Comparison among pulp capping materials in: calcium ion release, pH change, solubility and water sorption(An in vitro study)

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ABSTRACT

Background: Calcium hydroxide and calcium-silicate materials used as direct pulp capping materials. The aims of this in vitro study is to compare among these materials in, the calcium ion release and pH change in soaking water after immersion of materials' specimens in deionized water. Also Solubility and water sorption of materials' specimens measured after soaking time. Calcium-silicate materials used were Biodentine, TheraCal and MTA Plus.

Materials and methods: Four materials used in this study; Urbical lining (as control group), Biodentine, TheraCal and MTA Plus. Ten discs fabricated from each tested material, by using plastic moulds of 9 mm diameter and 1 mm thickness. Each specimen was immersed in 10 ml of deionized water and stored at 37°C using incubator for 3 hr, 24hr, 14 days and 30 days as a sequence. The amount of calcium ion (Ca^{+2}) released in soaking water was measured in each tube using atomic absorption spectrophotometer. Also pH analysis for soaking water measured by using pH meter. For solubility and water sorption measurement, the specimen (n=10) weighed with precision weighing scale before immersion in deionzed water to determine the initial Weight (W_1) and immediately after weighing immersed in 10 mL of deionized water at 37 °C for 1 week using an incubator, then removed and weighing again (W_2). The samples blotted dry using filter paper and dehydrated in an oven at 37 °C for 24 hr and weighed again (W_3). Then percentage of solubility and water sorption were determined. The obtained data were analysed using one-way **ANOVA** and **Tukey tests** at 0.05 significant levels.

Results: Statistical analysis showed highly significant differences (P<0. 05) among tested materials and in all tests (**Ca^{+2}** release, pH change, solubility and water sorption). Biodentine showed higher calcium ion released at four soaking time, with non significant difference with TheraCal and highly significant difference with MTA Plus and control group at 24 hr. immersion time; While MTA Plus showed non significant difference with control group at 24 hr. Less amount of calcium released was in control group. All tested materials induced alkalization of the soaking water that decreased with time. Means of solubility and water sorption showed that MTA Plus and biodentine had higher solubility in comparison with control group, while TheraCal showed less solubility than control group. The results of water sorption showed that less sorption percentage occurred in control group in comparison with other groups.

Conclusion: calcium-silicate materials released more **Ca^{+2}** with time than calcium hydroxide. TheraCal showed less solubility and higher water sorption in comparison with control group. Biodentine and MTA Plus showed higher solubility and water sorption in comparison with TheraCal and control group.

Keywords: calcium-silicate materials, calcium hydroxide, solubility, calcium ion and pH. **(J Bagh Coll Dentistry 2017; 29(3):9-16)**

INTRODUCTION

The procedure of pulp capping relies primarily on the ability of pulpal tissue to heal. Various factors affect this process including age, periodontal condition and stage of root formation. Procedural factors such as: size of exposure, its nature (traumatic, mechanical or carious) and microbial contamination of the site have also been described as determinants of the success of pulp capping. However, the importance of these factors has been challenged. Wide arrays of materials have been used for pulp capping, but calcium hydroxide remains the standard [(1)]. For many decades' calcium hydroxide has been the standard material for maintaining pulp vitality, used in a direct and indirect pulp capping, because it's capable of stimulating the formation of tertiary dentin by the pulp, which seals exposures by newly formed hard tissue [(2)].Nevertheless, calcium hydroxide has some drawbacks such as poor bonding to dentin, material resorption and mechanical prevent microleakage in term, because instability, so thatit does not of the porosities (tunnel defects) of the newly formed hard tissue, which may act as a portal of entry for microorganisms. These may cause secondary inflammation of the pulp tissue and thought to be responsible for failed maintenance of tooth vitality. In addition, the high pH (approximately 12.5-12.8) of calcium hydroxide suspensions causes liquefaction necrosis at the surface of the pulp tissue [(3, 4)]. The bioactivity of pulp capping agents was often associated with ability to release hydroxyl and calcium ion (Ca^{+2}) [(4)]. Hydroxyl ion (OH^-) provides an antimicrobial effect by formation alkaline media (higher pH) that create an adverse environment for bacterial survival and proliferation [(5,6)], and causes pulpal necrosis that triggers tissue repair and prompts the release of proteoglycans, metalloproteinases and growth factors from the mineralized dentine matrix. OH^- ion can signal pulpal undifferentiated cells to migrate to the injury site, proliferate and differentiate into odontoblasts like cells to secrete organic extracellular matrix and initiate mineralization [(7)]. **Ca^{+2}**ion is also necessary for

