Comparative Efficacy of Biodentine® and Calcium Hydroxide in Pulp Capping Treatment

Oburo FO[1], Awotile AO[2], Adegbulugbe IC[3], Dr Enone LL[2], Oyapero A[4]

Correspondence: *Oburo FO*
Email: *francesoburo1@gmail.com*

[1]Department of Restorative Dentistry, Dental Centre, Lagos State University Teaching Hospital Ikeja, Lagos, Nigeria.

[2]Department of Restorative Dentistry, Faculty of Dentistry, College of Medicine, Lagos State University, Ikeja, Lagos, Nigeria.

[3]Department of Restorative Dentistry, Faculty of Dental Sciences, College of Medicine, University of Lagos,Lagos, Nigeria;

[4] Department of Preventive Dentistry, Faculty of Dentistry, College of Medicine, Lagos State University, Ikeja, Lagos, Nigeria.

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ABSTRACT

Background: This study is focused on — Assessing Biodentine and Calcium hydroxide in indirect pulp capping procedures. Various materials have been used in indirect pulp capping but this comparative study may help appreciate which material produces better results: Biodentine or Calcium hydroxide.

Objective: To compare treatment outcomes post indirect pulp capping treatment using Biodentine® and Calcium hydroxide ($Ca(OH)_2$).

Materials and Methods: A blinded, randomized clinical control trial involving 50 consenting subjects, comparing Biodentine® (test) and $Ca(OH)_2$ (control). Cavity preparation was done and the cavity was dressed with either Biodentine® or $Ca(OH)_2$ and then restored with Glass ionomer cement. The subjects' teeth were later examined clinically and radiographically at 3, 6, and 9 months post treatment. The indicators of clinical success were absence of pain, swellings, sinus, fistula, abscess, mobility, tenderness to percussion, normal response to electric pulp tester, and Endo-ice cold test. The indicator of radiographic success was absence of periapical pathosis. The probability level of $p<0.05$ was considered significant.

Results: The success rate at three months was 100% for both groups; at six months, it was 92% for both groups and at nine months, 92% of subjects were successful in the Biodentine® group while the $Ca(OH)_2$ group recorded 88% which was statistically insignificant (P=0.74).

Conclusion: Biodentine® and Calcium hydroxide have shown comparable effectiveness in improving treatment outcomes, thus, contributing to the longevity of the teeth, and the period of optimum efficaciousness of the pulp capping materials in this study was three months.

INTRODUCTION

The modern management of deep carious lesions involves dexterity in caries removal, halting caries progression by creating an adequate seal that protects the pulp dentin complex, with the use of materials that stimulate the release of bioactive substances from the dentin matrix, thereby increasing the thickness of dentin.[1] It also involves a good knowledge of the reparative and defensive characters of the pulp dentin interphase.[2] The use of the appropriate material is essential to achieve pulp preservation.[3] Studies comparing indirect pulp capping materials have been done, although there is paucity of such studies in Nigeria. [4,5,6] Different studies comparing outcomes of various materials used in indirect pulp capping such as mineral trioxide aggregate, glass ionomer cement with Theracal® and Portland cement with calcium hydroxide found that technique sensitivity and poor handling were reasons given by most clinicians for not routinely

using them, hence the introduction of Biodentine®.[7-11] Furthermore, a few studies have been done to compare the clinical outcomes of the use of Biodentine® and calcium hydroxide, with no statistically significant difference observed between them. [12,13] This study may, however, show the peculiarity of our environment.

