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Comparative Evaluation of pH, Solubility and Interfacial Adaptation of Three Different Root Repair Materials: An in-Vitro Study

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Abstract

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Introduction

Root perforations can occur pathologically as a result of resorption and caries or iatrogenically during root canal treatment 3,4 resulting in a compromised treatment outcome and persist as a significant complication if not repaired. 5 High pH responsible for the antimicrobial action and biological activity of the material is attained due to the constant release of calcium from MTA and the formation of Ca(OH)2. The usual pH (11 to 12) of MTA materials decreases slightly with time18. The mechanism of action of MTA is to stimulate the cementoblasts to produce matrix for cementum formation and is biocompatible with the periradicular tissues thus shows a superior sealing ability when used for perforation repair19.

In vitro studies have shown antibacterial activity of MTA against M. luteus, S. aureus, E. coli, P. aeruginosa, E. faecalis, and S. sanguis20, 21. MTA displays low or nearly no solubility. The bismuth trioxide present in it is responsible for this property. Chemical analysis and x-ray diffraction have demonstrated insolubility of 18.8% in water. Although MTA forms a porous matrix characterized by internal capillaries and water channels with increased liquid/powder ratio—which can increase the porosity and the solubility further—the solubility levels of GMTA have been shown to be stable over time22.

Biodentine is easy to handle owing to its ease of manipulation and a short setting time approximately 12 minutes, has high alkaline pH and is a biocompatible material makes it a material of choice for perforation repair38,39. Biodentine is a Bio active cement with dentin like mechanical properties and stimulates tissue regeneration40 and induces mineralization which occurs in the form of osteodentine by expressing markers of odontoblasts & increases TGF-Beta1 secretion from pulpal cells enabling early mineralization

BioRoot RCS is a silicatebased root canal sealer has less toxic effects on human periodontal ligament cells than zinc oxide-eugenol sealer and induces a higher secretion of angiogenic and osteogenic growth factors.45 The strongly alkaline pH of BioRoot inhibits growth, or even kills Enterococcus faecalis responsible for root canal treatment failures49.

Studies done previously regarding the evaluation of pH, solubility and interfacial adaptation of many biomaterials, root repair materials and sealers have shown various results.

The present study was conducted to compare the pH and solubility of MTA, Biodentine and Bio Root RCS at 3 different time intervals of 24 hours, 7 days and 6 months.

Evaluation of the penetration of these materials into the dentinal tubules after repairing the externally created perforation in the inner surface of the mesial root of mandibular molars in the curvature in the middle third of the root at an interval of 24 hours, 7 days and 6 months with hanks balanced solution as

the storage medium had been conducted under confocal laser microscopy in the present study.

The chemical characterization of these materials at the interface of the externally created perforation after 24 hours, 7 days and 6 months has also been evaluated by EDX analysis.

Thus the aim of the study was To evaluate the pH and solubility of MTA, Biodentine and BioRoot RCS in deionized water using a digital pH meter previously calibrated with the solutions of known pH after 24 hours, 7 days and 6 months, To evaluate the chemical charecterisatin of MTA, Biodentine and Bio root RCS in the tooth substrate Root repair material interface after 24 hours, 7 days and 6 months under EDX and To evaluate the penetration of MTA, Biodentine and BioRoot RCS into the dentinal tubules in the interface under Confocal laser microscopy.

The null hypothesis was There will be no difference in the pH and solubility among the 3 root repair materials MTA, Biodentine and Bio Root RCS after 24 hours, 7 days and 6 months, There will be no difference in the penetration of MTA, Biodentine and Bio Root RCS in the dentinal tubules after 24 hours, 7 days and 6 months and There will be no difference in the chemical charecterization at the interface of these 3 materials after 24 hours, 7 days and 6 months.

Materials & Methods: Extracted non carious matured human mandibular molar teeth with fully formed apices with 20 to 50 degree curvature in mesial roots determined by Schneider's method were included in the study. Molars with broken crown or roots, cracks or resorptive defects and severe anatomic variations were excluded.

