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Effect of Various Intracanal Calcium Hydroxide Dressing Materials on pH Changes in Simulated External Root Resorption Defects

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Abstract

Objectives: To evaluate the effect of placement of different CH dressing materials in the root canals on pH changes in simulated external root resorption defects.

Methods: Seventy-five extracted single rooted teeth were decoronated to the length of 14mm. Root canals were prepared with peeso reamers. An external defect of 0.7mm depth and 1.4mm in diameter were made on the root surface, 5 mm from the apex and then assigned into 5 groups with 15 teeth in each group. Group 1: CH+distilled water, Group 2: CH paste, Group 3: Biodentine, Group 4: CH+2% chlorhexidine gel+Zinc oxide, Group 5: Distilled water. The materials were placed in the assigned groups and pH was measured with a microelectrode at 30 minutes, 24 hours, 7 days, 14 days, 21 days, 28 days and 3 months respectively.

Results: Results revealed significant differences in the pH between the groups at all time intervals ($p \leq 0.05$). Group 1 samples showed highest pH at all time intervals when compared with other groups.

Conclusions: Calcium hydroxide and distilled water group maintained high pH at different time intervals in comparison with other groups followed by Biodentine group, calcium hydroxide paste and 2% CHX gel+CH+ZnO in the descending order and the pH could not be sustained by any of the material at the end of 3 months time interval.

Keywords: biodentine, calcium hydroxide, chlorhexidine, external root resorption

Introduction

Calcium hydroxide (CH) a commonly used dental material dissociates into calcium ions (Ca^{2+}) and hydroxyl ions (OH^-) in aqueous medium. The ability of OH^- to pass across the dentinal tubules helps to prevent the activity of clastic cells on the root surface from functioning and to provide an environment that encourages the action of hard tissue repair.[1] A number of factors could affect how quickly OH^- passes from dentin like the interplay of ions and dentin, thickness of dentin, shape of dentinal tubule and properties of the solute.[2] Aqueous, viscous, and oily vehicles are different delivery methods employed to provide intracanal calcium hydroxide. Previous research has shown that the type of vehicle used affects ion diffusion.[1] Following placement of CH inside the canals, continued depletion of OH^- is possible by several pathways, including the apical region, auxiliary canals, dentinal tubules, abnormalities brought on by resorption. The depletion of OH^- has also been associated with capacity of dentin to act as a buffer for CH and its ability to dissolve organic tissue.[3] It is necessary to keep changing calcium hydroxide from canals, depending on the degree of root resorption. According to Abbott, medication can be kept inside the canals upto 1 year while replacement needs to be done in every 90 days.[4] After four weeks, the pH significantly lowers, hence Chamberlain advised replacing CH pastes more frequently. Even though this kind of therapy is commonly acknowledged, frequent alterations of CH paste pose a clinical drawback.[5] Furthermore, repeated contact with CH over time changes characteristics of dentine, leading to fracture.[6]

In previous studies it has been proposed that the use of Mineral Trioxide Aggregate (MTA) may minimize the negative effects of long-term CH therapy.[7-11] Gilles and Olivier (Septodont, Saint-Maur-des-Fossés, France) introduced Biodentine (BD), a novel calcium silicate-based substance, in 2010. Biodentine results in production of CH along with calcium silicate hydrate, when mixed and can retain pH in the canal as well on the exterior of the canal. Additionally, biodentine helps reduce the adverse effects of prolonged CH therapy.[12]

In 2014, Zinc oxide (ZnO), CH and 2% chlorhexidine (CHX) gel mixture was also suggested in treating resorption on the exterior of the root.[13] When compared to medicaments without ZnO, this medication demonstrated better radiopacity and long-term stability in the canals without getting frequent replacement. None of the research have investigated the effect of duration of this medication's high pH in the management of external root resorption.[6] Therefore, the objective of this study was to compare the effect of CH alone, Biodentine and combination of 2% CHX gel, ZnO and CH on the pH changes in simulated external root resorption defects, the present study was undertaken.

Materials and Method

Study design and ethical approval

The institutional ethics committee received the study protocol and gave its approval vide Ref. No. TMDCRC/IEC/20-21/PPD1 dated 19/02/2021.The sample size was estimated following power analysis which was more than 80% along with confidence interval of 95%. Since there are 5 groups, the total sample size estimated was 15*5=75.