An in vivo study has shown that pulps mechanically exposed and capped with Biodentine resulted in effective dentinal repair. [14] The pH of calcium hydroxide is alkaline and it causes local necrosis around exposed pulp which results in inflammation, and pulpal repair is initiated by well controlled inflammation.[15] Biodentine® releases a lot of calcium hydroxide prior to being cured and releases more free calcium ions with higher diffusion levels than $Ca(OH)_2$ which aids in tissue repair. [16,17] Biodentine® has also been shown to be a bioactive material that promotes hard tissue regeneration, and does not stimulate moderate or severe pulp inflammation.[18] At high magnification, $Ca(OH)_2$ has been observed to form irregular thick reparative dentin with porosities and tunnel defects, whereas, Biodentine® produces thicker uniformed reparative dentin with minimal tunnel defects.[19] As such, Biodentine® penetrates into the dentin tubules with precipitation of its crystals in the tubules which reduces the dentin tubular permeability and fluid movement, resulting in reduced post-operative sensitivity. [20] Biodentine® also causes formation of orthodentin which is quite similar to normal dentinal tubules.[21] The purpose of this study was to compare the outcomes of treatment following use of Biodentine® and calcium hydroxide in indirect pulp capping in our environment.

MATERIALS AND METHODS

This study was done at the Conservative Clinic of the Restorative Dentistry Department of the Lagos State University Teaching Hospital (LASUTH) Ikeja, Lagos, Nigeria. It was a randomized controlled clinical trial comparing the treatment outcomes using of the study Biodentine® and Calcium Hydroxide (control) in indirect pulp capping treatment, over a 12 month duration. Ethical approval for this study was obtained from the Health Research Ethics Committee of the Lagos State University Teaching Hospital Ikeja, Lagos. Consenting subjects aged 19 to 55 years with deep carious lesions on occlusal or proximal surface(s) of a permanent posterior tooth showing (i) normal response to pulp testing, (ii) ICDAS (International Caries Detection and Assessment System) 4 and 5 [22]; (iii) symptoms of reversible pulpitis; and (iv) coronal radioluscency that was not communicating with the pulp, were included in the study. Subjects with spontaneous or chronic pain, tenderness on percussion, presence of other pathology or mobility and serious systemic illness like epilepsy, stroke, multiple sclerosis, and muscular dystrophy were excluded.

Sample size Determination:

The sample size was calculated using a formula for comparing two means,[23] utilizing values obtained from a previous study.[24] This referenced study showed an increase in dentin depth of 0.235±0.110mm at 6 months after use of MTA, and 0.221±0.059 after use of $Ca(OH)_2$ in indirect pulp capping.[24] The sample size was constrained using a formula for constraining sample sizes[25] due to the peculiarity of a limited study population. A total of 50 subjects, comprising 25 for the Biodentine (test) group and 25 for the Calcium Hydroxide (control) group, were involved in the study. Data were collected from subjects using a data entry form. Clinical examination was done by two blinded calibrated examiners who were not privy to the information on who had received Biodentine® or the $Ca(OH)_2$. Pain was scored using Visual Analogue Scale (VAS) and subjects that could not read would have been provided an interpreter, although all subjects in this present study were literate because most patients presenting in the teaching hospital were literate.

Teeth were classified using ICDAS and only clinical grade 4 (underlying dark shadow in dentin beneath) or 5 (distinct cavitation with visible dentin) were included in the study. [22,26] The selected tooth in each subject was confirmed for normal response to pulp test using the electric pulp tester and cold test using Endo ice®.[27] Radiographic examination of the teeth using a periapical digital dental x-ray and an x-ray film holder XCP Ds Fit Dentsply® for standardization purposes was done to check for coronal radiolucency getting to the inner third of

dentin without pulpal involvement, the presence of a dentin bridge, and the confirmation of absence of periapical pathosis. In event of disagreement between the two examiners, that particular subject would have been excluded from the study, although this scenario did not occur.

Treatment Procedure:

All treatments were performed by the principal investigator who could not be blinded due to the different application methods of the two materials. Treatment commenced with the administration of local anaesthesia and moisture control was achieved with the use of rubber dam, cotton wool rolls, and adequate suction. With the aid of magnification loupes for effective visualization, cavity preparation was performed using water cooled diamond fissure bur in a fast-speed hand piece to prevent transmitting heat to the pulp, and a spoon excavator was also used. A hard dry dentin surface remained on the outer walls, and in keeping with selective caries removal, the floor and axial walls were left slightly moist, firm, and leathery, giving a slight resistance to excavation with reasonably sound dentin. The cavity was washed thoroughly with water spray, air dried, and if wall was missing, a wedge was passed between two teeth and a matrix was adapted to the tooth then pulp capping was done with Biodentine® or the $Ca(OH)_2$. The pulp capping materials were used strictly according to the manufacturer's instructions.