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differentiation and mineralization of pulp cells [8] by reducing capillary permeability and in turn reducing, the serum flow and the levels of inhibitory pyrophosphates that causes mineralization [9]. In addition, the eluted Ca^{+2} ion increases the proliferation of human dental pulp cells in dose dependent manner [10,11] and activates pyrophosphatase which helps to maintain dentine mineralization and the formation of a dentine bridge [12].

Bioactive materials have been used in every field of dentistry and medicine. These materials are broadly used in the field of conservative dentistry and available in different form and composition that acts directly on vital tissue inducing its healing and repair induction of various growth factors and different cells. Bioactive materials (Calcium silicate– containing materials), including Mineral Trioxide Aggregate **(MTA), Biodentine and TheraCal LC** are new material that have numerous applications, such as direct pulp capping. Interestingly, calcium hydroxide are formed during their setting reaction, which impart with antibacterial and regenerative properties. For this reason, bioactive materials and calcium hydroxide are thought to share a similar mechanism of action [13]. However, studies showed less inflammation, better dentin bridging, hydroxyl apatite formation, and minimal cytotoxicity with bioactive materials [14, 15].

Water sorption and solubility are important physical properties of pulp capping material because degradation of the cement and lining materials, leads to debonding of the restoration and recurrent decay [16]. However, most of tests are static solubility tests, unrelated to the conditions found in the oral environment and applied only to short-term solubility, while some investigators studied the solubility in dynamic state (different pH) [17,18].

The aim of this in vitro study is first to compare between calcium hydroxide and calcium-silicate containing dental materials in: calcium ion released in deionized water, solubility, water sorption and whether their pH alters with time.

MATERIALS AND METHODS

Four types of pulp capping materials **(Table 1)** used in this study (four groups), the powder / liquid ratio and mixing of the components of each material was carried according to manufacturer instructions as follow:

Control group (Calcium hydroxide group): Urbical lining consist of two pastes mixed in a 1:1 weight proportion.

MTA Plus group: Mineral Trioxide Aggregate material consist of powder and liquid, manipulated by mixing of 3 parts of powder with 1 part of liquid to obtain putty like consistency, setting time for MTA about 55 min [19].

Biodentine group: Biodentine consist of powder and liquid. The powder was mixed with 5 drops of liquid in a capsule using a triturator (YDM, HANGZHOU YIN YA new materials CO. LTD, China) for 30 seconds, setting time about 12 to 15 minutes [20].

TheraCal group: TheraCal its light curing material, in this study cured by light emitted diode LED (LATTE, China) with light intensity 700mW/cm^2. Duration of light curing about 20 seconds for each layer which should not exceed 1mm in depth [21].

Specimens' construction

Fabrication of ten disc-shaped specimens from each tested material (Table 1), by using plastic moulds of 9 mm diameter and 1 mm thickness. Preweighed dental floss was embedded in the discs during fabrication to assist in handling of the samples. For fabrication of each specimen, the mould filled with the tested material which mixed according to manufacturers' instructions, in a room with climate-controlled conditions (50±10% humidity and 23±2ºC), then the filled mould was covered with a polyester strip and a glass plate (Figure 1), maintained under pressure until complete setting of chemical set materials, while light cure TheraCal LC did not need pressure [22, 23]. After construction of specimens, each specimen immersed in separated plastic tube containing 10 ml of deionized water for 3hr, 24hr, 14 days and 30 days as a sequence. At each immersion time, the soaking water subjected to the following testing: pH analysis and testing of calcium ions released. Solubility and water sorption percentage were measured for each material after immersion time 7 days.