Preparation of Samples for pH and solubility analysis8 –

135 polypropylene moulds each of 5 mm diameter and 5 mm height were taken for the sample preparation. 15 moulds for each root repair material [total 45 moulds] were taken for 24 hours study, 15 moulds for each root repair materials [total 45 moulds] were taken for 7 days study and 15 moulds for each root repair materials[total 45 moulds] were taken for 6 months study.Different samples were used for 3 different time intervals of the study. The root repair materials were manipulated according to the manufacturer's instructions.The materials were then condensed into the moulds. The moulds containing the condensed root repair materials were then kept undisturbed in an incubator at 37o C at 100% humidity till the materials were set completely. 135 plastic vials were filled with deionized water with the help of a plastic syringe.

Deionized water was used as the medium for this experiment. After the final setting of the root repair materials, the moulds were cut open and the samples were taken out. The weight of each sample was measured thrice in a precision balance and the mean weight was taken as the INITIAL WEIGHT of each sample. The samples were then immersed inside the plastic vial containing deionized water having 1 sample in each vial. The vials were then stored in an incubator at a temperature of 37o C in 100 percent humidity. pH and solubility of each sample was measured after 24 hours, 7 days and 6 months. 15 samples of each of MTA, Biodentine and BioRoot RCS were taken out after 3 different intervals of 24 hours, 7 days and 6 month. The pH of each sample was measured thrice with a digital pH meter and the mean value was taken for each time interval. The samples were then dried with absorbent paper and were then kept in a dehumidifier till the mass was stabilized. The samples were then kept in a desiccator for further drying. The dry samples were then again weighted in a precision balance with an accuracy of up to .001 gram. Each sample was weighted thrice and the mean weight was taken as the FINAL WEIGHT of each sample after 24 hours, 7 days and 6 months. The percentage of solubility was determined by [(IM – FM1)/ IM] x 100 [IM is the initial weight of the sample and FM1 was the final weight of the sample after 24 hours, 7 days and 6 months]

For Preparation of the sample for the evaluation of the penetration of the root repair materials in the dentinal tubules

Ninety freshly extracted human mandibular molars fulfilling the inclusion and exclusion criteria were taken for the study. Thirty specimens were taken for each time interval. The molars were kept immersed in 5 % sodium hypochlorite solution for disinfection before the sample preparation.

The intraoral periapical radiographs and RVG of each sample was taken for the evaluation of the curvature of the mesial roots. The curvature or angulations of the mesial roots of the molars were determined by

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Schneider's method. -The angulations between 20-50 degrees were chosen for the experiment. An external perforation was created on the curvature in the internal surface of the mesial root of each mandibular first molar with a round tungsten carbide bur number 4.The perforation was then irrigated with 5 percent sodium hypochlorite solution followed by normal saline, dried and was repaired with root repair materials. The root repair materials were manipulated according to manufacturer's instructions. 30 perforations were repaired with MTA, 30 perforations were repaired with Biodentine and Bio Root RCS was used to repair 30 perforations. After The final setting of the root repair materials, horizontal sectioning of .5 to 1 mm thickness along the middle of the perforation of each specimen was done. The samples were then immersed in Hank's Balanced Salt Solution. Each of 10 samples repaired with MTA, 10 samples repaired with Biodentine and 10 samples repaired with Bio Root RCS were taken out from the Hank's balanced salt solution after 24 hours, 7 days and 6 months. Each specimen was then mounted on a glass slide with the help of DPX solution (Dibutylphalate Polystyrene Xylene solution). The specimens were then studied under Confocal Laser Microscopy after 24 hours, 7 days and 6 months.

For Preparation of the sample for the chemical characterization at the interface, Ninety freshly extracted human mandibular molars fulfilling the inclusion and exclusion criteria were taken for the study.

Thirty specimens were taken for each time interval. Before the sample preparation, the molars were kept immersed in 5 % sodium hypochlorite solution for disinfection. The intraoral periapical radiographs and RVG of each sample was taken for the evaluation of the curvature of the mesial roots.