After placement of the appropriate pulp capping material, the cavity was restored with Glass ionomer cement, Fuji IX® following the manufacturer's instructions.

Post treatment evaluation:

The outcome measures for clinical success were absence of pain, swellings, sinus, fistula, abscess, mobility, tenderness to percussion; normal response to electric pulp tester and Endo-ice cold test. The outcome measure for radiographic success was absence of periapical pathosis. The subjects were recalled and the treated teeth reviewed clinically and radiographically by the two blinded calibrated examiners at the 3 months, 6 months, and 9 months post treatment periods. Pain was evaluated using the VAS measurement tool. The gingiva was assessed for periodontal pathosis by checking for swelling, sinus, fistula, pocket depth and tooth mobility. The treated teeth were tested for tenderness to percussion was assessed to rule out periapical pathosis. The vitality of the pulp was assessed using a Parkell electric pulp tester G-98853® and Endo-ice®. [27]

The digital periapical radiographs were evaluated at baseline, 3 months, 6 months and 9 months, for presence or absence of any periapical pathosis in the form of periapical radiolucency, internal or external root resorption and was recorded as present or absent. In event of disparity between the examiners, that particular subject would have been removed from the study, but this did not occur. Any subject with failed teeth in the course of the research was booked for root canal treatment where appropriate. Data was collected and analysed using Statistical package for social sciences IBM® (version 23). Mean, standard deviation and independent student test were presented for numeric variables. Categorical variables were presented using frequency and percentages. Association between categorical variables was assessed using Chi square. A multiple bar chart was used to compare success rates of treatment outcomes at different intervals. Significance level was set at $P< 0.05$ for all statistical tests.

Ethical approval for this study was obtained from the Health Research Ethics Committee of the Lagos State University Teaching Hospital Ikeja Lagos

RESULTS

Fifty subjects that attended the Conservative Clinic of the Department of Restorative Dentistry participated in this study. Seventeen (34%) subjects were males and thirty-three (66%) subjects were females. The age range for males was 19 to 45 years while that for females was 19 to 55 years. (Table 1)

Table 1: Socio-demographic characteristics of subjects

	Biodentine (n=25)	$Ca(OH)_2$ (n=25)	Total	χ^2	p-value
Gender					
Male	9(36.0)	8(32.0)	17(34.0)	0.089	0.765
Female	16(64.0)	17(68.0)	33(66.0)		
Age group (Years)					
≤30	6(24.0)	6(24.0)	12(24.0)	1.024	0.573
31-40	6(24.0)	5(20.0)	11(22.0)		
41-50	6(24.0)	9(36.0)	15(30.0)		
>50	7(28.0)	5(20.0)	12(24.0)		
Mean ±SD	36.72±11.9	36.23±10.8		0.738**	0.843

**Independent student test

Twenty-five (50%) teeth each were restored in the maxilla and mandible respectively. All the teeth restored were classified as ICDAS class 5.

At three months: There was no pain, swelling, sinus, fistula, abscess, mobility, and tenderness to percussion in both groups. All teeth had normal response to electric pulp test and cold test and there was no periapical pathosis. (Table 2).

At six months: There was no pain, swelling, sinus, fistula, abscess, tenderness to percussion and periapical pathosis in both groups. There was no mobility in the Biodentine group, but one tooth in the $Ca(OH)_2$ group developed grade 1 mobility. Two teeth did not respond to electric pulp test in the Biodentine group, while one tooth did not respond to electric pulp test in the $Ca(OH)_2$. All teeth had normal response to cold test in the Biodentine group, but one tooth in the $Ca(OH)_2$ group did not respond to cold test. (Table 2).