Testing of Solubility and Water Sorption

The American Dental Association's specification #8 (zinc phosphate cement solubility) was adopted with a few small modifications to design the methodology used in this study, the solubility tests used deionized water rather than oral fluids for immersion of specimens [4, 23]. The sample (n=10 for each tested materials) weighed with precision weighing scale (Professional Digital Table Top Scale, China) (figure1), before immersion in water to determine the initial Weight (W_1) and immediately weighing after immersed vertically by using dental floss, in 10 mL of deionized water in individually plastic tube at 37 °C for 1 week in an incubator (Memmert, Germany), then saturated sample removed and weighing again (W_2). The samples then blotted dry using filter paper, dehydrated in an oven at 37 °C for 24 hr, and weighed again (W_3). The loss of material (solubility) was obtained from the difference between the initial and the final drying mass (W_1- W_3) of each disc, discounting the mass of the dental floss. Each weight **(in µg/mm^3)** measurement was repeated three times. The percentage of solubility and water sorption were determined as follows [15, 24]:

% Solubility= $[(W_1 – W_3)/ W_3]$ 100%

%Water Sorption= $[(W_2 – W_3)/ W_3]$100%

W_1: The initial weight of sample

W_2: Sample saturated with water

W_3: The final weight of sample after dehydration

Testing of calcium ions release and pH analysis

Each disc-shaped specimen was immersed in 10 ml of deionized water and stored at 37ºC using incubator (Memmert, Germany) for 3 hr, 24hr, 14 days and 30 days.

The specimens removed from tube after tested times and amount of calcium ions released in soaking water was measured (in ppm) in each tube using atomic absorption spectrophotometer [25] (ICE 3300, Thermo Scientific, USA) and pH of each solution measured using pH meter (HANNA instruments, PH microprocessor PH meter and HI 1332 PH probe, China).

Statistical analysis was performed with **SPSS** software package (version 20.0). Data of each test collected and analyzed using analysis of variance test (One-Way ANOVA) and Tukey test to find any significance difference between the groups. Mean difference is significant at the 0.05 level.

Table (1): Types of materials used in the study, types of activation, manufacturer and batch number.

Materials	Composition	Activation	Manufacturer and Batch #
Urbical lining (Calcium hydroxide)	**Base paste:** Ester glycol salicylate, Zinc oxide, Calcium phosphate, Calcium tungstate Pigments **Catalyst paste:** Calcium hydroxide 26%, N-ethyl toluene sulphonamide, Zinc oxide, Titanium dioxide, Zinc stearate, Calcium wolframate, salicylate.	Chemical	Promedica, dental material GmbH, Domagkstra, Neumunster, Germany. Batch**#:** 2441
MTA Plus (Mineral Trioxide Aggregate**)**	**Powder:** tricalcium silicate **$(CaO)_3 \cdot SiO_2$**dicalcium silicate **$(CaO)_2 \cdot SiO_2$**tricalcium aluminate **$(CaO)_3 \cdot Al2O_3$**bismuth oxide **$Bi2O_3$,** gypsum **$CaSO_4 \cdot 2\,H_2O$** **liquid:** distilled water **H_2O**	Chemical	PPH CERKAMED company, Kwiat Kow Skiego, StalowaWola, Polska Batch **#:** 1809141
Biodentine™	**Powder:** tricalcium silicate **Ca_3SiO_5 (>70%)** dicalcium silicate **Ca_2SiO_4 (<15%)** zirconium oxide **ZrO_2 (5%)** calcium carbonate **$CaCO_3$ (>10%)** as filler Iron oxides **(<1%)** **liquid** water **H_2O**, calcium chloride **$CaCl_2$ (>15%)** as accelerator, hydro soluble polymer (polycarboxylate), water reducing agent	Chemical	Septodont, Saint Maurdes, Fosses, France. Batch**#:** B14835
TheraCal LC	**Paste:** **45%**wt mineral material (type III Portland cement), **10%**wt radiopaque component, **5%**wt hydrophilic thickening agent (fumed silica), **45%**metacrylic resin	Physical (Light)	BISCO, Irving Park Rd. Schaumburg, U.S.A. Batch **#:** 1500000915

