Evaluation of calcium and hydroxyl ions release from non-setting calcium hydroxide paste and mineral trioxide aggregate during apexification procedure

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ABSTRACT

Background: Several materials had been used as intracanal dressing to stimulate hard tissue formations during apexification procedure. Recently, a single appointment technique by using mineral trioxide aggregate (MTA) has been proposed as an alternative to the multiappointment calcium hydroxide apexification. The aim of this study was to evaluate the release of calcium and hydroxyl ions from calcium hydroxide paste and MTA through three different apical aperture sizes during pexification procedure.

Materials and Methods: The root canals of sixty extracted premolar teeth were instrumented to a master apical file No. 100, 120, and 140 and filled with either calcium hydroxide paste or MTA. Calcium ions concentrations and pH values of the surrounding media were measured at days 1, 3, 7, 14, 21, and 28 of the test period.

Results: Calcium ions concentrations and pH values of $Ca(OH)_2$ were more than that of MTA at days 1, 3, and 7, then the calcium ions concentrations of MTA increased with time and became more than that of $Ca(OH)_2$ which decreased with time. Ca^{+2} and OH^{-1} release from $Ca(OH)_2$ paste and MTA increased with larger apical aperture size at all time intervals.

Conclusions: MTA maintains a continuous calcium and hydroxyl ions release for longer time than that of $Ca(OH)_2$ paste.

Keywords: Apexification, calcium hydroxide, MTA. (J Bagh Coll Dentistry 2012; 24(Sp. Issue 2):156-160).

INTRODUCTION

Apexification procedure had been historically used to establish apical closure and avoid surgery.This procedure requires the chemomechanical debridement of the canal followed by placement of an intracanal medicament to assist or stimulate apical healing and formation of an apical barrier [1].

The most common material used in exification is calcium hydroxide. Its mode of action is elieved to be dependent on its ability to release calcium ions and hydroxyl ions, which then diffuse into surrounding tissue [2, 3]. Their concentrations increase with larger apical aperture sizes [4].

Despite the clinical success of calcium hydroxide apexification technique, the length of treatment can be too difficult for the patient to maintain motivation in addition to the unpredictability of apical closure. An alternative for multiappointment calcium hydroxide procedure, a single-step technique using a new material, which is mineral trioxide aggregate (MTA), had been introduced [5].

The mechanism of action of MTA has some similarity with that of calcium hydroxide, although MTA does not have calcium hydroxide in its composition but it has calcium oxide (CaO) that could react with tissue fluid to form $Ca(OH)_2$ which dissociates into Ca^{+2} and OH^{-1} ions [6-8].

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MATERIALS AND METHODS

Sixty freshly extracted human premolars with single straight root canals and closed apices were used in this study. The crown portion of each tooth was removed at the cementoenamel junction (CEJ) of the buccal surface by using a diamond disk to permit ideal access to the root canal [9]. The working length was determined and standardized to 14 mm length.

The roots were divided into 3 groups, 20 roots for each, as follow:

Group A: 20 root canals were instrumented conventionally to the master apical file No. 100 until the tip of the master apical file extended 1mm beyond the apex to have 1mm aperture size.Group B: 20 root canals were instrumented conventionally to the master apical file No. 120 until the tip of the master apical file extended 1mm beyond the apex to have 1.2 mm aperture size.

Group C: 20 root canals were instrumented conventionally to the master apical file No. 140 until the tip of the master apical file extended 1mm beyond the apex to have 1.4 mm aperture size.

At the cervical portion of each root, a cavity of 2mm depth and 1mm floor around the circumference of the root canal was prepared to receive the cervical seal [10]. Two coats of clear nail polish were applied to the entire external root surface except the apical foramen, and allowed to dry at room temperature [11]. Each root was placed in a polyethylene vial containing 25 ml of

synthetic tissue fluid (STF) and incubated at 37°C for three days as a control period. After three days, the Ca^{+2} concentrations and pH values of the surrounding media were measured using the atomic absorption spectrophotometer (AAS) and digital pH-meter respectively [12]. The roots were taken out of the STF, the cervical seals were removed, and each group was subdivided into 2 subgroups (A1, A2), (B1, B2), and (C1, C2).

The canals of subgroups A1, B1, and C1 were packed with calcium hydroxide paste 2 mm shorter than the working length. A radiograph was taken immediately to assess the quality of the obturation and the extent of the filling material. The canals of subgroups A2, B2, and C2 were packed with 4mm apical plugs of MTA with the aid of an endodontic messing gun. Roots were radiographed to ensure that an adequate apical obturation had been performed. Gutta-percha and zinc oxide eugenol (ZOE) sealer filled the canals to the coronal ends of the apical plugs. The roots were radiographed to determine if the root canals were properly filled.

After replacing the cervical seals, the roots were kept in the same solutions in which they were immersed at the control period.