A total of 115 single rooted, extracted teeth were collected from the Department of Oral and Maxillofacial Surgery. Immediately after extraction all the teeth were subjected to thorough washing to get rid of blood & the adherent tissues and debridement of surface was done with hand scaler, followed by ultrasonic scaler and rubber cup with applied slurry pumice. The samples were subsequently preserved in distilled water with 0.1 % thymol crystals were added to it at 4°C for a maximum of 7 days. Thereafter samples were stored using distilled water grade 3 ISO 3696 in a refrigerator and the distilled water was replaced weekly to limit the deterioration of samples. Single rooted human teeth with intact root extracted due to orthodontic/periodontal reasons were included. Teeth with enamel cracks, fractures or fracture lines, developmental malformations, carious lesions and/or restorations and with erosions were excluded.

A total number of 95 single rooted extracted teeth from collected specimens were distributed randomly in 5 groups. Group 1: Calcium hydroxide powder + distilled water; Group 2: Commercially available Calcium hydroxide paste; Group 3: Biodentine; Group 4: Calcium hydroxide powder+ Zinc oxide powder+ 2% Chlorhexidine gel; Group 5: Distilled water

All the teeth were decoronated at cementoenamel junction (CEJ) to equal root length of 14mm by using a diamond disk (Figure 1). An external defect of 0.7 mm in depth, diameter 1.4 mm on the buccal surface of the

root surface, 5 mm from apical end was made by using a round bur. The external cavities were washed with 3 ml of 17% ethylene diamine tetra acetic acid (EDTA) for one minute and again washed with 5ml of distilled water. Then the root canals were accessed, and pulp tissue was removed. Initially the canals were instrumented with 'k' files followed by enlargement upto peeso reamer size '3'. All the canals were irrigated with 5.25% sodium hypochlorite and rinsed with distilled water followed by drying the canals with paper points. The distribution of collected tooth specimens to respective study groups after processing is shown in Flow chart 1 as per CRIS guidelines (Checklist for Reporting *In vitro* Studies).

Group 1 (n=15): A manually prepared mixture of Calcium hydroxide powder (Prodent, Ratnagiri, Maharashtra, India) and distilled water in the ratio of 1gm:1ml was filled in all the root specimens using 18-gauge needle.

Group 2: (n=15): Commercially available calcium hydroxide pastes (Ammdent, Mohali, Punjab, India) was placed into the prepared canals.

Group 3: (n=15): Biodentine (Septodont,Saint-Maur-des-Fossés, France) was mixed as per manufacturer's instructions and inserted into the canals of prepared samples using 'k' files.

Group 4: (n=15): In this group, calcium hydroxide powder (Prodent, Ratnagiri, Maharashtra, India), 2% chlorhexidine gel (Prevest Denpro, Jammu, Jammu and Kashmir, India) and zinc oxide powder (Deepak enterprises, Mulund, Mumbai, India) were mixed in 2:1:2 ratio as described by Soares *et al.*[13] All three materials were placed on a glass slab and then mixed with mixing spatula until a creamy consistency is achieved. The mixed paste was then placed into the canals using a 'k' file.

Group 5: (n=15): Control group where the root canals were filled with distilled water.

Once materials were placed into the canals, these were evaluated radiographically for any voids (Figure 1). If voids are detected, then canals were refilled with respective material in all the groups except group 5. The surfaces of all root specimens were painted with nail varnish, leaving the external defect area. The apical and coronal ends of the root specimens were sealed with sticky wax to ensure proper placement of the materials. Nail varnish and sticky wax ensured that the OH^- can only diffuse into the medium through the external root resorption defect that has been prepared. Each root specimen was stored in separate screw capped vials which were filled with distilled water up to the root tip (Figure 2). The root specimens were attached to the inside of the lid of the vial using sticky wax. This is to ensure better handling of the specimens while measuring the pH. After measuring the pH, the root specimens were kept in the vials with distilled water and stored at 37° Celsius and regularly changed at different time intervals after pH measurements.

Measurements of pH were done using a pH meter with microelectrode (WTW Sentix, Xylem Analytics, Germany) (Figure 3). The pH of the specimens with external root defects stored in distilled water was determined at following time intervals: 30 minutes, 24 hrs, 7 days, 14 days, 21 days, 28 days and 3 months. Along with the pH meter and microelectrode, the equipment had 3 buffer solutions (pH 4.01, pH 7.00 and pH 10.01) and a potassium chloride (KCl) solution (Figure 3). Before