Figure 1: Some of equipment and instruments used in this study

RESULTS

Table 2 summarizes **Ca^{+2}** ion released means and standard deviations for tested materials, the results showed that all tested materials released Ca^{+2} ion in soaking time and the released decreased with time, with the exception of biodentine at 30 days, the mount released more than at 14 days. All calcium silicate-containing materials released more Ca^{+2} ion than $Ca(OH)_2$ material (Table 2), except MTA Plus at 14 and 30 days. One Way ANOVA showed highly significant differences among the groups in alkalization effect on soaking water. All materials induced alkalization of the soaking water that decreased with time (Table 2). One Way ANOVA and Tukey test showed highly significant differences among the groups in Ca^{+2} ion released (Table 4). Higher solubility occurred in MTA Plus followed by Biodentine, Urbical and less percentage occurred with TheraCal (Table 3). The results of water sorption test, showed highly significant differences among the groups with higher percentage of sorption occurred in MTA Plus group followed by, Biodentine, TheraCal and less percentage occurred with Urbical (Table 3, 5).

DISCUSSION

The ability to release calcium and hydroxyl ions is a key factor for successful pulp capping therapy because of calcium's action on pulp cell differentiation and hard tissue mineralization [(26)]. The therapeutic effect of calcium hydroxide materials is due to its ability to break down into calcium and hydroxyl ions. Hydroxyl ion show an affinity to various biologically active substances such as microbes causes endodontic diseases **[(27)]**. Their antimicrobial activity is formation of potent alkaline medium leading to the destruction of lipids, which are the main component of bacterial cell membrane and causing structural damage to bacterial proteins and nucleic acids **[(28)]**. Chemically, calcium hydroxideis classified as a strong base with high pH. Although some studies have confirmed its efficacy against endodontic bacteria, other studies have questioned its effectiveness **[(29)]**.

In this study calcium hydroxide compared with calcium silicate materials including, MTA Plus, Biodentine and TheraCal in calcium ion release, because these materials formed calcium hydroxide during their setting reaction **[(30)]**. Mineral Trioxide Aggregate introduced by Torabinejad in 1993 **[(31)]**. It's a bioactive material has a common characteristic of apatite formation **[(19)]**. This is a material of choice for vital pulp therapy, apexification, apexogenesis, correcting procedural errors as well as for root-end filling material in apicoectomy procedures **[(13)]**. The exact mechanism of dentinal bridge formation when MTA is used is not known completely. However, it was found that when MTA was used as a pulp capping agent it induces cytologic and functional changes within pulpal cells, resulting in formation of fibro dentine and reparative dentin at the surface of mechanically exposed dental pulp, its causes proliferation, migration and differentiation of odontoblast-like cells that produce a collagen matrix. This formed mineralized matrix by osteodentin initially and then by tertiary dentin formation **[(19)]**.

Biodentine with Active Biosilicate Technology announced by dental material manufacturer Septodent in September of 2010, and made available in January of 2011. Biodentine is a calcium silicate based material having similar properties of dentin and has a positive effect on vital pulp cells stimulating tertiary dentin formation **[(32)]**, used for the treatment of root perforation or for the pulpal floor, internal and external resorption, apexification, retrograde root canal obturation, pulpotomy and also for temporary sealing of cavities and cervical filling **[(33)]**. Septodent claimed that Biodentine is not mutagenic **[(34)]** and can resist microleakage in comparison with MTA **[(35)]**.

TheraCal It is a light cured resin modified calcium silicate filled liner used for insulating and protecting dentin-pulp complex in a direct and indirect pulp capping, and as a protective base/liner under composites, amalgams, cements and other base materials **[(21)]**. TheraCal has the ability to form hydroxyl apatite when immersed in a phosphate-containing solution [(36)] with lowest cytopathic effects [(14)].In this in vitro study, calcium silicate groups showed highly significant differences in comparison with control group ($p<0.001$).

