saputera[2)], Rahmad Arifin[2)], Pindobilowo[3)], Rosihan Adhani[4)]

[1)] Department of Dental Material, Faculty of Dentistry, University of Lambung Mangkurat, Banjarmasin
[2)] Department of Prosthodontics, Faculty of Dentistry, University of Lambung Mangkurat, Banjarmasin
[3)] Department of Public Dental Health, Faculty of Dentistry, Universitas Prof. Dr. Moestopo (Beragama), Jakarta, Indonesia
[4)] Department of Public Dental Health, Faculty of Dentistry, Lambung Mangkurat University, Banjarmasin, Indonesia

ABSTRACT

Background*: Calcium hydroxide [Ca(OH)$_2$] is the gold standard material in pulp capping treatment due to reparative dentin formation and antibacterial. However, Ca(OH)$_2$ deficiency forms reparative dentin with tunnel defects and is easily soluble in water and acid. Mauli banana stem extract (MBSE) functions as an antibacterial and anti-inflammatory and is expected to form better reparative dentin. The combination of Ca(OH)$_2$ and MBSE is assumed to be able to improve the physical properties of Ca(OH)$_2$.* ***Purpose:*** *to analyze the effect of 50% MBSE+ Ca(OH)$_2$ combination on solubility and water absorption as a pulp capping material.* ***Methods:*** *The group were combination of MBSE+Ca(OH)$_2$+PG (1.5:1:0.375), (1:1.5:0.375) and Ca(OH)$_2$ + aquadest (1:1). Each group consisted of 5 samples with 6 groups and 2 tests, a total of 60 samples with dimensions of 15 mm x 1 mm. Samples were measured for solubility and water absorption ability by weighing before and after dissolving in 50 mL of artificial saliva for 24 hours, drying, incubating, and weighing a second time. The result of the mass reduction divided by the volume of the sample was considered as the solubility and water absorption rate in 1 and 7 days. The data was analyzed using One Way Anova with significant difference <0.05.* ***Results****: The solubility of MBSE+Ca(OH$_2$+PG at (1.5:1:0.375) and (1:1.5:0.375)was lower than Ca(OH)$_2$+aquadest (1:1) after immersion for 1 day and 7 day. The water absorption of MBSE+Ca(OH)$_2$+PG (1.5:1:0.375) was not different from Ca(OH$_2$+aquadest (1:1) after immersion for 1 day, but higher in 7 day (p<0,05).* ***Conclusion:*** *The solubility of the MBSE-Ca(OH) combination is lower than Ca(OH$_2$ alone, the water absorption of the MBSE- Ca(OH$_2$ combination is higher than that of Ca(OH$_2$ alone.*

Keywords : *Calcium hydroxide, Mauli banana stem extract, Solubility, Water absorption.*

*** Correspondence:** Agung Satria Wardhana; Department of Dental Material, Faculty of Dentistry, University of Lambung Mangkurat, Banjarmasin; E-mail: agung.wardhana@ulm.ac.id

INTRODUCTION

The vital pulp treatment (VPT) goal is to preserve the health and functionality of pulp tissue that has been harmed by dental trauma, iatrogenic causes, surgical procedures, or carious lesions.[1] Direct pulp capping is a method of applying a more protective layer of material to treat dental pulp exposed by mechanical activity in the form of iatrogenic injury during tooth preparation to treat carious teeth. The gold standard material for pulp capping is calcium hydroxide (Ca(OH)$_2$) due to its ability to stimulate the formation of reparative dentin that protects the pulp.[2,3]

Several studies have shown that Ca(OH)$_2$ application to exposed pulp causes inflammation resulting in superficial coagulation necrosis, forming porous reparative dentin due to the formation of tunnel defects.[4,5] Tunnel defects can impact the health of the pulp tissue as bacteria and their products can diffuse into the pulp tissue and cause inflammation through pores or micro-leakage resulting in pulp death.[6] The high solubility and water absorption of Ca(OH)$_2$ can result in softening of the pulp capping material causing it to dissolve easily and micro-leakage to occur. Therefore, an innovative material that can replace Ca(OH)$_2$ is needed, among others, by utilizing natural ingredients with minimum side effects, or by mixing natural ingredients in Ca(OH)$_2$ preparations. Banana mauli (*Musa acuminata*) is a typical banana of South Kalimantan that is easy to find.[7]