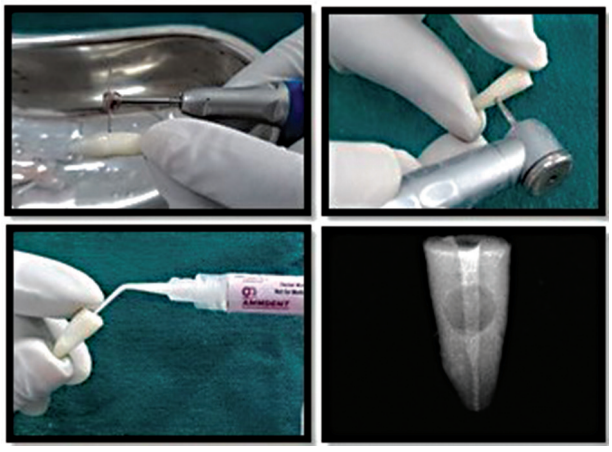
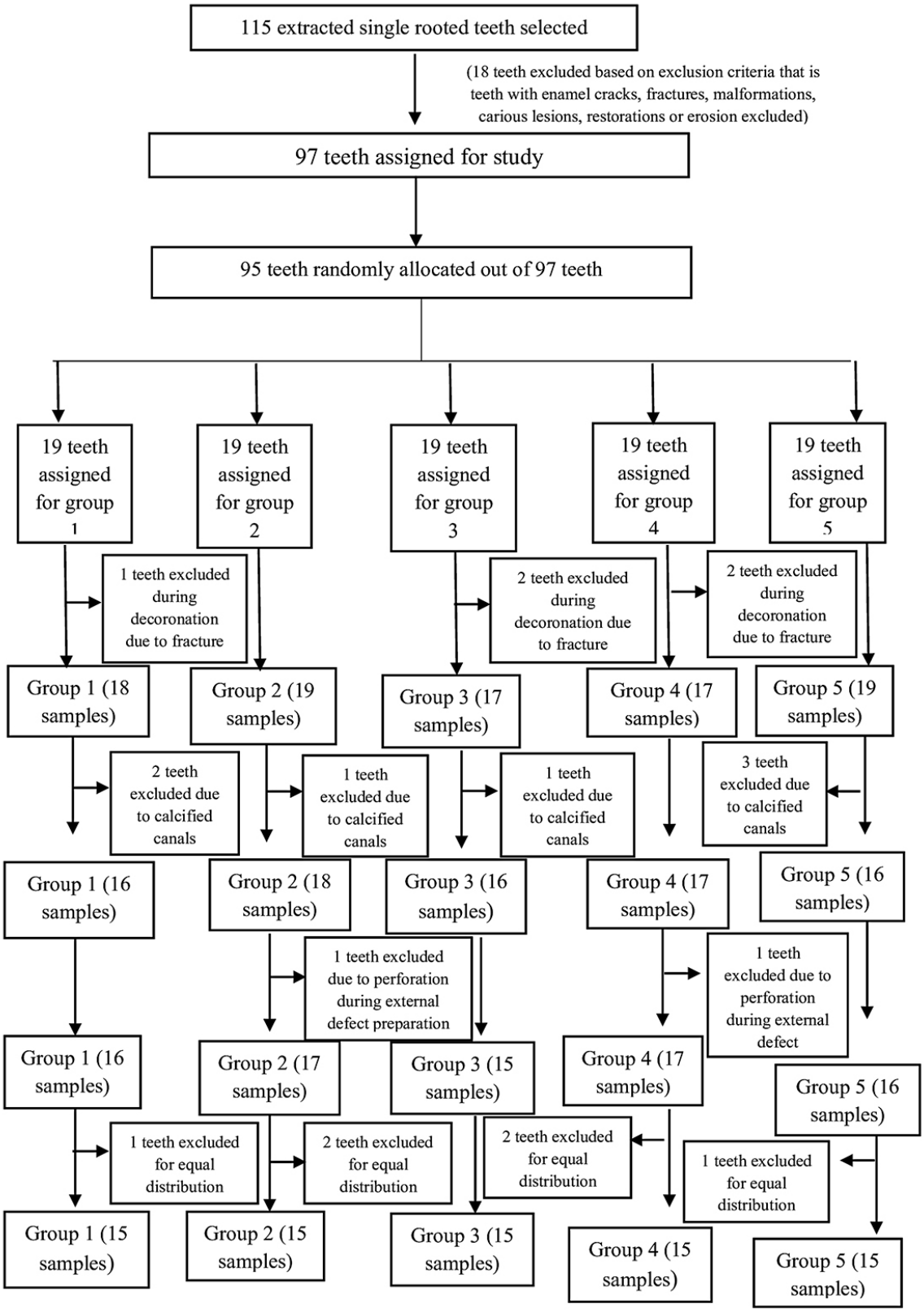


Figure 1: Preparation of samples followed by placement of CAOH based material and radiographic confirmation.

Figure 2: Prepared samples of all the 5 groups.



Flow chart 1: Distribution of processed samples according to CRIS guidelines. (Checklist for Reporting *In vitro* studies)

initiating the pH measurements of the samples, calibration of the pH electrode was done to ensure high measurement accuracy (Figure 4).

Figure 3: pH meter with microelectrode.