Biodentine demonstrated higher alkalinizing capability and calcium ion than other groups at all soaking time (3 h, 24 h, 14 days and 30 days), the

Ca^{+2} ions and pH of soaking waterdecrease with time and pH range from (11.06-9.17) with highly significant differences among subgroups of biodentine. These results agreed with Gandolfi M. et al., 2013[15] and Gandolfi M. et al., 2014 [37]. Tukey test revealed highly significant differences among subgroups of materials, except between control and MTA Plus groups, and between biodentine and TheraCal groups at 24 hr. immersion time, the results were non-significant differences. The high Ca^{+2} ion released of biodentine can be correlated with the presence of calcium silicate component and calcium chloride [15]. MTA Plus similar to Biodentine in composition, the results showed higher Ca^{+2}release and higher pH (11.65-8.21) in comparison with TheraCal and control group. The calcium ion release and alkalizing decrease with time. These results agreed with Gandolfi M. et al., 2013 [15] and Gandolfi M. et al., 2014 [37], but disagree with Gandolfi M.G. et al., 2012 [21] who showed that TheraCal release moreCa^{+2} ions in comparison with Dycal and ProRoot MTA. Calcium silicate materials leached large amounts of Ca^{+2} and OH^- ions (high pH) because, the hydration reaction of the calcium silicate particles triggers the dissolution of their surface with the formation of a calcium silicate hydrate gel and $Ca(OH)_2$, together with the release of Ca^{+2} and OH^- [15], which impart them with antibacterial and regenerative properties [13, 38].

Bioactive materials were used in contact with periapical bone tissue or with vital pulp. For this reason, they should possess specific bio-properties like biocompatibility, bio-interactivity (release of biologically relevant ions), and bioactivity (apatite-forming ability) in order to promote the activity of mineralizing cells and the formation of new periapical bone or reparative dentine [15].

All tested materials caused alkaline soaking water and alkalinity decreased with time. The elevated pH of calcium hydroxide and calcium silicate materials activated alkaline phosphatise which was hydrolytic enzyme that acted by liberation of inorganic phosphate from the esters of phosphate, it's important for process of mineralization [38, 39]. The best pH for activation of this enzyme ranged from (8.6 to 10.3) [40, 41]. This enzyme can separate the phosphoric esters, freeing phosphate ions, which once free react with Ca^{+2} ion from the blood stream to form a precipitate calcium phosphate in the organic matrix. This precipitate is the molecular unit of hydroxyl apatite [15]. Ion release depends on the nature of the mineral particles and on the network structure of the cement responsible for water sorption and solubility as well as the permeability of the material to water diffusion (porosity) [37]. Calcium release and pH were measuredin deionized water rather than simulated body fluid in order to standardize the test conditions and hence allow a comparison of the data with other future studies [15].

Solubility test found that calcium hydroxide had less solubility (6.45%) than Biodentine and MTA Plus, but more solubility than TheraCal, with highly significant differences among the groups. While water sorption of control group was less than other groups.Biodentine showed less solubility (13.05%) and water sorption (16.3%) in comparison with MTA Plus (solubility (19.35%) and water sorption (26.48%), correlated with the restricted amount of dispersing water-reducer super plasticizing mixing fluid likely based on polycarboxylic ether. These results in agreement with Gandolfi et al, 2014 [37], but disagree with Gandolfi etal., 2013 [15] who found that biodentine had lower watersorption than ProRoot MTA while the solubility values for ProRoot MTA lower than Biodentine. Biodentine and MTA Plus were prepared by mixing the mineral powder with water-based liquid using very different liquid/powder weight proportions for each material. The liquid susceptible to evaporation in the drying procedure needed for the solubility test to obtain the final dry mass. The hydration of calcium silicate cements proceeds by converting liquid into structural and constrained water. This process occurs mainly in the first few days, moreover the leaching of water-soluble components causes' weight loss. This means that the reduction of the original weight obtained in the dry mass will not be entirely due to the solubility of the material, because much of the weight loss is caused by evaporation of the mixing free water during the final drying of the samples. All this must be taken in consideration when collecting the data of solubility [15].It was reported in previous studies that long–time storage of dental cements in water affected the mechanical properties of the cements [42, 43]. Cattani-Lorente et al [44] found that deterioration of the physical properties of the cements after long–term storage in an aqueous environment could be related to the water absorption of these materials. Part of absorbed water acted as a plasticizer, inducing a decrease in strength. Weakening resulted from erosion and plasticizing effect of water. In the present study, TheraCal showed low solubility (3.59%) and less water sorption (11.53%) compared with the other materials, these related to the presence of a light-curable resin and the ability to release a moderate but constant amount of Ca^{+2} ions. As a conclusion of this study the reveal that, biodentine is superior to calcium hydroxide and other calcium silicate materials in Ca^{+2}ions released, while TheraCal is better insolubility and water sorption. Further studies are needed to compare the results of this in vitro study with future in vivo study.