The curvature or angulations of the mesial roots of the molars were determined by Schneider's method. The angulations between 20- 50 degrees were chosen for the experiment. An external perforation was created on the curvature in the internal surface of the mesial root of each mandibular first molar with a round tungsten carbide bur number 4. The perforation was then irrigated with 5 percent sodium hypochlorite solution followed by normal saline.

The perforation was then dried and was repaired with root repair materials. The root repair materials were manipulated according to the manufacturer's instructions. 30 perforations were repaired with MTA, 30 perforations were repaired with Biodentine and Bio Root RCS was used to repair 30 perforations. After The final setting of the root repair materials, the samples were immersed in Hank's Balanced

Salt Solution. Each of 10 samples repaired with MTA, 10 samples repaired with Biodentine and 10 samples repaired with Bio Root RCS were taken out from the Hank's balanced salt solution after an interval of 24 hours, 7 days and 6 months.The samples were then mounted and were kept in a dehumidifier for drying.

They were then transferred into the vacuum chamber and platinum sputtering was done on each mounted specimen. The samples were then studied under EDX machine.

Statistical Analysis: For pH and solubility analysis, Sample size estimation was done by using GPower software (version 3.0). Sample size was estimated for F test and ANOVA: Repeated measures, between factors, for 3 groups and 3 measurements, were chosen. A minimum total sample size of 45 (15 per root repair material

group), was found to be sufficient for an alpha of 0.05, power of 80%, 0.4 as effect size (assessed for difference in pH from similar articles).

Sample size estimation was done by using GPower software (version 3.0). Sample size was estimated for F test and ANOVA: Omnibus fixed one way, for 3 groups with equal sample size was chosen.Data was analysed using Statistical Package for Social Sciences (SPSS) version 21. Graphs was prepared on Microsoft Excel. Continuous data was tested for normality by using Shapiro Wilk test. If the data achieve normality, the parametric tests of significance (One way ANOVA &Repeated measures of ANOVA test) will be used for inferential statistics. The level of statistical significance was set at 0.05.

Results

Comparison of mean pH values of the three root repair materials at different time points

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Among the samples, it was shown that after 24 hours the pH is highest among MTA samples with a mean value of

10.47 (SD 0.00816), with maximum value of 10.49 and minimum value of 10.46. After 7 days also the pH is highest among the MTA samples with a mean value of 10.8(SD 0.01397), with maximum value of 10.82 and minimum value of 10.77 After 6 months the pH is highest among Bio root RCS samples with a mean value of

10.03 (SD 0.25464), with maximum value of 10.6 and minimum value of 9.54 Multiple Comparisons between the three root repair materials (Tukey HSD)

Tuckey's test reveals that, After 24 hours, statistically significant difference in pH was found between Biodentine and Bio root RCS as well as between MTA and Bio root RCS. No significant difference was found between the pH of MTA and Biodentine. After 7 days, there is statistically significant difference found between Biodentine and Bio root RCS as well as between MTA and Bio root RCS and between MTA and Biodentine. After 6 months, no statistically significant differences were found between any of the root repair materials.

Descriptives (Mean, SD) for each group at each time point (SOLUBILITY ANALYSIS)

Among the samples, after 24 hours, the %Solubility is highest among Bioroot RCS samples with a mean value of 1.814 (SD 1.9). After 7 days, % Solubility is highest among the Biodentine samples with a mean value of 3.0093 (SD 1.04907). After 6 months, the %solubility is highest among Bio root RCS samples with a mean value of 2.85233 (SD 1.145468).

Multiple Comparisons of % Solubility between the three root repair materials (Tukey HSD)

Tuckey's test reveals that, after 24 hours there no statistically significant difference found between the % solubility of any of the root repair materials. After 7 days, statistically significant difference found between Biodentine and Bio root RCS as well as between MTA and Bio root RCS and between MTA and Biodentine. After 6 months, statistically significant difference found between Biodentine and Bio root RCS as well as between MTA and Bio root RCS and between MTA and Biodentine.Hence the 1st null hypothesis rejected

Comparison of mean penetration of materials into dentinal tubule of the three root repair materials at different time points Among the samples, after 24 hours the penetration of materials in the dentinal tubules is highest among Biodentine samples with a mean value of 362.698 (SD 57.99).After 7 days the penetration of materials in the dentinal tubules is highest among the Biodentine samples with a mean value of 591.3820 (SD 114.08303).