Figure 4: Microelectrode being rinsed with distilled water and dabbed dried with tissue paper.

For measuring the pH, the microelectrode tip was dipped at least or beyond its platinum junction in the solution/ medium to be tested (Figure 5). Therefore, the vials in which the samples were stored in distilled water were brought below the microelectrode tip and dipped until the level of the distilled water crossed the platinum junction of the microelectrode. The AR (automatic reading) display on the pH meter display will blink with automatic upward or downward adjustment of pH value until the exact pH value is displayed and blinking of AR on the pH meter stops. Then the final pH value that was displayed on the pH meter will be recorded as pH of that sample. In between each reading, the pH microelectrode washed using distilled water and was dried with the help of tissue paper. The same procedure was repeated for all the 15 samples in each group. If the level of reference electrolyte (KCL) inside the microelectrode becomes low with time, refilling was done through the opening using the KCl bottle supplied by the manufacturer. The mean of 3 readings was recorded as pH for each root specimen.

The data thus obtained was inserted in Microsoft excel 2009 spread sheet and analyzed using SPSS software version 20.0 for windows (statistical package for social sciences, IBM SPSS statistics, IBM corp., 2011). Analysis of variance was utilized to compare pH among the groups at different time intervals with post hoc Bonferroni for inter group comparison. A repeated measure ANOVA was applied to compare the pH of different time intervals within the group with post hoc Bonferroni for comparison between subsequent time intervals. The level of significance was pre-determined at $p \leq 0.05$.

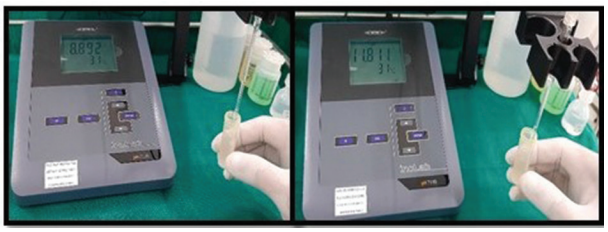


Figure 5: Evaluation of pH of samples in various groups.

Results

Table 1 shows the pH of various materials used in this study. Table 2 shows the comparison of pH levels across five groups over different time intervals using the ANOVA test. Group 1 shows a significant change in pH over time, with a consistently decreasing trend from a mean of 9.9 at 30 minutes to 7.74 at 3 months (p=0.001 for all intervals). The other groups (2-5) show minimal fluctuations in pH, with their mean values remaining relatively stable across all time intervals. Group 5 consistently maintains the lowest pH levels, ranging from 7.06 at 30 minutes to 6.55 at 3 months, while Groups 2, 3, and 4 show only minor variations. The significant p-value for Group 1 suggests a notable impact over time, while the other groups do not show statistically significant changes. This indicates that only Group 1 experienced a meaningful shift in pH, while the rest remained largely stable.

Table 3 shows the intergroup comparison of pH using post hoc Bonferroni test. Table 3 presents the inter-group comparison of pH levels using the Post hoc Bonferroni test at different time intervals. Group 1 consistently shows

Table 1: pH values of materials used in the study.

S.No.	Material	pH
1.	Distilled water (fresh)	6.124
2.	Distilled water (3 months storage)	5.701
3.	KCl solution (microelectrode under hydration)	7.583
4.	CAOH paste+ Distilled water (after mixing)	12.622
5.	CAOH paste (commercial product)	11.607
6.	Biodentine (commercial product)	12.107
7.	Chlorhexidine gel	8.112
8.	CAOH powder+ Zinc oxide powder+ CHX gel (after mixing)	12.326

Table 2: Comparison of the pH among the groups at different time intervals using ANOVA test.