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Table (2): Descriptive statistic for pH analysis and Calcium ions released with one-way ANOVA test among the subgroups of each group.

Groups (n=10)	Times	pH analysis Mean	S.D.	F-Test	p- value	Sig.	Calcium ions released Mean	S.D.	F-Test	p-value	Sig.
Control	3 hr.	10.25	0.18	138.246	0.000	HS	33.94	3.81	83.257	0.000	HS
	24 hr.	10.43	0.08				26.42	3.94			
	14 days	9.57	0.03				15.77	2.15			
	30 days	9.74	0.06				14.21	2.63			
Biodentine	3 hr.	11.06	0.27	97.984	0.000	HS	92.73	2.10	2218.629	0.000	HS
	24 hr.	11.63	0.25				35.19	1.47			
	14 days	9.41	0.60				28.67	1.56			
	30 days	9.17	0.30				34.03	2.71			
MTA	3 hr.	11.65	0.26	296.100	0.000	HS	46.48	2.91	609.521	0.000	HS
	24 hr.	11.42	0.16				26.23	1.22			
	14 days	8.37	0.46				11.43	1.16			
	30 days	8.21	0.403				8.82	1.12			
TheraCal	3 hr.	10.60	0.87	29.379	0.000	HS	63.28	2.57	815.388	0.000	HS
	24 hr.	8.87	0.43				36.67	2.81			
	14 days	8.67	0.33				22.91	2.10			
	30 days	7.97	0.49				17.82	1.18			

P > 0.05: Non significant (NS), P < 0. 05: Significant (S), P≤ 0.01: Highly differences (HS)

Table (3): Descriptive statistic of Solubility and Water sorption tests, and comparison among the groups using one-way ANOVA.

Groups (n=10)	Solubility test				Water sorption test			
	Descriptive statistic		Comparison		Descriptive statistic		Comparison	
	Mean	S.D.	F-Test	p- value	Mean	S.D.	F-Test	p- value
Control	6.45	0.36	966.503	0.000 HS	6.03	0.44	1922.701	0.000 HS
Biodentine	13.05	0.88			16.301	0.87		
MTA	19.35	0.93			26.48	0.38		
TheraCal	3.59	0.51			11.53	0.66		

Table (4): Tukey test and one-way ANOVA for comparison among the tested materials in calcium ions released (in ppm) at each immersion time.