After 6 months the penetration of materials in the dentinal tubules is highest among MTA samples with a mean value of 1015.94 (SD 59.66).

Multiple Comparisons between the three root repair materials (Tuckey's post hoc test)

Tuckey's test reveals that, after 24 hours there is statistically significant difference in the penetration of the root repair materials into the dentinal tubules between Biodentine and Bioroot RCS, between MTA and Bio root RCS and MTA and Biodentine After 7 days, it is found that, there is statistically significant difference in the penetration of the root repair materials into the dentinal tubules between Biodentine and Bioroot RCS, between MTA and Bio root RCS and MTA and Biodentine After 6 months, it is found that, there is statistically significant difference in the penetration of the root repair materials into the dentinal tubules between MTA and Biodentine. No significant difference can be found between Biodentine and Bioroot RCS, between MTA and Bio root RCS. Hence the second null hypothesis rejected

Comparison of chemical characterization in the interface (weight %) in 24hrs between three different root repair material groups

The SEM-EDX study to compare the chemical characterization of several elements among the three root repair materials (MTA, Biodentine, Bio root RCS). After 24 hours detects the presence of chemical elements such as sodium, magnesium, aluminium, silica, phosphorus, zirconium, chloride, calcium which are statistically significant. Among these chemical elements, the weight% of aluminium, sodium and chloride are highest in MTA, the weight% of calcium is the highest in Biodentine and the weight% of magnesium, silica, phosphorus and zirconium are highest in Bio root RCS in the interface.

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Comparison of chemical characterization (weight %) in 7days between different treatments

The SEM-EDX study to compare the chemical characterization of several elements among the three root repair materials (MTA, Biodentine, Bio root RCS) after 7 days detects The presence of chemical elements such as aluminium, silica, phosphorus, zirconium, chloride, calcium and barium which are statistically significant. Among these chemical elements the weight% of aluminium and chloride are highest among MTA, the weight% of phosphorus and calcium is the highest among Biodentine and the weight% of magnesium, silica, zirconium and barium are highest among Bio root RCS

Comparison of chemical characterization (weight %) in 6 months between different treatments

Among these chemical elements, the weight% of magnesium and silica are highest among MTA, the weight% of aluminium, phosphorus and calcium is the highest among Biodentine and the weight% of carbon, sodium, and zirconium are highest among Bio root RCS. Hence the 3rd null hypothesis rejected.

DISCUSSION: George Taccio de Miranda Canderio and Fabricia Campelo Correia et al (20l2)146evaluated the Radiopacity, ph, release of calcium ions and flow of a bioceramic root canal sealer. They found that the bioceramic root canal sealer or the BC Sealer showed the higher ph of 11.21 after 10 days compared to AH Plus. Claudio Poggio, Alberto Dagna, Matteo Ceci et al (2017) 99 found that, among root canal sealers such as Bio root RCS, Total fill BC Sealer, MTA Fillapex, SealapexTM, AH Plus, the BC Sealer and Sealapex exhibited highest alkaline ph values over time. A long term investigation conducted try Kent Urban, Julian Newhaus,David Donnermeyer, Edgar Schafer and Till Dammaschke (2018)147 found that, among all the materials the BioRoot RCS and the MTA Fillapex were soluble during the entire investigation period. ($p<.05$).. After 6 months. BioRoot RCS showed the highest ph of 10.3 in distilled water and ph 7.5 in phosphate buffer solution. In the current study the pH of MTA, Biodentine and BioRoot RCS in deionized water was evaluated using a digital pH meter previously calibrated with the solutions of known pH. From the results we found that, after 24 hours the pH was the highest among MTA samples with a mean value of