Time interval	Groups	Minimum	Maximum	Mean	S.D	*p* value
30 min	Group 1	7.56	12.28	9.9	1.2	0.001*
	Group 2	7.44	8.89	8.06	0.38	
	Group 3	8.16	9.82	8.8	0.54	
	Group 4	8.14	8.89	8.4	0.2	
	Group 5	6.94	7.15	7.06	0.06	
24 hrs	Group 1	7.45	11.1	9.39	1.27	0.001*
	Group 2	6.85	10.77	8.06	0.88	
	Group 3	7.82	9.54	8.36	0.37	
	Group 4	7.94	10.46	8.45	0.62	
	Group 5	6.87	7.21	7.01	0.09	
7 days	Group 1	7.38	11.57	9.35	1.73	0.001*
	Group 2	7.56	9.51	8.07	0.46	
	Group 3	7.55	8.25	7.99	0.17	
	Group 4	7.55	8.71	8	0.33	
	Group 5	6.59	7.01	6.86	0.12	
14 days	Group 1	8.02	11.55	9.58	1.38	0.001*
	Group 2	7.96	8.69	8.24	0.23	
	Group 3	7.72	8.29	7.98	0.2	
	Group 4	7.36	8.09	7.81	0.21	
	Group 5	6.47	7.06	6.79	0.16	
21 days	Group 1	7.85	11.78	9.25	1.52	0.001*
	Group 2	7.78	8.26	8.07	0.15	
	Group 3	7.61	8.3	7.95	0.17	
	Group 4	7.11	7.95	7.48	0.26	
	Group 5	6.63	6.99	6.78	0.1	
28 days	Group 1	7.86	11.76	8.95	1.24	0.001*
	Group 2	7.05	7.4	7.21	0.12	
	Group 3	7.65	8.39	8.02	0.21	
	Group 4	7.22	8.14	7.68	0.28	
	Group 5	6.65	6.82	6.71	0.06	
3 months	Group 1	6.93	10.59	7.74	0.83	0.001*
	Group 2	6.69	7.76	7.41	0.33	
	Group 3	6.86	8.01	7.42	0.28	
	Group 4	6.02	6.97	6.65	0.31	
	Group 5	6	7.13	6.55	0.32	

*significant

significant differences (p<0.001) when compared to Groups 2, 3, 4, and 5 across all time intervals, indicating a distinct change in pH over time. The mean differences between Group 1 and other groups gradually decrease over time, reflecting a declining trend in pH for Group 1. Comparisons between Groups 2, 3, 4, and 5 mostly show non-significant differences (p>0.05), suggesting relatively stable pH levels among these groups. However, at 3 months, Group 1 vs. Groups 3 and 4 remain significantly different (p<0.001), while comparisons with Group 2 become non-significant, indicating that Group 1's pH approaches other groups over time.

Table 4 and Figure 6 represents the comparison of change in pH within the groups at different time intervals using Repeated measures ANOVA. The intra-group comparison between various time intervals was also statistically significant at p≤0.05. Calcium hydroxides mixed with distilled water showed sustain high release of hydroxyl ions at all tested time intervals when compared with other groups. Table 4 shows the comparison of pH changes within each group over different time intervals using repeated measures ANOVA. Group 1 showed a significant pH decline over time (p<0.001), starting with the highest mean pH at 30 minutes (9.90) and dropping to 7.74 at 3 months. This suggests a substantial decrease in pH over time. Group 2 maintained a relatively stable pH, with minor fluctuations from 8.06 at 30 minutes to 7.41 at 3 months. Similarly, Group 3 and Group 4 experienced gradual declines, with pH values staying close over time but showing statistically significant changes (p<0.001). Group 5 had the lowest and most stable pH values, ranging from 7.06 at 30 minutes to 6.55 at 3 months. The graph illustrates the comparative pH changes within different groups over time. Group 1 (blue line) starts with the highest pH (9.9 at 30 minutes) and shows a steady decline, reaching 7.74 at 3 months, indicating a significant drop over time. Groups 2, 3, and 4 (yellow and orange lines) show moderate declines, with pH values remaining relatively stable until around 14 days before gradually decreasing further. Group 5 (brown line) consistently maintains the lowest pH values, starting at 7.06 and dropping slightly to 6.55 at 3 months, showing the least variation among all groups. Group 3 exhibits minor fluctuations, initially increasing slightly before following a downward trend. The overall trend suggests that Group 1 experiences the most substantial pH reduction over time, while Group 5 remains the most stable. The significant differences across time intervals highlight the impact of prolonged exposure on pH levels.

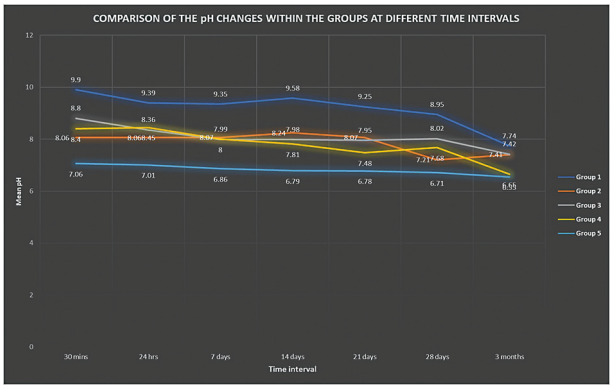


Figure 6: Graphical representation of comparative pH changes within the groups at different time interval.

