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CLINICAL AND RADIOGRAPHIC EVALUATION OF INDIRECT PULP TREATMENT OF PERMANENT MOLARS USING CALCIUM SILICATES VERSUS ACTIVA BioACTIVE-BASE/LINER

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Abstract

Objectives: The aim of this study was to clinically compare the bioactive behavior of three indirect pulp capping materials through 18 months. **Materials and Methods:** Forty five posterior teeth in fifteen patients aged (18-35) years were used in the study. These were randomly divided into three equal groups (n=15) according to the pulp capping material used, Group A (ProRoot MTA), Group B (Biodentine), Group C (ACTIVA BioACTIVE-BASE/LINER). Carious dentin was removed by sterile excavator & smart burs leaving the caries affected dentin. Cavities were restored using Filtek Bulk Fill composite resin. Remaining dentin thickness was measured using preoperative and follow-up periapical digital radiographs. Post-operative sensitivity was evaluated using (USPHS) criteria at baseline, 3, 6, 12 and 18 months. Pulp vitality was assessed using pulse oximeter. **Statistical analysis:** ANOVA test was used to compare the three groups within each duration and to compare the durations within each group. Pairwise Tukey test was used to compare each two groups regarding the same duration. Chi square test was used for the nominal data. **Results:** Remaining dentin thickness of all groups gradually increased with no significant difference among the groups ($p>0.05$), and a highly significant difference among the durations within each group ($p<0.001$**). Mild post-operative sensitivity that was recorded at baseline in all cases of the three groups, reduced after 3 months and disappeared at 6 months with a significant difference between durations ($p<0.05$). **Conclusions:** ProRoot MTA and Biodentine have significantly high performance in indirect pulp capping procedures. Although; ACTIVA BioACTIVE-BASE/LINER has shown promising results.

Index Terms: ACTIVA BioACTIVE, Biodentine, ProRoot MTA, Pulp Capping.

1. INTRODUCTION

Although numerous studies have been carried out, which have helped to increase the awareness about dental caries and reduce its prevalence, it remains a major public health problem [1].

The promotion of biologically-based treatment strategies has been advocated for partial caries removal aimed at avoiding carious pulp exposure [2]. After nearly a century, the concept of minimal intervention brought a change in the philosophy of care with the removal of all infected dentin; while affected dentin is preserved [3]. This selective carious tissue removal approach needs different pulp capping materials to modify the underlying remaining affected layer [4].

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Advances in biomaterials, such as Resin Modified Glass Ionomer Cements, Mineral Trioxide Aggregate (MTA), Biodentine, Bioceramics, and others, allow the formation of dental tissues that can trigger healing [5]. These materials were reported to release fluoride, calcium, and phosphate ions that promote precipitation or formation of apatite crystal over a partially demineralized collagen matrix [6].

Among the currently used indirect pulp capping (IPC) materials, is ProRoot MTA which consists of fine hydrophilic particles [7].This silicate cement is antibacterial, biocompatible, with a high pH, and is found to aid in the release of bioactive dentin matrix proteins. In addition it has an important advantage that it has a low solubility and a radiopacity slightly greater than that of dentin [8].

Biodentine, is a bioactive calcium silicate based cement that has been recently introduced in the dental market as ‘dentin substitute’. It is capable of providing protection to the underlying pulp through inducing the synthesis of tertiary dentin [9]. Moreover, a recent study [10] has reported that it enhances the human dental pulp stem cells proliferation and odontogenic differentiation and thus could be a novel strategy for dentin regeneration used for IPC therapies. Furthermore, it was also confirmed by others [11] that it is a promising IPC material which exhibits superior sealing ability than many other well-known IPC materials like calcium hydroxide.

ACTIVA BioACTIVE-BASE/LINER is a commercially available bioactive glass-incorporated, light-curable IPC material, launched in 2014 claiming the strength, aesthetics and physical properties of composites and was also reported to exhibit the potential to stimulate biomineralization at the same level as MTA, Biodentine and TheraCal LC through releasing the same amount of calcium and hydroxyl ions like the other IPC materials [12].