10.47 (SD 0.00816). After 7 days also the pH was highest among the MTA samples with a mean value of 10.8(SD 0.01397. After 6 months, the pH is highest among Bio root RCS samples with a mean value of

10.03 (SD 0.25464). However, Tuckey's test reveals that, After 24 hours there is statistically significant difference found between Biodentine and Bio root RCS as well as between MTA and Bio root RCS. No significant difference was found between the pH of MTA and Biodentine. After 7 days, there is statistically significant difference found between Biodentine and Bio root RCS as well as between MTA and Bio root RCS and between MTA and Biodentine. After 6 months, no statistically significant differences were found between any of the root repair materials. Therefore it can be said that in the long run the BioRoot RCS sample is most suitable as a root repair material considering its high pH even after a long time period of 6 months.The mean pH of MTA was 10.47 after 24 hours, after 7 days it was 10.8 and after 6 months the mean pH of MTA was 10.008. The mean pHof Biodentine was 9.91 after 24 hours, after 7 days it was 10.77and after 6 months the mean pHof Biodentine was 9.87. The mean pHof Bioroot RCS was 10.42 after 24 hours, after 7 days it was 10.57and after 6 months the mean pHof Bioroot RCS was 10.03 Here, in all the three root repair materials the pH gradually increased upto 7 days and then decreased. The pH observed after 6 months was lower than the initial pH.

Claudio Poggio, Alberto Dagna, Matteo Ceci et al (2017) 99in their study of comparing the solubility of several root canal sealers such as Bio root RCS, Total fill BC Sealer, MTA Fillapex, SealapexTM, AH Plus, EasySeal, Pulp Canal Sealer and N2 concluded that, there was a significantly higher solubility ($p<0.05$) of Bio Root RCS and Total Fill BC sealer amongst all the other materials. Kent Urban, Julian Newhaus, David Donnermeyer, Edgar Schafer and Till Dammaschke (2018) 147in their long term investigation comparing the solubility of BioRoot RCS. MTA Fillapex and AH Plus during a longer period of time found that, the BioRoot RCS and the MTA Fillapex were soluble during the entire investigation period. In our study we found that, that after 24 hours the %Solubility was highest among Bioroot RCS samples with a mean value of 1.814 (SD 1.9).After 7 days % Solubility was highest

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among the Biodentine samples with a mean value of 3.0093 (SD 1.04907). After 6 months the %solubility was highest among Bio root RCS samples with a mean value of 2.85233 (SD 1.145468).Tuckey's test revealed that, After 24 hours there was no statistically significant difference found between the % of solubility of any of the root repair materials. After 7 days, there was statistically significant difference found between Biodentine and Bio root RCS as well as between MTA and Bio root RCS and between MTA and Biodentine. After 6 months, there was statistically significant difference found between Biodentine and Bio root RCS as well as between MTA and Bio root