At nine months: There was grade 2 pain in a tooth in the Biodentine group but no pain in the $Ca(OH)_2$ group. There were no swellings, sinus, fistula, and abscess in both groups. Two teeth were mobile in the Biodentine group and one tooth was mobile in the $Ca(OH)_2$ group. One tooth was tender to percussion in both groups and one tooth did not respond to electric pulp test in both groups. All teeth had normal response to cold test in the Biodentine group but one tooth in the $Ca(OH)_2$ group did not respond to cold test. One tooth in both groups had periapical pathosis. (Table 2).

Table 2: Treatment outcomes among subjects

	Biodentine (n=25)	$Ca(OH)_2$ (n=25)	Total	f	p-value
	Pain				
3 months	0 (0.0)	0(0.0)	0(0.0)	0.000	1.000
6 months	0 (0.0)	0(0.0)	0(0.0)	0.000	1.000
9 months	1(4.0)	0(0.0)	1(2.0)	1.020	0.312
	Swelling. sinus, fistula or abscess				
3 months	0 (0.0)	0(0.0)	0(0.0)	0.000	1.000
6 months	0 (0.0)	0(0.0)	0(0.0)	0.000	1.000
9 months	0 (0.0)	0(0.0)	0(0.0)	0.000	1.000
	Mobility				
3 months	0 (0.0)	0(0.0)	0(0.0)	0.000	1.000
6 months	0(0.0)	1(4.0)	1(2.0)	1.020	0.312
9 months	2(8.0)	1(4.0)	3(6.0)	0.943	0.234
	Teeth tender to palpation or percussion				
3 months	0 (0.0)	0(0.0)	0(0.0)	0.000	1.000
6 months	0 (0.0)	0(0.0)	0(0.0)	0.000	1.000
9 months	1(4.0)	1(4.0)	2(4.0)	0.000	1.000
	Tooth non-response to electric pulp tester				
3 months	0 (0.0)	0(0.0)	0(0.0)	0.000	1.000
6 months	2(8.0)	1(4.0)	3(6.0)	0.943	0.234
9 months	1(4.0)	1(4.0)	2(4.0)	0.000	1.000
	Tooth non-response to cold test using Endo ice				
3 months	0 (0.0)	0(0.0)	0(0.0)	0.000	1.000
6 months	0 (0.0)	1(4.0)	1(2.0)	1.020	0.312
9 months	0 (0.0)	1(4.0)	1(2.0)	1.020	0.312
	Periapical pathosis				
3 months	0 (0.0)	0(0.0)	0(0.0)	0.000	1.000
6 months	0 (0.0)	0(0.0)	0(0.0)	0.000	1.000
9 months	1(4.0)	1(4.0)	2(4.0)	1.020	0.312

A 100% overall success rate was recorded in both groups at three months; however, at six months, two teeth each had failed in both groups. At nine months, two teeth indicated failure in the Biodentine® group with one grade I mobile tooth that was non responsive to the electric pulp tester and another tooth with grade 2 pain, grade I mobility, tenderness to percussion and periapical pathosis. Three teeth in the $Ca(OH)_2$ group at nine months had failed with one grade I mobile tooth, another tooth tender to percussion with periapical pathosis, and a third tooth was non responsive to electric pulp tester and cold test. Overall, at nine months, 23 subjects' teeth out of 25 subjects' teeth (92%) were successful in the Biodentine® group and 22 subjects' teeth out of 25 subjects' teeth (88%) in the $Ca(OH)_2$, group which was statistically insignificant at a P value of 0.74 (Figure 1).