Considering the material’s characteristics, the application of ACTIVA BioACTIVE in direct and indirect pulp capping might be justified. However, studies were recommended to accurately assess ACTIVA BioACTIVE-BASE/LINER’s reparative potential on the vital pulp in pulp capping procedures in vivo [13]. Therefore, the aim of this study was to investigate the reparative dentin formation potential of ProRoot MTA, Biodentine, and ACTIVA BioACTIVE-BASE/LINER and to evaluate the post-operative sensitivity associated with these materials after IPC treatment over 18 months follow-up aiming to preserve the tooth vitality and maintaining the integrity of the dental pulp in cases of deep caries involvement.

The tested hypotheses of this study were that (1) The application of a bioactive material in deep carious lesions would induce a reparative response through stimulation of the cells of vital pulps preserved under caries affected dentin layers, and (2) The application of the bioactive material would result in lower tooth post-operative sensitivity through induction of the formation of reparative dentin barrier.

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2. MATERIALS AND METHODS

2.1 Protocol registration and approval of ethics:

The current clinical study was carried out following the code of ethics of the World Medical Association (Declaration of Helsinki), thus informed consents were obtained from the patients according to the guidelines on human research adopted by the Research Ethics Committee of Tanta University and received approval number (R-RD-2-21-9).

2.2 Inclusion and exclusion criteria:

The inclusion criteria consisted of a cooperative, educated patient who exhibited good oral hygiene maintaining acceptable home dental cleaning regimen. Furthermore, only patients with at least three posterior (premolars or molars) Class I deep carious lesions (according to G.V Black's classification) classified as vital with normal response to tooth vitality test using ethyl chloride were considered eligible candidates for the study these may have a history of pain with cold or sweets related to any of the three cavities. Additionally, it was necessary to find a well-defined dentin bridge over the pulp on preoperative radiographic images.

Patients who demonstrated uncooperative behavior, parafunctional habits or abnormal occlusion, were excluded from the study. Additionally, individuals with history of persistent or continuous pain related to any of the three cavities, or compromised periodontal conditions were ruled out. Patients who exhibited bad attitude or low pain threshold, thus being uncooperative were not considered eligible.

2.3 Sample size calculation:

The sample size was calculated using a computer program, G Power version 3.1.9 based on a previous study [14]. For the present study, the power sample size was more than 80%, the significance level was 0.05, the confidence interval was 95%, and the actual power was 96.16%. To boost the validity of the findings and to compensate for any unexpected dropouts the sample size was expanded to 45 teeth.

2.4 Materials:

The bioactive pulp capping materials used in this study were ProRoot MTA, Biodentine and ACTIVA BioACTIVE-BASE/LINER. ProRoot MTA (Dentsply, USA) is a calcium silicate in the form of powder (tricalcium silicate, dicalcium silicate, tricalcium aluminate, bismuth oxide, gypsum) and a liquid composed of distilled water. Biodentine (Septodont, France) is a calcium silicate in the form of powder (tricalcium silicate, dicalcium silicate, calcium oxide, calcium carbonate, zirconium oxide, iron oxide) and a liquid composed of calcium chloride and water. ACTIVA BioACTIVE-BASE/LINER (Pulpdent, USA) has a dual cure chemistry composed of (UDMA, barium glass, ionomer glass, polyacrylic acid/maleic acid copolymer, sodium fluoride, colorants) and has no Bisphenol A, nor Bis-GMA or Benzoyl peroxide derivatives. Together with Filtek Bulk Fill Composite (3M ESPE, USA) and its recommended adhesive 3M Single Bond Universal adhesive (3M ESPE, USA).