Mauli banana stems contain bioactive components such as flavonoids, saponins, alkaloids, ascorbic acid, lycopene, isoleucine (Ile), caffeic acid (CA), cinnamic acid and tannin which function not only as antibacterial but also as anti-inflammatory, antioxidant and immunomodulator.[7–9] In order to produce a pulp capping material that can form better reparative dentin, a combination of two ingredients between mauli banana stem extract and $Ca(OH)_2$ is needed to provide optimal function. The combination of MBSE and $Ca(OH)_2$ as a pulp capping material is a new material or material that has not been tested for all its properties in order to create a good pulp capping material so it needs to be tested to get the proportional combination formulation. Previous research on compression strength tests showed good strength in the ratio of MBSE: $Ca(OH)_2$: propylene glycole = 1: 1.5: 0.375.[3]

Solubility is influenced by the strength of chemical bonds that depend on electronegative differences and molecular polarity. Solubility and water uptake represent important physical properties of pulp capping materials. Solubility is determined by the water absorption characteristics which is an important factor in the physical properties of capping pulp materials. After some time, perhaps due to dissolution and water uptake, $Ca(OH)_2$ proved unable to remain stable and exit the cavity.[10] It is necessary to conduct research on the solubility and absorption of the combination of MBSE and $Ca(OH)_2$ compared to $Ca(OH)_2$ that role as pulp capping materials.

METHODS

Plant identification was performed on the mauli banana stem that will be utilized in the investigation. In order to make the maceration technique extract, the mauli banana stem is first cleaned under running water, then it is sliced into little pieces and dried in an oven set to 40–60°C for three days. After being ground into a powder, mauli banana stems were steeped in 70% ethanol for three 24-hour periods, stirring regularly, and filtered daily.

In order to produce a thick extract and fine particles, the extraction products were first evaporated at 40–50°C in a vacuum rotary evaporator and then again in a waterbath. By adding potassium dichromate liquid (K2Cr2O7), MBSE was evaluated for ethanol freeness; if no color change occurred, the extract was deemed ethanol free. After being put in a container, the 100% MBSE was kept in the refrigerator.[11]

Preparation of MBSE+$Ca(OH)_2$ combination disc sample in this study, pure calcium hydroxide (Emsure) powder was used for analysis. Preparation of a combination sample of 50% MBSE with $Ca(OH)_2$ by mixing 1 ml of mauli banana stem extract, 1.5 g $Ca(OH)_2$; and 0.375 ml of 40% propylene glycol (PG) in a ratio of 1:1.5:0.375. The addition of 40% PG to EPBM can improve the flexural strength properties as a pulp capping material.

In accordance with ISO 2009:4049, $Ca(OH)_2$ samples were made by combining pure $Ca(OH)_2$ powder with aquadest in a 1:1 ratio (0.9 g $Ca(OH)_2$ powder and 0.9 mL aquadest), stirring with a cement spatula on a glass slab until the mixture had a paste-like consistency, and then placing the sample in a cylindrical mold (15 mm in diameter and 1 mm thick). A celluloid strip was then placed on top of the sample, pressed with a 1 cm thick cover glass, loaded with 0.5 kg brass load, and allowed to set before the sample was taken out of the mold and its edges were smoothed with a sharp knife scalpel.

Each sample had a sewing thread put in the middle, which doubled as a handle while it was immersed. Prior to being weighed using a digital scale, each sample was incubated for 24 hours at 37°C. To get a constant starting weight (referred to as M1), measurements were made three times and the results were averaged (based on ISO 2009:4049). By combining 1 milliliter of MBSE, 1.5 grams of $Ca(OH)_2$, and 0.375 milliliters of 40% PG in a ratio of 1:1.5:0.375, a 50% MBSE with $Ca(OH)_2$ combination sample is created. In contrast, the other group used the same method as for creating $Ca(OH)_2$ samples, combining 1.5 ml of mauli banana stem extract, 1 g $Ca(OH)_2$, and 0.375 ml PG 40% in a single container with a ratio of 1.5:1:0.375 (ISO 2009: 4049). The reason for the use of PG is as a pulp capping material, mauli banana stem extract and $Ca(OH)_2$ flexural strength characteristics can be enhanced by adding 40% PG. [3,10]

For testing water solubility and absorption ability, artificial saliva was used to be immersion media by the means of each sample was immersed in a container at 37°C for 1 day and 7 days. The sample were taken out from the liquid using the thread without coming into touch with it and container was then removed. To absorb the artificial saliva from each sample, absorbent paper was used before weighing it three times to obtain the average weight (called M2). Each sample was then incubated in an incubator at 37°C for 24 hours and then reweighed to obtain a constant weight (called M3) based on ISO 2009:4049. The following formula is used to calculate the material's solubility: Solubility = (M1 - M3)/V where V is the sample's volume, M1 is the sample's weight before to soaking, and M3 is the sample's weight following soaking for one day or seven days and subsequent incubation.