Discussion

There are multiple factors that affects the tissue response to trauma but all these factors lead to clastic activity which eventually results in the resorptive mechanism.[2] Since odontoclasts need an acidic environment to dissolve minerals, the alkaline environment that is formed as a result of placement of calcium hydroxide in the root canals might inhibit their activity.[14] Previous studies have made attempts in showing the impact of calcium hydroxide in repairing periodontium and external root resorption.[2,15] It was observed that CH based materials when placed inside the canal of the specimens showed varying pH changes at all the time intervals.[16] There was a gradual decrease in the pH of group 1 at 30 mins, 24 hrs and 7 days then rise in pH was observed at 14th day followed by gradual decrease at 21 days, 28 months and 3 months. In group 2 pH showed slight increase from 8.06±0.38 to 8.07±0.46 at 7th day and 8.24 at 14th day followed by decrease in pH at 21st day, 28th day and 3 months. Group 3 showed gradual decrease in pH after 30 mins, 24 hrs, 7 days, 14 days, 21 days then a slight increase in pH at 28 days followed by decrease in pH at 3 months. Group 4 results showed increase in pH after 30 mins at 24 hrs followed by decrease in pH at 7 day, 14 day, 21 day, 28 day and 3 months. Group 5 showed decrease in pH during all the time intervals from 7.06±0.06 to 6.55±0.32 since the specimens had distilled water inside the canals. And distilled water has the tendency to gradually turn acidic with time.

Table 3: Inter group comparison of pH using Post hoc Bonferroni test.

		Group 1 V/s				Group 2 V/s			Group 3 V/s		Group 4 V/s
		Group 2	Group 3	Group 4	Group 5	Group 3	Group 4	Group 5	Group 4	Group 5	Group 5
30 min	Mean diff	1.84	1.10	1.50	2.85	-0.74	-0.34	1.01	0.40	1.75	1.35
	p value	0.001*	0.001*	0.001*	0.001*	0.017*	1.00	0.001*	0.82	0.001*	0.001*
24 hrs	Mean diff	1.33	1.03	0.94	2.38	-0.30	-0.40	1.05	-0.10	1.35	1.44
	p value	0.001*	0.001*	0.012*	0.001*	1.00	1.00	0.001*	1.00	0.001*	0.001*
7 days	Mean diff	1.28	1.36	1.34	2.49	0.08	0.06	1.21	-0.02	1.13	1.14
	p value	0.001*	0.001*	0.001*	0.001*	1.00	1.00	0.001*	1.00	0.001*	0.001*
14 days	Mean diff	1.33	1.59	1.76	2.78	0.26	0.43	1.45	0.17	1.19	1.02
	p value	0.001*	0.001*	0.001*	0.001*	1.00	0.74	0.001*	1.00	0.001*	0.001*
21 days	Mean diff	1.18	1.30	1.77	2.47	0.12	0.59	1.29	0.47	1.17	0.70
	p value	0.001*	0.001*	0.001*	0.001*	1.00	0.23	0.001*	0.69	0.001*	0.07
28 days	Mean diff	1.74	0.93	1.27	2.24	-0.81	-0.47	0.50	0.34	1.31	0.97
	p value	0.001*	0.001*	0.001*	0.001*	0.001*	0.31	0.21	1.00	0.001*	0.001*
3 months	Mean diff	0.33	0.32	1.09	1.19	-0.01	0.77	0.86	0.77	0.87	0.10
	p value	0.56	0.60	0.001*	0.001*	1.00	0.001*	0.001*	0.001*	0.001*	1.00

*significant

Table 4: Comparison of the pH changes within the groups at different time intervals using repeated measures ANOVA.

Groups	Time interval	N	Minimum	Maximum	Mean	S.D	*p* value
Group 1	30 mins	15	7.56	12.28	9.90	1.20	0.001*
	24 hrs	15	7.45	11.10	9.39	1.27	
	7 days	15	7.38	11.57	9.35	1.73	
	14 days	15	8.02	11.55	9.58	1.38	
	21 days	15	7.85	11.78	9.25	1.52	
	28 days	15	7.86	11.76	8.95	1.24	
	3 months	15	6.93	10.59	7.74	0.83	
Group 2	30 mins	15	7.44	8.89	8.06	0.38	0.001*
	24 hrs	15	6.85	10.77	8.06	0.88	
	7 days	15	7.56	9.51	8.07	0.46	
	14 days	15	7.96	8.69	8.24	0.23	
	21 days	15	7.78	8.26	8.07	0.15	
	28 days	15	7.05	7.40	7.21	0.12	
	3 months	15	6.69	7.76	7.41	0.33	
Group 3	30 mins	15	8.16	9.82	8.80	0.54	0.001*
	24 hrs	15	7.82	9.54	8.36	0.37	
	7 days	15	7.55	8.25	7.99	0.17	
	14 days	15	7.72	8.29	7.98	0.20	
	21 days	15	7.61	8.30	7.95	0.17	
	28 days	15	7.65	8.39	8.02	0.21	
	3 months	15	6.86	8.01	7.42	0.28	
Group 4	30 mins	15	8.14	8.89	8.40	0.20	0.001*
	24 hrs	15	7.94	10.46	8.45	0.62	
	7 days	15	7.55	8.71	8.00	0.33	
	14 days	15	7.36	8.09	7.81	0.21	
	21 days	15	7.11	7.95	7.48	0.26	
	28 days	15	7.22	8.14	7.68	0.28	
	3 months	15	6.02	6.97	6.65	0.31	
Group 5	30 mins	15	6.94	7.15	7.06	0.06	0.001*
	24 hrs	15	6.87	7.21	7.01	0.09	
	7 days	15	6.59	7.01	6.86	0.12	
	14 days	15	6.47	7.06	6.79	0.16	
	21 days	15	6.63	6.99	6.78	0.10	
	28 days	15	6.65	6.82	6.71	0.06	
	3 months	15	6.00	7.13	6.55	0.32	