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2.5 Patient selection:

Fifteen patients aged between 18-35 years were randomly selected. Every patient had at least three vital posterior teeth exhibiting deep occlusal Class I carious lesions.

2.6 Patient preparation:

For each patient the teeth were examined carefully using a plane dental mirror to ensure that the caries status of the selected teeth belong to only codes 5 (Distinct cavity with visible dentin) or 6 (Extensive distinct cavity with visible dentin) according to the International Caries Detection and Assessment System (ICDAS) visual criteria. The pulp state of the tooth was assessed using a cotton pellet soaked with ethyl chloride (Maquira, Brazil) applied for 3-5 seconds. The pulpal response was considered normal when pain disappeared within 1-3 seconds after removal of the stimulus. Pulse oximeter (Nihon Kohden, Japan) was used to evaluate the pulpal health of the selected teeth. The pulpal health was considered normal when oxygen saturation levels readings were above 77.5 % [15].

2.7 Study intervention:

The study was divided into three groups (n=45): Group A (Cavities treated with ProRoot MTA pulp capping material), Group B (Cavities treated with Biodentine pulp capping material), and Group C (Cavities treated with ACTIVA BioACTIVE-BASE/LINER).

2.8 Clinical procedures:

2.8.1 Restorative Procedures: In all selected cases a preoperative digital x-ray was taken to ensure that at least a dent in thickness of 0.25-1 mm covering the pulp was present. After rubber dam isolation, the outline form was done with a sterile #330 and #245 carbide burs (Komet, Germany) rotating in high-speed under copious water cooling. Carious tissue removal to hard dentin was performed in a single visit [16] using a sharp sterile spoon double-ended excavator (Dentsply, USA) and smart rose head burs (SS White, USA), the remaining affected dentin was left to be covered with the capping materials. The prepared teeth were then cleaned and dried with cotton pellets.

2.8.2 Randomization and allocation concealment: Simple randomization technique utilizing slips of papers was used to allocate the three selected teeth in each patient to the application of the pulp capping materials under investigation where each material received a paper slip stored in an indistinguishable container. Then, random papers were selected by pulling a slip from the container [17].

2.8.3 Application of the pulp capping materials: Group A - ProRoot MTA - the powder was mixed with the supplied liquid over a mixing paper pad in a 3:1 P/L ratio by weight for 60 seconds to obtain wet creamy consistency using a plastic spatula in circular motion. The mix was then carried to the cavity using a clean ball burnisher and allowed to flow to fill the deepest portions of the cavity floor.

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Group B - Biodentine - the content of the supplied dropper was evacuated in the capsule then it was mixed for 30 seconds in an amalgamator to reach a paste of creamy consistency and applied using a clean ball burnisher

Group C - ACTIVA BioACTIVE-BASE/LINER - the content of the syringe was injected gently using the supplied automix injection tip to the deepest portion of the cavity and allowed to flow then light cured for 20 seconds using low intensity light curing device (Ivoclar, Liechtenstein) following the manufacturer's recommendations.

Three small preset amalgam beads were gently placed just above the pulp capping material before its setting, to serve as reference points for future measurements under radiographic evaluation at the different follow up periods. Followed by application of an approximately 2 mm thick layer of ACTIVA BioACTIVE-BASE/LINER to act as a base then it was light cured. Enamel margins of all cavities were selectively etched using 37.5% phosphoric acid gel (Kerr, USA) followed by application of 3M Single Bond Universal Adhesive then restored by Filtek Bulk Fill composite resin following the manufacturer's instructions, then finished and polished.

2.9 Clinical evaluation:

2.9.1 Measurement of the dentin thickness: For measuring the dentin thickness at the different follow up periods, digital periapical radiographs of each tooth were exactly reproduced utilizing an extension cone paralleling (XCP) device. A specialized computer software Digora for Windows 2.5 (Soredex Orion, Finland) was used to analyze the digital radiographic images of the restorations [17]. A perpendicular line was drawn starting at the amalgam bead placed immediately over the pulp capping material related to the deepest point of the cavity that serve as fixed reference point reaching the roof of the pulp chamber which represented the thickness of dentin at the deepest point of the prepared cavity in mm. The values obtained at each follow up were subtracted from those at baseline to be the thickness of reparative dentin formed in each time period through four subtractions from baseline to 3, 6, 12 and 18 months.