RCS and between MTA and Biodentine. From this we can conclude is considering the solubility MTA showed the lowest solubility among the other root repair materials. The mean %solubility of MTA was 1.31 after 24 hours, after 7 days it was 1.09 and after 6 months the mean %solubility of MTA was 1.53. The mean %solubility of Biodentine was 1.36 after 24 hours, after 7 days it was 3.01 and after 6 months the mean %solubility of Biodentine was 2.65. The mean %solubility of Bioroot RCS was 1.81 after 24 hours, after 7 days it was 2.172 and after 6 months the mean %solubility of Bioroot RCS was 2.85. Here, in case of MTA and Bioroot RCS a similar pattern is seen. The %solubility decreased up to 7 days and then it increased. The mean %solubility after 6 months in MTA and Bioroot RCS is greater than that observed after 24 hours. The %solubility of Biodentine showed a different pattern. The mean %solubility of Biodentine increased up to 7 days and then decreased to some extent after 6 months. Several studies are done to evaluate and compare the interfacial adaptation among different root canal sealer materials. Study conducted by Tushar Kanti Majumdar, Sayantan Mukherjee and Paromita Mazumdar (2021) found that, at all root regions, among others the Gutta Flow Bioseal sealer exhibited more sealer penetration and minimum interfacial adaptation whereas the Apexit Plus sealer exhibited less sealer penetration and maximum interfacial adaptation81. One such study was done by Sampath Kumar Arikatla, Uma Chalasani and Jyoti Mandavaet al for the evaluation of Interfacial Adaptation and Penetration depth of the Bioceramic Endodontic sealers (2018). They concluded that, among Bioroot RCS, MTA plus sealers and AH Plus sealer, the AH Plus showed more depth of dentinal penetration and better marginal adaptation than the Bioceramic sealers. **D. V. Patel, M. Sherriff and T. R P. Ford et al (2006)** in their study to evaluate the penetration of RealSeal Primer and Tubliseal into root canal dentinal tubules under Confocal Laser Microscope showed that the penetration of the Real Seal was higher than the tubliseal ($p< 0.05$) in each one thirds of the root canals. Sealer Penetration into Dentinal Tubules in the Presence or Absence of smear layer was a Confocal Laser Scanning Microscopic study (2014) which was performed by **Astrit Kuci, Tayfun Alacam and Ozer Yavas et al** concluded that, the MTA fillapex with cold lateral compaction technique and the AH26 with the warm vertical compaction technique offer greater tubular penetration of the sealers. **Altaf al Haddad, Noor Hayatey and Abu Kasim et al** in their study regarding The Interfacial Adaptation and Thickness of Bioceramic based Root Canal Sealers (2015) stated that, among Endosequence BC Sealer. MTA Fillapex, Sankin Apatite Root Canal Sealer and AH Plus, the AH Plus sealer showed the lowest number of gap containing regions. The bioceramic based sealers exhibited more gap containing regions when compared with AH plus.

In the present study, **after 24 hours** the penetration of materials in the dentinal tubules was the highest among Biodentine samples with a mean value of 362.698 (SD 57.99).**After 7 days** the penetration of materials in the dentinal tubules was the highest among the Biodentine samples with a mean value of 591.3820 (SD 114.08303). **After 6 months** the penetration of materials in the dentinal tubules was the highest among MTA samples with a mean value of 1015.94 (SD 59.66). Tuckey's test revealed that, **after 24 hours** there was statistically significant difference in the penetration of the root repair materials into the dentinal tubules between Biodentine and Bioroot RCS, between MTA and Bio root RCS and MTA and Biodentine. **After 7 days,** it was found that, there is statistically significant difference in the penetration of the root repair materials into the dentinal tubules between Biodentine and Bioroot RCS, between MTA and Bio root RCS and MTA and Biodentine. **After 6 months,** it is found that, there is statistically significant difference in the penetration of the root repair materials into the dentinal tubules between MTA and

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Biodentine. No significant difference was found between Biodentine and Bioroot RCS, between MTA and Bio root RCS. Therefore within the limitations of the present study, MTA showed the highest penetration into the dentinal tubules among the three root repair material even after a long period of time.

Thus, the second null hypothesis was rejected.

Chemical characterization of several root canal repair materials is evaluated using SEM-EDX analysis. M.G. Gandolfi, A. P. Parrilli and

M. Fini et al (2012) studied the Interface voids and the chemical composition at the interface w using 3d micro-CT analysis and ESEM-EDX analysis. In this study they found that, After 24 hours and 7 days, The surfaces of MTA after appeared irregular and were covered by precipitates. EDX revealed high Ca peaks and also P, Si. sulphur (S), barium (Ba), Mg, Cl and Na. After 28 days the surface of the MTA Flow was covered with thick multilayered deposit composed of agglomerates of 0.5 to 0.6 micron spherulites. Apetite deposition was detected on MTA Flow.