*significant

The diffusion of OH^- into the external root resorption defect was shown in several studies.[5,17] Aguiar *et al.,* in their study demonstrated that CH within the canal increases pH of the external root surface.[18] Therapeutic effect of calcium hydroxide relies on dissociation of Ca^{2+} and OH^- and the availability of OH^- to alter the pH of medium. The pH raises as amount of OH^- increase.[19] Not only OH^- even Ca^{2+} might play an important role. But how the presence of Ca^{2+} affects the pH measurements is unknown. Hence, Ca^{2+} and OH^- dissociation and the interplay between these ions need to be addressed.

The pH level in the exterior defect on the surface was shown by Tsesis *et al.,*[20] to be inversely related to the thickness of the dentin, and difficult to control in investigations since different individuals can have different thickness of dentin.

According to Chamberlain *et al.,*[5] the pH of the experimental group increased quickly over the first 14 days compared to the control group, and then gradually decreased to the control group's average pH level at 21 and

28 days. Hence their results showed that the pH dropped after 14 days similar to the present study. Heward *et al.,*[7] also observed significantly higher pH at 4 weeks in CH group and MTA group. Soares *et al.,*[13] used a new combination of CH+ 2% CHX gel +ZnO and this paste demonstrated antimicrobial properties. Lima *et al.,*[6] in their study assessed effect of CHX in gel and liquid form and ZnO in CH paste on root pH in resorption defects and showed that despite having higher viscosity than other pastes, the combination of 2% CHX gel, CH, and ZnO allowed the diffusion of OH^- through dentin tubules and maintained alkaline pH. There are no studies available in the literature that had investigated the root dentin pH using this combination material along with other CH based materials.

The effect of intra oral temperature *in-vivo* on the dissociation curve of CH has not been explored in this study. The initial pH values of materials and the values of the solution as a result of OH^- diffusion from the external defects showed significant difference. Therefore, there is some delay of several days when rise in pH could be observed. At each time point after the pH of solution is measured, the solution was replaced to avoid the saturation of the solution. Based on the observations of this study, Group 1 showed highest alkaline pH followed by other test groups but long-term sustainability of the same needs to be further explored. The difference between the present study and the previous ones could be attributed to various compositions of dressing materials and observation for a longer time for pH measurements. This study included CH powder, CH pastes, Biodentine, CH with CHX gel and ZnO.

Further studies on the rate of dissociation of Ca^{2+} and OH^- need to be explored more extensively since this study focused only on the dissociation of OH^-, but Ca^{2+} also have a role to play. Fracture resistance of CH treated teeth/roots is another aspect that requires attention since use of CH as intracanal has a drawback of weakening the dentin structure eventually leading to tooth fracture. *In vivo* comparison of CH based materials in reimplanted cases/external root resorption cases also needs to be explored. Future histologic/biochemical studies are also required to evaluate the interaction of clastic cells involved in root resorption mechanism with Ca^{2+} and OH^-.

Conclusions

• OH^- diffuse through the dentine and potentially enabling them to reach a site of simulated resorption defect.

• Placement of different calcium hydroxide dressing materials resulted in varying pH changes on the external root surface at different time intervals.

• Calcium hydroxide and distilled water group maintained high pH at different time intervals in comparison with other groups followed by Biodentine group, CH paste and 2% CHX gel+CH+ZnO in the descending order and the pH could not be sustained by any of the material at the end of 3 months' time interval.

Declarations

Ethics approval

Institutional ethics committee gave its approval with Ref. No. TMDCRC/IEC/20-21/PPD1 dated 19/02/2021.

Competing interests

The authors declare no competing interests.