2.9.2 Post-operative sensitivity evaluation: The degree of post-operative sensitivity for each patient was evaluated according to the modified USPHS criteria by two trained examiners who were not involved in the restoration placement utilizing the Visual Analogue Scale (VAS) by asking the patient to rate the intensity of their response to pain by application of air from the triple way dental syringe and questioned verbally concerning the following criteria: sensitivity to cold and/or hot, spontaneous pain either prolonged or not, any pain during mastication or sensitivity from other stimuli. This was recorded by marking off the line so that it corresponds to the severity of perceived pain, this was then given as a score (Alpha, Bravo, Charlie, Delta), where Alpha denotes no pain and Delta in cases of severe pain necessitating immediate replacement of restoration. This was done for each restored tooth at baseline, 3, 6, 12, and 18 months after therapy.

2.9.3 Pulp state assessment: The pulp vitality of the restored teeth was assessed using Pulse Oximeter to assess the oxygen saturation level in the blood capillaries of the dental pulp at each follow up period.

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2.10 Statistical analysis:

The collected quantitative data regarding dentin thickness measurement was tabulated and statistically analyzed using ANOVA test. Pairwise Tukey test was used for multiple comparisons. For the nominal data regarding post-operative sensitivity; Chi-square test was used. All tests were done using SPSS Package 21 for Microsoft Windows. p-Value less than 0.05 was considered statistically significant, and p-value less than 0.001 was considered highly significant.

3. RESULTS

Regarding the reparative effect of the pulp capping materials through the study time on the remaining dentin of the cavities, ANOVA test revealed no statistically significant difference among the three groups ($p>0.05$) at all the evaluation periods. However, a highly statistically significant difference among the durations within each group was detected ($p<0.001$**) Table 1.

Table 1: Comparison between the three groups regarding the mean (mm) remaining dentin thickness values.

Duration	Group A ProRoot MTA Mean ±SD	Group B Biodentine Mean ±SD	Group C ACTIVA BioACTIVE Mean ±SD	ANOVA *p* Value
Baseline	0.85±0.2	0.84±0.21	0.91±0.09	0.70
3 months	1.11±0.19	1.14±0.2	1.10±0.08	0.75
6 months	1.36±0.18	1.42±0.19	1.32±0.09	0.81
12 months	1.68±0.2	1.76±0.2	1.7±0.07	0.72
18 months	1.94±0.18	2.05±0.18	1.87±0.08	0.59
ANOVA *p* Value	<0.001**	<0.001**	<0.001**	-----

Note: p≤ 0.05 (Statistically significant)

Subtraction of the dentin thickness values at each follow up from those at baseline was performed to obtain the net increase in dentin thickness Table 2. ANOVA test revealed statistically significant difference ($p<0.05$) between the mean values of the three study groups in the different durations. While it showed a highly statistically significant difference ($p<0.001$**) within each group denoting the association of time with the reparative effect of the pulp capping materials.

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Table 2: Comparison between the three groups regarding the mean (mm) remaining dentin thickness subtractions.