Tukey test						One-way ANOVA		
Times	Comparison among the groups		Mean difference	p-value	Sig.	F-Test	p-value	Sig.
3hr	Control	Biodentine	-58.79	0.000	HS	759.147	0.000	HS
		MTA	-12.54	0.000	HS			
		TheraCal	-29.34	0.000	HS			
	Biodentine	MTA	46.25	0.000	HS			
		TheraCal	29.45	0.000	HS			
	MTA	TheraCal	-16.80	0.000	HS			
24hr	Control	Biodentine	-8.77	0.000	HS	45.944	0.000	HS
		MTA	0.19	0.998	NS			
		TheraCal	-10.25	0.000	HS			
	Biodentine	MTA	8.96	0.000	HS			
		TheraCal	-1.48	0.587	NS			
	MTA	TheraCal	-10.44	0.000	HS			
14 days	Control	Biodentine	-12.90	0.000	HS	181.010	0.000	HS
		MTA	4.34	0.000	HS			
		TheraCal	-7.14	0.000	HS			
	Biodentine	MTA	17.24	0.000	HS			
		TheraCal	5.76	0.000	HS			
	MTA	TheraCal	-11.48	0.000	HS			
30 days	Control	Biodentine	-19.82	0.000	HS	277.150	0.000	HS
		MTA	5.39	0.000	HS			
		TheraCal	-3.61	0.002	HS			
	Biodentine	MTA	25.21	0.000	HS			
		TheraCal	16.21	0.000	HS			
	MTA	TheraCal	-9.00	0.000	HS			

Table (5): Tukey test for comparison among the tested materials in Solubility and Water sorption.

Tukeytest comparison among the Groups		For solubility			For water sorption		
		Mean difference	p-value	Sig.	Mean difference	p-value	Sig.
Control	**Biodentine**	-6.59	0.000	**HS**	-10.26	0.000	**HS**
	MTA	-12.89	0.000	**HS**	-20.45	0.000	**HS**
	TheraCal	2.86	0.000	**HS**	-5.50	0.000	**HS**
Biodentine	**MTA**	-6.30	0.000	**HS**	-10.18	0.000	**HS**
	TheraCal	9.46	0.000	**HS**	4.76	0.000	**HS**
MTA	**TheraCal**	15.76	0.000	**HS**	14.95	0.000	**HS**

الخلاصة

المقدمة: قامت هذه الدراسة من اجل المقارنة بين هيدروكسيد الكالسيوم وسيليكات الكالسيوم في تحرير ايونات الكالسيوم وتغيير درجة حموضة الماء وقياس ذوبان وامتصاص الماء.

المواد والطريقة المستعملة في البحث: المواد المستعملة في هذا البحث هي: هيدوكسيد الكالسيوم (مجموعة السيطرة) , بايودنتين, ام تي اي بلاس وثريكال.عشرة عينات من كل نوع تصنع باستعمال قوالب بلاستيكية ثم تغمر في10 مل من الماء منزوع الأيونات ويتم حفظها في درجة حرارة 37 درجة سليليزية باستعمال الحاضنة لمدة 3 ساعات, 24 ساعة, 14 يوم و 30 يوم. كمية ايونات الكالسيوم المحررة في ماء الغمر تقاس باستعمال مطياف الامتصاص الذري. أيضا درجة حموضة ماء الغمر تقاس باستعمال جهاز قياس الحامضية. بعد ذلك تخضع العينات لنسبة درجة الذوبان ونسبة امتصاص الماء. تحلل البيانات الناتجة إحصائيا باستعمال اختبار تحليل التباين (ANOVA) واختبار الفرق المعنوي(Tukey test)

النتائج: أظهر التحليل الإحصائي وجود فروقا معنوية بين المواد وفي جميع الاختبارات. أظهر بايودنتين أعلى نسبة في تحرير أيونات الكالسيوم وفي جميع الأوقات. فيما اظهر اختبار حموضة الماء نقصان قلوية الماء مع الوقت. وأظهرت نتائج الذوبان وامتصاص الماء بأن البايودنتين و الام تي اي بلاس كانا أعلى ذوبان بالمقارنة مع مجموعة السيطرة، وأظهرت نتائج امتصاص الماء بان أقل نسبة امتصاص وقعت في مجموعة السيطرة بالمقارنة مع المجموعات الأخرى.

الاستنتاج : سيليكات الكالسيوم تحرر ايونات كالسيوم أكثر وتقل الكمية مع الوقت. أما بالنسبة لقلوية الماء فانها تقل مع الوقت. الثريكال لديه أقل نسبة ذوبان من بقية المواد وامتصاص اقل من مجموعة السيطرة. البايودنتين والام تي اي بلاس اظهرا أعلى نسبة ذوبان وامتصاص من الثريكال ومجموعة السيطرة.