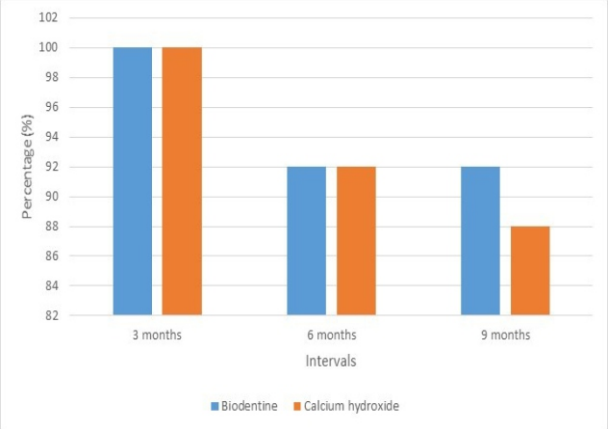

Figure 1: Overall success rates at different intervals

Multivariate logistic regression shows that females have statistically significant lower odds of failure compared to males (OR=0.384; 95% CI=0.037). Age, jaw, teeth type and type of intervention were not found to independently affect failure. (Table 3)

Table 3: Multivariate logistic regression of independent predictors of failure

	Odd ratio	95% CI	p-value
Age group (Years)			
≤30	1.094	0.381-5.093	0.893
31-40	1.004	0.221-6.214	0.792
41-50	0.983	0.451-6.990	0.822
>50	0.994	0.593-0.473	0.919
Gender			
Male	1		
Female	0.384	0.189-0.833	**0.037***
Jaw			
Maxilla	1		
Mandible	1.397	0.279-7.002	0.684
Teeth type			
Premolar	1		
Molar	0.540	0.107-2.715	0.455
Intervention			
Control	1		
Bio dentine	0.765	0.372-1.091	0.093

DISCUSSION

In this study, majority of subjects were females, and this could be due to the positive health seeking behaviour of females compared to males.[28,29] There was a near even distribution of males and females in Biodentine® and calcium hydroxide groups. In this study, only subjects with absence of spontaneous pain were assessed in accordance with symptoms of reversible pulpitis and only a subject in the Biodentine developed pain at nine months due to possible undetected ongoing pulpal inflammation as reported in another study.[26,30] These findings are similar to those reported in a previous study where pain was assessed following indirect pulp capping.[31] Tooth tenderness to percussion was statistically insignificant and was not in line with another study that showed statistically significant difference in favour of Biodentine® over $Ca(OH)_2$ at nine months.[32] Mobility of teeth in this study was similar to findings reported in another study and the cause of mobility in the Biodentine® group may be due to development of perio-endo lesion (primarily endodontic lesion with secondary periodontal involvement due to relaxation in maintenance of oral hygiene practice).[32] The disparity in the electric pulp test and Endo-ice cold test may be due to

various factors such as technical error, faulty device, excessive calcification, extensive restorations creating a distance between the pulp and the electrode's tip, as well as apprehension.[30,33] In agreement with this study, the cold test has been shown in a previous study[34] to be more sensitive than the electric test. There was no statistically significant difference between pulp vitality and type of restorative material used as seen in another study.[35] The good result on absence of periapical pathosis was similar to another study.[12] The few subjects that developed periapical pathosis may be due to unresolved underlying pulpal disease.

The successful outcome in this study is close to that reported in another study and showed that indirect pulp capping is efficacious in the management of deep carious lesions in this environment.[36] At three months, the success rate of 100% in both groups was in line with previous studies.[12,37] The period of optimum efficaciousness of the pulp capping materials in this study was three months as reported by Benoist et al.[24] At six months, the overall success rate for both materials was higher than that reported by Kusumvalli et al, which had a smaller sample size.[36] The success rate of the Biodentine® group at six months was comparable to that of another study and this may be due to the similar sample size.[38] The success rate in the $Ca(OH)_2$ group at six months was higher than that of a previous study carried out in Senegal and this may be due to proper case selection in this present study.[24] At nine months, the success rate of Biodentine® and $Ca(OH)_2$ was similar to that of another study on vital pulp therapy.[32] The performance of Biodentine® relative to $Ca(OH)_2$ in this study could be due to a) Biodentine having a three to four fold lesser porosity than $Ca(OH)_2$,[14] b) Biodentine® also releases a lot of calcium hydroxide prior to being cured and this aids in tissue repair.[16] c) Biodentine® as a dentin substitute for direct and indirect pulp capping has better mechanical properties likened to dentin, bonds firmly to dentin and has antibacterial properties that are greatly needed in deep carious lesions.[39,40]