Subtraction	Group A ProRoot MTA Mean ±SD	Group B Biodentine Mean ±SD	Group C ACTIVA BioACTIVE Mean ±SD	ANOVA *p* Value
Baseline to 3 months	0.26±0.035	0.29±0.01	0.19±0.04	<0.001**
Baseline to 6 months	0.50±0.08	0.56±0.02	0.41±0.03	0.004*
Baseline to 12 months	0.86±0.06	0.91±0.02	0.77±0.05	0.001*
Baseline to 18 months	1.15±0.05	1.20±0.02	0.96±0.03	<0.001**
ANOVA *p* Value	<0.001**	<0.001**	<0.001**	-----

Note: p≤ 0.05 (Statistically significant)

Pairwise Tukey test Table 3 showed none significant difference (p>0.05) between Group A versus B at the four subtractions of baseline to 3, 6, 12&18 months denoting their comparable reparative effect on the remaining dentin. While significant difference (p<0.05) between both Group A and B versus Group C was recorded at all subtractions of baseline to 3, 6, 12&18 months reflecting the significantly better reparative effect of (ProRoot MTA) and (Biodentine) on the remaining dentin compared to (ACTIVA BioACTIVE-BASE/LINER). Furthermore, Pairwise Tukey test within each group revealed highly significant difference (p<0.001) at the 4 subtractions of baseline to 3, 6, 12&18 months, reflecting that the tested pulp capping material's reparative effect was increasing with time.

Table 3: Multiple comparisons between the groups regarding the remaining dentin thickness subtractions using Pairwise Tukey test.

Subtraction	Group A vs. B	Group A vs. C	Group B vs. C
Baseline to 3 months	0.357	0.004*	0.005*
Baseline to 6 months	0.219	0.049*	0.003*
Baseline to 12 months	0.197	0.017*	0.001*
Baseline to 18 months	0.132	<0.001**	<0.001**

Note: p≤ 0.05 (Statistically significant)

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Concerning the post-operative sensitivity associated with the pulp capping material Table 4, mild post-operative sensitivity (Bravo Score) was recorded at baseline: MTA=33.3%, Biodentine=40% and ACTIVA BioACTIVE =33.3% of the cases in the three groups respectively. These were reduced to MTA=13.3, Biodentine=20% & ACTIVA BioACTIVE 20% after 3 months and disappeared at 6 months with no significant difference between the groups ($p>0.05$) using Chi-Square test. Furthermore, Chi-Square test revealed no statistically significant difference ($p>0.05$) between the baseline sensitivity scores versus those after 3 months in all groups indicating the persistence of sensitivity in the first 3 months. While statistically significant difference ($p<0.05$) was found between baseline scores versus after 6, 12, 18 months in the three groups indicating reduction of pain with time Table 5.

Table 4. Comparison between the three groups regarding the percentages of the recorded post-operative sensitivity.

Evaluation period	Group A ProRoot MTA (n=15)	Group B Biodentine (n=15)	Group C ACTIVA BioACTIVE (n=15)	Chi-Square *p* Value
Baseline				
Alpha	9 (60.0%)	7 (46.67%)	8 (53.3%)	0.94
Bravo	5 (33.3%)	6 (40.0%)	5 (33.3%)	
Charlie	1 (6.7%)	2 (13.3%)	2 (13.3%)	
After 3 Months				
Alpha	13 (86.7%)	12 (80.0%)	12 (80.0%)	0.85
Bravo	2 (13.3%)	3 (20.0%)	3 (20.0%)	
Charlie	0 (0.0%)	0 (0.0%)	0 (0.0%)	
After 6 Months				
Alpha	15 (100.0%)	15 (100.0%)	15 (100.0%)	--
After 12 Months				
Alpha	15 (100.0%)	15 (100.0%)	15 (100.0%)	--
After 18 Months				
Alpha	15 (100.0%)	15 (100.0%)	15 (100.0%)	--

Note: p≤ 0.05 (Statistically significant)

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Table 5: Comparison between the durations within each group regarding the percentages of the recorded post-operative sensitivity.