Calcium ions concentrations and pH values of the surrounding STF media were measured at days 1, 3, 7, 14, 21, and 28 of the test period.

RESULTS

$Ca(OH)_2$ subgroups (A1, B1, C1) revealed an increase in the release of calcium ions during the initial test period until they reached their maximum values followed by a decrease in Ca^{+2} release with time. Subgroups C1 showed the highest Ca^{+2} concentrations in the surrounding STF media, whereas subgroups B1 came next, and subgroups A1showed the lowest Ca^{+2} concentrations at all time intervals (Table 1).

MTA subgroups (A2, B2, C2) revealed a continuous increase in calcium ions concentrations throughout the test period until they reached their maximum values at day 28. Subgroups C2 showed the highest Ca^{+2} concentrations in the surrounding STF media, whereas subgroups B2 came next, and subgroups A2 showed the lowest Ca^{+2} concentrations at all time intervals (Table 2).

$Ca(OH)_2$ subgroups (A1,B1,C1) revealed an increase in the release of hydroxyl ions during the initial test period until they reached their maximum values at day 7 followed by a decrease in hydroxyl ions release with time. Subgroups C1 showed the highest pH values in the surrounding STF media, whereas subgroups B1 came next and subgroups A1 showed the lowest pH values at all time intervals (Table 3).

MTA subgroups (A2, B2,C2) revealed a continuous increase in pH values throughout the test period until they reached their maximum values at day 28. Subgroups C2 showed the highest pH values in the surrounding STF media, whereas subgroups B2 came next and subgroups A2 showed the lowest pH values at all time intervals (Table 4).

DISCUSSION

Aperture sizes of induced open apices canals were 1 mm, 1.2 mm, and 1.4 mm. This difference in the diameter of the apertures revealed significant increase in the surface area and circumference of the apical apertures [13].

STF was chosen to simulate the in vivo conditions in which Ca $(OH)_2$ paste and MTA were used [14].

The control period of three days concerned with the release of Ca^{+2} and OH^{-1} from roots structure after placing them in the STF solution. During this period, the maximum loss of Ca^{+2} and OH^{-1} from roots structure occurred [15].

The comparison of calcium ions release and hydroxyl ions release from $Ca(OH)_2$ paste and MTA through the canal of the same aperture size revealed that there was a delay of seven days in the release of calcium ions and hydroxyl ions from MTA as compared with $Ca(OH)_2$ paste. These results emphasize the fact that the $Ca(OH)_2$ paste dissociates directly into calcium and hydroxyl ions, whereas calcium oxide (CaO) which present within the composition of MTA reacts with tissue fluid and gives $Ca(OH)_2$ which then can dissociate into calcium and hydroxyl ions, this reaction between CaO and STF might delay the Ca^{+2} concentrations and pH values increase. After day 7, there was a continuous increase in the release of calcium ions and hydroxyl ions from MTA as compared with $Ca(OH)_2$ paste that had a decrease in its Ca^{+2} concentrations and pH values with time. This can be explained by the fact that $Ca(OH)_2$ paste undergoes disintegration over time, whereas the composition of MTA gives an idea that there are many sources of calcium ions other than CaO and a mixture of high concentrations of alkaline salts like tricalcium silicate, dicalcium silicate, tricalcium aluminate, calcium sulfate dihydrate that react with aqueous medium and then give calcium and hydroxyl ions. No previous study was done compared the calcium and hydroxyl ions release from Ca $(OH)_2$ paste and MTA through the canal of the same aperture size to compare this result with it.

Subgroups C showed the highest Ca^{+2} concentrations and pH values at all time interval followed by subgroups B, and then subgroups A. This indicates that more Ca^{+2} and OH^{-1} diffused from larger apical aperture size. This result is in agreement with Murray et al. [16] who reported that the dimension of the exposed sample surface area was an important physical constraint to Ca^{+2} and OH^{-1} release from non-setting products, whereas it was not an important physical constraint with setting products. This result is also in agreement with Robert et al. [4] who stated that Ca^{+2} and OH^{-1} diffusion depended on both the medicament and the size of the apical aperture in which their release increase with increase aperture size. This is because that the contact surface area with STF in the canal of large aperture size was greater than that in the canal of small aperture size that led to increase in Ca^{+2} and OH^{-1} release.

There were no significant differences in the pH values among $Ca(OH)_2$ subgroups or MTA subgroups during the test period. This may be attributed to the fact that the STF, in which the roots were immersed, is a buffer solution which has the ability to bind or release H^{+1} in solution, thus keeping the pH of the solution relatively constant despite the addition of considerable quantities of acid or base. Therefore, the alkalinity of $Ca(OH)_2$ paste and MTA is controlled by buffering action of tissue fluid to prevent it from being rise above the accepted biological level.