References

1. Nopnakeepongsa W, Jantarat J, Surarit R, Smutkeeree A. Assessment of root dentin pH changes in primary and permanent molars with different types of calcium hydroxide intracanal medication. Pediatr Dent J. 2019;29(1):23-9.
2. Kazemipoor M, Tabrizizadeh M, Dastani M, Hakimian R. The effect of retreatment procedure on the pH changes at the surface of root dentin using two different calcium hydroxide pastes. J Conserv Dent. 2012;15(4):346-50.
3. Andreasen J, Jensen J, Steno S, Christensen A. Relationship between calcium hydroxide pH levels in the root canals and periodontal healing after replantation of avulsed teeth. Endod Topics. 2006;14:93-101.
4. Abbott PV. Prevention and management of external inflammatory resorption following trauma to teeth. Aust Dent J. 2016;61(S1):82-94.
5. Chamberlain TM, Kirkpatrick TC, Rutledge RE. pH changes in external root surface cavities after calcium hydroxide is placed at 1, 3 and 5 mm short of the radiographic apex. Dent Traumatol. 2009;25(5):470-4.
6. Lima TFR, Ascendino JF, Cavalcante IO, D´assunção FLC, Salazar-Silva JR, Silva EJNLD, *et al*. Influence of chlorhexidine and zinc oxide in calcium hydroxide pastes on pH changes in external root surface. Braz Oral Res. 2019;33:e005. doi:10.1590/1807-3107bor-2019.vol33.0005.

7. Heward S, Sedgley CM. Effects of intracanal mineral trioxide aggregate and calcium hydroxide during four weeks on pH changes in simulated root surface resorption defects: an *in vitro* study using matched pairs of human teeth. J Endod. 2011;37(1):40-4.
8. Parirokh M, Torabinejad M. Mineral trioxide aggregate: a comprehensive literature review—part I: chemical, physical, and antibacterial properties. J Endod. 2010;36(1):16-27.
9. Sarkar NK, Caicedo R, Ritwik P, Moiseyeva R, Kawashima I. Physicochemical basis of the biologic properties of mineral trioxide aggregate. J Endod. 2005;31(2):97-100.
10. Sumer M, Muglali M, Bodrumlu E, Guvenc T. Reactions of connective tissue to amalgam, intermediate restorative material, mineral trioxide aggregate, and mineral trioxide aggregate mixed with chlorhexidine. J Endod. 2006; 32(11):1094-6.
11. Hansen SW, Marshall JG, Sedgley CM. Comparison of intracanal endosequence root repair material and ProRoot MTA to induce pH changes in simulated root resorption defects over 4 weeks in matched pairs of human teeth. J Endod. 2011;37(4):502-6.
12. Malkondu Ö, KarapinarKazandağ M, Kazazoğlu E. A review on biodentine, a contemporary dentine replacement and repair material. Biomed Res Int. 2014;160951. doi: 10.1155/2014/160951.
13. Soares AJ, Lima TF, Nagata JY, Gomes BP, Zaia AA, SouzaFilho F. Intracanal dressing paste composed by calcium hydroxide, chlorhexidine and zinc oxide for the treatment of immature and mature traumatized teeth. Braz J Oral Sci. 2014;13(1):6-11.
14. Forghani M, Mashhoor H, Rouhani A, Jafarzadeh H. Comparison of pH changes induced by calcium enriched mixture and those of calcium hydroxide in simulated root resorption defects. J Endod. 2014;40(12):2070-3.
15. Athanassiadis B, Abbott PV, Walsh LJ. The use of calcium hydroxide, antibiotics and biocides as antimicrobial medicaments in endodontics. Aust Dent J. 2007;52(1):64-82.
16. Angkasuvan V, Panichuttra A, Nawachinda M, Ratisoontorn C. Evaluation of pH and calcium ion release at the simulated external root resorption cavities of teeth obturated with bioceramic sealer. Clin Exp Dent Res. 2022;8(4):900-5.
17. Nerwich A, Figdor D, Messer HH. pH changes in root dentin over a 4-week period following root canal dressing with calcium hydroxide. J Endod. 1993;19(6):302-6.
18. Aguiar AS, Guerreiro-Tanomaru JM, Faria G, Leonardo RT, Tanomaru-Filho M. Antimicrobial activity and ph of calcium hydroxide and zinc oxide nanoparticles intracanal medication and association with chlorhexidine. J Contemp Dent Pract 2015;16(8):624-9.
19. Safavi KE, Nakayama TA. Influence of mixing vehicle on dissociation of calcium hydroxide in solution. J Endod. 2000;26(11):649-51.
20. Tsesis I, Lin S, Weiss EI, Fuss Z. Dentinal pH changes following electrophoretically activated calcium hydroxide ions in the root canal space of bovine teeth. Dent Traumatol. 2005;21(3):146-9.