Subtraction	Group A ProRoot MTA	Group B Biodentine	Group C ACTIVA BioACTIVE
Baseline Vs. After 3 Months	0.22	0.11	0.19
Baseline Vs. After 6 Months	0.024*	0.004*	0.010*
Baseline Vs. After 12 Months	0.024*	0.004*	0.010*
Baseline Vs. After 18 Months	0.024*	0.004*	0.010*

Note: p≤ 0.05 (Statistically significant)

4. DISCUSSION

The conventional approach to the treatment of carious lesions is being increasingly questioned by the dental profession. The need to remove deep dentinal caries to the point of being hard and stain-free while risking pulpal exposure if the tooth has been symptom-free is no longer necessary [18].

In the treatment of vital pulp in deep carious lesions, maintaining the vitality of the dentin-pulp complex is essential. The pulp requires protection against bacterial invasion, thermal and chemical insults, and from the overlying restorative materials, therefore the bioactive materials have an important role in providing adequate closure, eliminating bacteria, and triggering remineralization [19]. Thus, three different bioactive pulp capping materials were clinically evaluated in the current study in an indirect pulp capping procedure throughout 18 months period.

The patients involved in this study were selected with good oral hygiene and free of periodontal problems, so a low rate of restoration failure was anticipated, having at least three vital teeth with deep Class I caries involvement.

Currently, caries removal was done in one visit (one-step excavation) to firm leathery dentin leaving the caries affected dentin tissue, which was maintained according to others [19] to reduce the risk of exposing the pulp.

Selective excavation technique was performed with smart rose head bur to distinguish infected from affected dentin. Thus, the limit of selective caries excavation boundaries became more pronounced to reduce the risk of bias in this study [20]. Affected dentin was left based on previous conclusions that for the remineralization of affected dentin to occur, at least 10% of the dentin minerals should remain [21], using with this method an application of bioactive material to the deep carious lesions, thus the process of remineralization was insured [19].

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Permanent rather than interim restoration was preferred to offer good marginal seal thus deprive the microorganisms from the oral cavity substrates [22]. Additionally it was reported that caries can be arrested if a well-sealed restoration, without marginal defects was present even with a slowly or rapidly progressing carious lesions [5], [18]. This was explained by the process of reparative dentin formation and tubular sclerosis which reduce the permeability of the remaining dentin, thus the remaining microorganisms are entombed by the seal of the restoration on one side and the reduced permeability of the remaining dentin on the other side [5], [8], [18].Thus taking these strong evidences into consideration, maintaining a hermetic seal of the coronal restoration was of prime importance.

Currently it was found that the amount of the formed reparative dentin was gradually increasing over time in all groups recording the highest increase value in the first 3 months after application. However a significantly lower value was recorded with ACTIVA BioACTIVE-BASE/LINER than those of ProRoot MTA and Biodentine. This coincides with the results of a similar study [23] reporting a significantly lower rate of dentin structure formation in histological sections with bioactive glass than with MTA.

Furthermore, others [24] agreed the current findings reporting a statistically significant difference in reparative dentin formation in ProRoot MTA and Biodentine groups versus ACTIVA BioACTIVE-BASE/LINER group as IPC materials in histological sections.

The highest mean increase after 3 months was recorded with the Biodentine group followed by ProRoot MTA then ACTIVA BioACTIVE-BASE/LINER. These findings could be confirmed by the histological sections of dogs' teeth in an experimental study [25] examined after using the same IPC materials, where it recorded a higher rate of dentin structure formation after 3 months (> 0.25 mm) with Biodentine than with MTA.

These were also consistent with a similar study [26] recording the highest amount of tertiary dentin deposition in the Biodentine group in comparison to MTA group in human permanent teeth after 3 and 6 months.

However the difference between ProRoot MTA versus Biodentine was not significant and this was supported by the experimental study [25] and a clinical study [27] reporting comparable clinical and radiographic success rates for both ProRoot MTA and Biodentine in human permanent molars. In addition, others [28] have reported none statistically significant difference in the reparative dentin formation with either of these materials.