The overall success rate of 90% in this adult study following the use of both materials, Biodentine® and $Ca(OH)_2$ in indirect pulp capping at nine months is comparable to that of previous studies.[7,9] The good success rates show that Biodentine® and $Ca(OH)_2$ have proven to be effective in prolonging the longevity of the tooth by improving treatment outcomes: absence of pain, absence of periodontal pathosis, absence of periapical pathosis and normal response to pulp testing. This may be due to Biodentine® and $Ca(OH)_2$ primarily causing tissue irritation which may result in early inflammatory reaction with resultant repair and mineralization of dentin.[41] The $Ca(OH)_2$ group in this study also showed a successful clinical outcome even with its limitations of heterogeneous dentin formation, inclusion bodies and marginal leakage.[14,42] The success rate in this study reduced over time as reported in literature.[43] This decline in success rate with time may be due to insufficient caries removal and poor handling techniques which could result in poor strength of the restorative materials as reported by Arshad et al.[12] The failures in this study may also be due to ongoing undetected degenerative process in dentin as reported in another study that related failures to non detection of microleakage by the operator.[32] Multivariate logistic regression showed that females had statistically significant lower odds of failure compared to males (OR=0.384; 95% CI=0.037). This may also be due to their positive health seeking behaviour.[28]

CONCLUSION

Based on this study, Biodentine® and Calcium Hydroxide have shown comparable effectiveness in improving treatment outcomes of absence of pain, absence of periodontal pathosis, absence of periapical pathosis, and normal response to pulp testing, and have contributed to the prolongation of the longevity of the tooth. Both materials can be used successfully in the management of deep carious lesions as seen in the successful outcomes recorded in this study.

LIMITATION

This study utilized sensibility tests which does not assess the flow of blood in the pulp.

RECOMMENDATION

Biodentine® and Ca(OH)2 should both be used in indirect pulp capping as both materials showed successful treatment outcomes. More studies could be done utilizing pulp vitality tests that would assess the flow of blood in the pulp.