The following formula is used to determine a material's water absorption:

$$\text{Absorption of water} = (M2\text{-}M1)/V$$

where V is the sample's volume, M1 is the sample's weight before to immersion, and M2 is the sample's weight following one or seven days of immersion. [10]

Statistical analyses were performed using SPSS version 22. The data obtained was tested for normality using the

Kolmogorov test. The groups were compared using One-way ANOVA test to determine whether there was a difference or not and followed by the LSD post hoc test to analyze which groups were significantly different. The significance level was set at 0.05

RESULTS

The solubility of MBSE+$Ca(OH)_2$ mean and standard deviation (SD) were presented in Table 1 and water absorption were presented in Table 2.

Table 1. The solubility of MBSE+Ca(OH)2 after immersion in the media of artifical saliva

Group	Mean ± SD	*p-value*
I	11.31±0.16[a]	
II	08.20±0.23[b]	
III	07.48±0.20[b]	0.00*
IV	14.10±0.45[c]	
V	11.01±0.20[d]	
VI	10.20±0.14[d]	

* there was a significant difference ($p<0.05$) using One Way ANOVA
LSD post hoc test, different superscripts show the significant different among the group ($p<0.05$)
Group I: $Ca(OH)_2$+aquadest for 1 day
Group II: MBSE+$Ca(OH)_2$+PG (1.5:1:0.375) for 1 day
Group III: MBSE+$Ca(OH)_2$+PG (1:1:5:0..375) for 1 day
Group IV: Ca(OH)2+aquadest for 7 day
Group V: MBSE+$Ca(OH)_2$+PG (1.5:1:0.375) for 7 day
Group VI: MBSE+$Ca(OH)_2$+PG (1:1:5:0..375) for 7 day

Table 2. The water absorption of MBSE+$Ca(OH)_2$ after immersion in the media of artifical saliva

Group	Mean ± SD	*p-value*
I	10.41±1.03[a]	
II	10.02±1.23 [a]	
III	10.45±1.20 [a]	0.00*
IV	13.30±1.45[b]	
V	17.11±1.20[c]	
VI	17.80±1.10[c]	

* there was a significant difference ($p<0.05$) using One Way ANOVA
LSD post hoc test, different superscripts show the significant different among the group ($p<0.05$)
Group I: $Ca(OH)_2$+aquadest for 1 day
Group II: MBSE+$Ca(OH)_2$+PG (1.5:1:0.375) for 1 day
Group III: MBSE+$Ca(OH)_2$+PG (1:1:5:0..375) for 1 day
Group IV: $Ca(OH)_2$+aquadest for 7 day
Group V: MBSE+$Ca(OH)_2$+PG (1.5:1:0.375) for 7 day
Group VI: MBSE+$Ca(OH)_2$+PG (1:1:5:0..375) for 7 day

Based on the results of the One-way Anova and LSD post hoc test (Table 1), groups II and III were significantly lower than group I, and groups V and VI were significantly lower than group IV, which means that the combination show lower solubility than Ca(OH)2 itself, but no significant differences in combination of MBSE+$Ca(OH)_2$+PG (1:1:5:0..375) with MBSE+$Ca(OH)_2$+PG (1:1:5:0..375). Table 2 represent the water absorption ability and show that groups II and III were not significantly different than group I, and groups V and VI were significantly higher than group IV, which means that the combination show higher water absoption than Ca(OH)2 itself in 7 days, but no significant differences in Ca(OH)2 , combination of MBSE+$Ca(OH)_2$+PG (1:1:5:0..375) with MBSE+$Ca(OH)_2$+PG (1:1:5:0..375) in 1 day.

DISCUSSION

The ability of pulp capping materials to resist solubility in oral fluids is a key factor in ensuring the longevity and effectiveness of dental restorations. Minimal solubility helps prevent issues such as microleakage, pulp irritation, and secondary caries. One widely used method to evaluate solubility involves immersing the material in a solution, where

any change in mass before and after immersion reflects the material's solubility level. [10] When exposed to a solution, restorative materials undergo different processes, including water absorption or sorption—where liquid molecules diffuse into the material's structure—leading to an increase in mass. Conversely, solubility results in the release of unreacted monomer components, causing a reduction in mass.[10,12]