Moreover, the histological findings of a similar clinical study [29] supported the current results reporting none significant difference neither in the quality nor the quantity of the formed reparative dentin structure under MTA and Biodentine IPC materials in permanent molars after 3 months period. Furthermore, another clinical study [30] reported the same efficacy of both ProRoot MTA and Biodentine for the formation of reparative dentin in permanent molars after 3 and 6 months radiographical follow up.

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Regarding the current results of the remaining dentine thickness subtractions, it was found that both Group A and B were nearly similar and both were higher than Group C at the same time period. These results coincided with those obtained by a similar clinical study [31] which recorded a mean remaining dentin thickness increase of (0.52 mm) after 6 months with ProRoot MTA application. While another clinical study [32] found that the increase in thickness was only (0.12 mm) after 3 months and (0.23 mm) after 6 months using ProRoot MTA. They reported a slower dentin tissue formation rate from baseline to 3 months with ProRoot MTA compared to other studies claiming the reason for the assessment method they utilized.

Concerning the post-operative sensitivity evaluation, VAS was used according to others [33] claiming that this scale is a more sensitive tool to measure small changes and describe pain as mild or slight, moderate, or severe to agonizing, in addition no sophisticated training is required for ordinary people to use it other than the ability to determine a score.

Currently, some patients in the three groups experienced pain with varying intensities at baseline just after the restorative procedure. These findings were supported by the analysis of a clinical study [34] which explained the post-operative sensitivity after IPC procedure to be a result of sensitization of nociceptors in the pulp by the restorative treatment procedures which result in a transient inflammatory response that is best resolved after a maximum of 3 months period.

After 3 months there was a reduction of post-operative sensitivity in all groups. Regarding ProRoot MTA, this was consistent with a clinical study [34] which evaluated post-operative sensitivity after vital pulp therapy utilizing MTA. Moreover, this post-operative sensitivity reduction was found also with Biodentine which came in agreement with a review article [9]. The reduction in post-operative sensitivity in these two groups was due to reduction in the dentin permeability immediately resulting after application of these pulp capping materials due to the precipitation of crystals within the tubules decreasing the tubule permeability and fluid movement as mentioned by an experimental study [35]. Concerning ACTIVA BioACTIVE-BASE/LINER, pain reduction can be due to the occlusion of the dentinal tubules which minimize its permeability to various stimuli as explained by the conclusions of other researches [36].

Currently, pain disappeared in all groups after 6 months which was consistent with the increased remaining dentin thickness after this time period. This improvement can be explained and supported by the conclusions of other researchers [37] reporting that vitality allows the pulp to deposit dentinal hard tissue in the form of reparative or reactionary dentin, this production of this thick mineral tissue over the pulp makes it well protected from future various stimuli decreasing the post-operative sensitivity which improves with time.

In this regard, assessment of pulp vitality is essential for evaluation of the pulpal health of teeth having deep carious lesions and for assessment of the IPC therapies at each follow up period [38], [39]. Currently, the maintained pulp vitality was checked at each

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follow up utilizing pulse oximeter according to a diagnostic study [40] which concluded that pulse oximetry is a true pulp vitality testing device which depends on the oxygen saturation measurements of the pulp to help in the diagnosis of different pulpal conditions.

5. CONCLUSIONS

Within the limitations of the current study, it could be concluded that ProRoot MTA and Biodentine pulp capping materials have comparable efficiency in vital pulp capping procedures with slight superiority of the reparative potential of Biodentine, however, ACTIVA BioACTIVE-BASE/LINER has proved reparative potential capabilities as well. Furthermore, the post-operative sensitivity after indirect pulp capping procedure in deep cavities is prevalent and finally reversible. The highest peak of sensitivity occurs within the initial 24 hours following treatment which may last to 3 months with diminishing intensity and gradually disappears within 6 months.

Moreover, Pulse oximeter is a valuable tool in determining the state of pulpal health in vital pulp therapies which can be effectively used during follow up intervals to assess the level of pulpal oxygen saturation levels.

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