REFERENCES

1. Alex G. Direct and indirect pulp capping: A brief history, material innovations, and clinical case report. Compend Contin Educ Dent. 2018;39(3):182–9.
2. Bjorndal L, Simon S, Tomson PL, Duncan HF. Management of deep caries and the exposed pulp. Int Endod J. 2019;52:949–73.
3. Schwendicke F, Brouwer F, Schwendicke A, Paris S. Different materials for direct pulp capping : systematic review and meta-analysis and trial sequential analysis. Clin Oral Invest. 2016;20:1121–32.
4. Vural UK, Kiremitçi A, Gökalp S. Clinical assessment of mineral trioxide aggregate in the treatment of deep carious lesions. Niger J Clin Pract. 2017;20(5):600–5.
5. Oz F, Bolay S, Bayazit E, Bicer C, Isikhan S. Long term survival of different deep dentin caries treatments: A 5-year clinical study. Niger J Clin Pract. 2019;22:117–24.
6. Carti O, Oznurhanle F. Evaluation and comparison of mineral trioxide aggregate and Biodentine in primary tooth pulpotomy: Clinical and radiographic study. Niger J Clin Pract. 2017;20:1604–9.
7. Hashem D, Manocci F, Patel S, Manoharan A, Watson T, Banerjee A. Evaluation of the efficacy of calcium silicate vs . glass ionomer cement indirect pulp capping and restoration assessment criteria : randomised controlled clinical trial — 2-year results. Clin Oral Investig. 2019;23:1931–9.
8. Gurcan AT, Seymen F. Clinical and radiographic evaluation of indirect pulp capping with three different materials: A 2-year follow-up study. Eur J Paediatr Dent. 2019;20(2):105–10.
9. Petrou MA, Alhamoui FA, Welk A, Altarabulsi MB, Alkilzy M, Splieth CH. A randomized clinical trial on the use of medical portland cement, MTA and calcium hydroxide in indirect pulp treatment. Clin Oral Investig. 2014;18(5):1383–9.
10. Baskaran S, Ahamed S, Narayana S, Bhavani S, Rajaraman G. A randomized controlled study of the use of mineral trioxide aggregate angelus (white) and biodentine as pulp capping materials. Endodontology. 2018;30(1):69–75.
11. Jalan AL, Warhadpande MM, Dakshindas DM. A comparison of human dental pulp response to calcium hydroxide and Biodentine as direct pulp-capping agents. J Conserv Dent. 2020;20(2):129–33.
12. Arshad E, Gyanendra K, Dhillon JK. Comparative evaluation of clinical outcome of indirect pulp treatment with calcium hydroxide, calcium silicate and Er,Cr:YSGG laser in permanent molars. Laser Ther. 2019;28(2):123–30.
13. Boddeda KR, Rani CR, Vanga NR, Chandrabhatla SK. Comparative evaluation of biodentine, 2% chlorhexidine with RMGIC and calcium hydroxide as indirect pulp capping materials in primary molars: An in vivo study. J Indian Soc Pedod Prev Den. 2019;37(1):60–6.
14. Tran X, Chaussain C, Willig C, Gorin C, Baroukh B, Pellat B, et al. Effect of a calcium-silicate-based restorative cement on pulp repair. J Dent Res. 2012;91(12):1166–71.
15. Goldberg M, Farges J, Lacerda-Pinheiro S. Inflammatory and immunological aspects of dental pulp repair. Pharma Res. 2008;58(2):137–47.
16. Camilleri J. Characterization of hydration

products of mineral trioxide aggregate. Int Endod J. 2008;41(5):408–17.

17. Aksoy MK, Oz FT, Orhan K. Evaluation of calcium (Ca 2+) and hydroxide (OH −) ion diffusion rates of indirect pulp capping materials. Int J Artif Organis. 2017;40(11):641–6.

18. Malkondu Ö, Kazanda MK, Kazazo lu E. A review on biodentine, a contemporary dentine replacement and repair material. BioMed Res Int. 2014;1–10.

19. Nowicka A, Wilk G, Lipski M. Tomographic evaluation of reparative dentin formation after direct pulp capping with Ca(OH)2, MTA, Biodentine and dentin bonding system in human teeth. J Endod. 2015;41(8):1234–40.

20. About I. Biodentine: From biochemical and bioactive properties to clinical applications. G Ital Endod. 2016;30:81–8.

21. Simon S, Cooper P, Smith A, Picard B, Naulin Ifi C, Berdal A. Evaluation of a new laboratory model for pulp healing: Preliminary study. Int Endod J. 2008;41(9):781–90.

22. Pitts NB, Ismail AI, Martignon S, Ekstrand K, Douglas G V, Longbottom C. ICCMS TM Guide for practitioners and educators. ICDAS Found. 2014;1–84.

23. Clifton L, Birks J, Clifton DA. Comparing different ways of calculating sample size for two independent means : A worked example. Contemp Clin Trials Comm. 2019;13:1–7.

24. Benoist FL, Ndiaye FG, Kane AW, Benoist HM, Farge P. Evaluation of mineral trioxide aggregate (MTA) versus calcium hydroxide cement (Dycal) in the formation of a dentine bridge : a randomised controlled trial. Int Dent J. 2012;62:33–9.

25. Israel GD. Determining sample size. Inst Food Agric Sci. 2003;PEOD6:1–5.

26. Sultana R, Hossain M, Alam S. Evaluation of clinical and radiological outcomes of mineral trioxide aggregate and calcium hydroxide as indirect pulp capping agents in the treatment of deep carious lesion of permanent teeth. Bangabandhu Sheikh Mujib Med Univ J. 2016;9:140–5.