From the results of this study, it can be stated that "for apexification procedure, non-setting $Ca(OH)_2$ paste (Medical ™) is suitable for a considerable period of time regarding the aperture size and MTA (Pro Root MTA ™) is preferred to be an option to the multiple calcium hydroxide treatment because of a continuous calcium and hydroxyl ions release regardless the aperture size".

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Table 1: The differences in Ca^{+2} concentrations within and among the $Ca(OH)_2$ subgroups at all time intervals .

Sizes / Days	A1=1 mm n=10		B1=1.2 mm n=10		C1=1.4 mm n=10		F-value	P-value	Sig.
	Mean	±SD	Mean	±SD	Mean	±SD			
Control	7.56	0.041	7.59	0.032	7.54	0.025	3.630	0.083	NS
1day	7.65	0.033	7.83	0.029	8.32	0.032	11.934	0.004	HS**
3day	8.22	0.068	8.53	0.023	9.82	0.049	27.93	0.000	HS**
7day	8.84	0.044	9.52	0.027	9.66	0.035	14.56	0.000	HS**
14day	9.10	0.216	9.31	0.048	9.48	0.052	2.998	0.083	NS
21day	8.88	0.042	8.95	0.029	9.00	0.072	2.999	0.088	NS
28day	8.43	0.140	8.51	0.052	8.60	0.319	1.740	0.194	NS
P-value	0.001		0.001		0.001				
Sig.	HS**		HS**		HS**				

P>0.05 Non significant difference (NS)
****P<0.01 Highly significant difference (HS)**

Table 2: The differences in Ca^{+2} concentrations within and among MTA subgroups at all time intervals.

Sizes Days	A2=1 mm n=10		B2=1.2 mm n=10		C2=1.4mm n=10		F-value	P-value	Sig.
	Mean	±SD	Mean	±SD	Mean	±SD			
Control	7.52	0.018	7.58	0.038	7.53	0.018	1.442	0.172	NS
1day	7.60	0.035	7.63	0.022	7.64	0.029	3.000	0.083	NS
3day	8.13	0.026	8.15	0.087	8.18	0.034	1.990	0.156	NS
7day	8.36	0.034	8.38	0.026	8.41	0.035	3.002	0.083	NS
14day	9.72	0.034	9.75	0.044	9.78	0.093	2.250	0.125	NS
21day	11.80	0.279	11.84	0.042	11.89	0.052	0.740	0.487	NS
28day	14.37	0.090	14.38	0.046	14.40	0.249	0.090	0.911	NS
P-value	0.001		0.001		0.001				
Sig.	HS**		HS**		HS**				

P>0.05 Non significant difference (NS)
****P<0.01 Highly significant difference (HS)**

Table 3: The differences in pH values within and among the $Ca(OH)_2$ subgroups at all time intervals.

Sizes / Days	A1=1 mm n=10		B1=1.2 mm n=10		C1=1.4 mm n=10		F-value	P-value	Sig.
	Mean	±SD	Mean	±SD	Mean	±SD			
Control	7.35	0.005	7.36	0.005	7.36	0.005	1.170	0.324	NS
1day	7.40	0.011	7.43	0.014	7.44	0.028	3.721	0.078	NS
3day	7.48	0.007	7.58	0.020	7.70	0.015	3.800	0.099	NS
7day	7.68	0.008	7.78	0.013	7.90	0.020	3.912	0.090	NS
14day	7.65	0.043	7.72	0.020	7.81	0.029	3.879	0.090	NS
21day	7.60	0.014	7.69	0.010	7.78	0.020	3.853	0.090	NS
28day	7.59	0.004	7.65	0.017	7.73	0.024	3.834	0.090	NS
P-value	0.001		0.001		0.001				
Sig.	HS**		HS**		HS**				

P>0.05 Non significant difference (NS)
****P<0.01 Highly significant difference (HS)**

Table 4: The differences in pH values within and among the MTA subgroups at all time intervals.

Sizes / Days	A2=1 mm n=10		B2=1.2 mm n=10		C2=1.4 mm n=10		F-value	P-value	Sig.
	Mean	±SD	Mean	±SD	Mean	±SD			
Control	7.35	0.004	7.35	0.005	7.36	0.005	2.800	0.0780	NS
1day	7.40	0.008	7.41	0.018	7.42	0.073	0.250	0.7790	NS
3day	7.45	0.011	7.46	0.029	7.47	0.070	0.080	0.920 0	NS
7day	7.54	0.025	7.55	0.039	7.56	0.071	0.410	0.6650	NS
14day	7.78	0.014	7.79	0.022	7.84	0.029	3.915	0.0800	NS
21day	7.80	0.027	7.82	0.078	7.86	0.027	2.999	0.0788	NS
28day	7.93	0.033	7.96	0.020	7.98	0.010	3.990	0.0820	NS
P-value	0.001		0.001		0.001				
Sig.	HS**		HS**		HS**				

P>0.05 Non significant difference (NS)
****P<0.01 Highly significant difference (HS)**