For a restorative material to be considered ideal, it should exhibit near-zero solubility, ensuring its structural stability when in contact with oral fluids. Additionally, factors such as material composition, chemical changes after application, and interactions with the oral environment influence its overall durability.[10]

Calcium hydroxide ($Ca(OH)_2$) has been widely used for direct pulp capping due to its high alkalinity, antibacterial properties, and ability to promote dentin bridge formation. However, its high solubility and degradation over time can compromise the integrity of the restoration. This study investigates the potential of Mauli banana (*Musa acuminata)* as an additive to enhance the stability of $Ca(OH)_2$ as a pulp capping material. The combination was assessed for its solubility, water absorption, and bioactivity. This study analyzed calcium hydroxide ($Ca(OH)_2$) samples and a formulation combining $Ca(OH)_2$ with Mauli banana stem extract (MBSE) in the solubility and the water absorption. The Mauli banana stem extract was chosen due to its biocompatibility and non-toxic properties, antibacterial, antiinflammatory and immunomodulatory making it a suitable option for pulp tissue applications. [7–9]

To prepare the $Ca(OH)_2$ disc samples, calcium hydroxide powder was mixed with water in a 1:1 ratio according to the manufacturer's instructions. The MBSE-$Ca(OH)_2$ formulation was created by blending Mauli banana stem extract, calcium hydroxide, and propylene glycol in specific proportions with the ratio at 1.5:1:0.375 and 1:1.5:0.375. Each sample was molded into a disc with dimensions of 15 mm in diameter and 1 mm in thickness, then immersed for either 1 or 7 days at 37°C, following the ISO 4049 standards set by the International Standards Organization (2009).

Artificial saliva served as the immersion medium to replicate the conditions of the oral cavity, as its mineral composition closely mirrors that of natural saliva. The experiment was conducted over a 24-hour period, based on findings by Pribadi (2020), who noted that material solubility increases within the first 24 hours due to the early release of unreacted monomers. Pribadi (2020) also showed that the study indicated that solubility continues to rise with extended immersion time.[10]

According to the current study, even after one and seven days, the solubility of the MBSE-Ca(OH) combination is lower than that of Ca(OH) alone. This is because, when mixed with mauli banana stem extract, Ca(OH) undergoes a chemical reaction throughout the immersion period in artificial saliva media. When submerged, the combination will attack and break chemical bonds, releasing metal ions like Ca^{2+} ions as a byproduct of the chemical process. As secondary metabolites, mauli banana stem extract includes cinnamic acid and caffeic acid. Caffeic acid (CA), also known as 3-(3,4-dihydroxyphenyl)-2-propenoic acid, is a commonly used polyphenol due to its strong antioxidative, antibacterial and anti-inflammatory properties. Caffeic acid has also been utilized to modify synthetic biomaterials in order to improve scaffold bioactivity. The calcium ions (Ca^{2+}) from $Ca(OH)_2$ combine with the caffeic acid molecules ($C_9H_8O_4$) in mauli banana stem extract to generate calcium salt. Additionally, water is created when the hydroxide ions (OH^-) from calcium hydroxide and the hydrogen ions (H^+) from caffeic acid interact. $Ca(OH)_2$ and caffeic acid form both ionic and hydrogen bonds. It is believed that the formation of calcium salt reduces the solubility of $Ca(OH)_2$ and MBSE relative to $Ca(OH)_2$ itself. [10,13]

In this study, after immersion for 7 days the water absorption of MBSE and $Ca(OH)_2$ combination show higher than it is after 1 day. When solubility increases after seven days as opposed to one day, this indicates that solubility is linear. Solubility is directly impacted by the capacity to absorb water. Low water sorption compounds have low solubility. One important component of pulp capping's setting action is water absorption. The consequent of high water sorption seen in this material may be explained by the swelling of components in the water-occupied areas brought on by the expansion brought on by water diffusion. According to the comparison, MBSE- $Ca(OH)_2$ has a higher water sorption than Ca(OH), although it is less soluble than $Ca(OH)_2$. These discrepancies can be explained by the fact that the complex chemical bonds found in the $Ca(OH)_2$,-MBSE combination—which include ionic, hydrogen, and Van der Waals forces—are stronger than those found $Ca(OH)_2$, which just comprise hydrogen and these forces. [10] It can be concluded that The solubility of the MBSE-$Ca(OH)_2$ combination is lower than that of $Ca(OH)_2$ alone, the water absorption of the MBSE- $Ca(OH)_2$ combination is higher than that of $Ca(OH)_2$ alone.

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CONFLICT OF INTERESTS

All authors have none to declare

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