27. Ford TRP, Patel S. Technical equipment for assessment of dental pulp status. Endod Top. 2004;7:2–13.

28. Ajayi DM, Abiodun-Solanke I, Gbadebo SO. A 5-year retrospective study of rampant dental caries among adult patients in a Nigerian teaching hospital. Indian J Dent Res. 2015;26:267–70.

29. Bakare TI, Okoturo E, Obisesan B, Oyapero A. Patients attitudes toward screening for medical conditions in a dental clinic at the Lagos State University Teaching Hospital Ikeja. Int J Heal Allied Sci. 2018;7:150–8.

30. Jafarzadeh H, Abbott P V. Review of pulp sensibility tests . Part I : general information and thermal tests. Int Endod J. 2010;43:738–62.

31. Stafuzza CT, Vitor LLR, Rios D, Cruvinel T, Neto NL, Sakai VT et al. A randomized clinical trial of cavity liners after selective caries removal : one-year follow-up. J Appl Oral Sci. 2019;27:1–7.

32. Caruso S, Dinoi T, Marzo G, Campanella V, Giuca MR, Gatto R, et al. Clinical and radiographic evaluation of biodentine versus calcium hydroxide in primary teeth pulpotomies: A retrospective study. BMC Oral Health. 2018;18(1):1–7.

33. Udoye CI, Jafarzadeh H, Okechi UC, Aguwa EN. Appropriate electrode placement site for electric pulp testing of anterior teeth in Nigerian adults : a clinical study. J Oral Sci. 2010;52(2):287–92.

34. Villa-chávez CE, Patiño-marín N, Loyola-rodriguez JP, Zavala-Alonso N V, Martínez-Castañón GA, Medina-Solis CE. Predictive values of thermal and electrical dental pulp tests : A clinical study. J Endod. 2013;39:965–9.

35. Hashem D, Mannocci F, Patel S, Manoharan A, Brown JE, Watson TF, et al. Clinical and radiographic assessment of the efficacy of calcium silicate indirect pulp capping : A randomized controlled

clinical trial. J Dent Res. 2015;94(4):562–8.

36. Kusumvalli S, Diwan A, Pasha S, Devale M, Chowdhary C, Saikia P. Clinical evaluation of biodentine: Its efficacy in the management of deep dental caries. Indian J Dent Res. 2019;30(2):191–5.

37. Lipski M, Nowicka A, Kot K, Stefanska LP, Jankowicz IW, Borkowski L et al. Factors affecting the outcomes of direct pulp capping using Biodentine. Clin Oral Investig. 2018;22:2021–9.

38. Awawdeh L, Al-Qudah A, Hamouri H, Chakra RJ. Outcomes of vital pulp therapy using mineral trioxide aggregate or Biodentine: A Prospective randomized clinical trial. J Endod. 2018;44(11):1–7.

39. Bakopoulou A, About I. Biodentine TM , a promising bioactive material for the preservation of pulp vitality in restorative dentistry. Int J Dent African Ed. 2014;4(1):34–44.

40. Koubi G, Colon P, Franquin JC, Hartmann A, Richard G, Faure MO, et al. Clinical evaluation of the performance and safety of a new dentine substitute, Biodentine, in the restoration of posterior teeth - a prospective study. Clin Oral Investig. 2013;17(1):243–9.

41. Simon S, Tomson PL, Berdal A. Regenerative endodontics : regeneration or repair ? J Endod. 2014;40(4):570–5.

42. Kiranmayi G, Hussainy N, Lavanya A, Swapna S. Clinical performance of mineral trioxide aggregate versus calcium hydroxide as indirect pulp-capping agents in permanent teeth: A systematic review and meta-analysis. J Int Oral Heal. 2019;11(5):235.

43. Akhlaghi N, Khademi A. Outcomes of vital pulp therapy in permanent teeth with different medicaments based on review of the literature. Dent Res J. 2015;12(5):406–17.