In our current study, the SEM-EDX study to compare the chemical characterization of several elements among the three root repair materials (MTA, Biodentine, Bio root RCS) after 24 hours detects the presence of chemical elements such as sodium, magnesium, aluminium, silica, phosphorus, zirconium, chloride, calcium which are statistically significant. Among these chemical elements the weight% of aluminium, sodium and chloride are highest among MTA, the weight% of calcium is the highest among Biodentine and the weight% of magnesium, silica, phosphorus and zirconium are highest among Bio root RCS. After 7 days, detects the presence of chemical elements such as aluminium, silica, phosphorus, zirconium, chloride, calcium and barium which are statistically significant. Among these chemical elements the weight% of aluminium and chloride are highest among MTA, the weight% of phosphorus and calcium is the highest among Biodentine and the weight% of magnesium, silica, zirconium and barium are highest among Bio root RCS. After 6 months, detects the presence of chemical elements such as carbon, sodium, magnesium, aluminium, silica, phosphorus, zirconium, and calcium which are statistically significant. For MTA we found that, the weight% of oxygen, sodium, aluminium was the highest after 24 hours which then lowers gradually. The weight% of calcium, phosphorus and platinum is the same after 7 days as in after 24 hours which then increases gradually. The weight% of magnesium, silica, phosphorus, calcium, and platinum was the highest after 6 months. In case of Biodentine, it was found that the weight% of oxygen, sodium, barium was the highest after 24 hours which then lowers gradually. The weight% of magnesium and zirconium are the highest after 7 days which then decreased gradually. The weight% of aluminium, phosphorus, chloride, and platinum was the highest after 6 months. In case of BioRoot RCS we found that, the weight% of oxygen, sodium, aluminium, and silica were the highest after 24 hours which then lowered gradually. The weight% of zirconium was the highest after 7 days which then decreased gradually. The weight% of phosphorus, chloride, and platinum was the highest after 6 months.

Conclusion

Within the limitations of the present study, considering the pH, BioRoot RCS is having the desired property whereas considering the solubility and interfacial adaptation, MTA can be considered as the best among the three materials. Thus it can be concluded that, no specific root perforation repair material can contain all the ideal desired properties. Numerous perforation repair materials and techniques have been tested over the years with varying results and the search for the ideal root repair material will go on. Hence this present study can surely contribute significantly for future research endeavours.

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pH Analysis

Descriptive statistics for each group at each time point

Within-Subjects Factors

Measure: Solubility

Root Repair Material	Dependent Variable
1	GrA
2	GrB
3	GrC

Table 1. Descriptives (Mean, SD) for each group at each time point (pH Analysis)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
GrA	1	15	10.4733	.00816	.00211	10.4688	10.4779	10.46	10.49
	2	15	9.9140	.40872	.10553	9.6877	10.1403	9.45	10.51
	3	15	10.4287	.06151	.01588	10.3946	10.4627	10.33	10.48
	Total	45	10.2720	.34678	.05170	10.1678	10.3762	9.45	10.51

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Gr B	1	15	10.8033	.01397	.00361	10.7956	10.8111	10.77	10.82
	2	15	10.7707	.01163	.00300	10.7642	10.7771	10.75	10.78
	3	15	10.5693	.02915	.00753	10.5532	10.5855	10.48	10.59
	Total	45	10.7144	.10642	.01586	10.6825	10.7464	10.48	10.82
Gr C	1	15	10.0080	.17126	.04422	9.9132	10.1028	9.72	10.23
	2	15	9.8740	.29403	.07592	9.7112	10.0368	9.22	10.26
	3	15	10.0347	.25464	.06575	9.8937	10.1757	9.54	10.60
	Total	45	9.9722	.25005	.03728	9.8971	10.0473	9.22	10.60

Table 2. Comparison of mean pH values of different root repair materials (one-way ANOVA)

		Sum of Squares	df	Mean Square	F	Sig.
Gr A	Between Groups	2.899	2	1.449	25.441	.000
	Within Groups	2.393	42	.057		
	Total	5.291	44			
Gr B	Between Groups	.482	2	.241	612.446	.000
	Within Groups	.017	42	.000		
	Total	.498	44			
Gr C	Between Groups	.222	2	.111	1.847	.170
	Within Groups	2.529	42	.060		
	Total	2.751	44			

Table 3. Descriptives (Mean, SD) for each group at each time point (solubility Analysis)

	V1	Mean	Std. Deviation	N
Gr A	1	1.3140	.36265	15
	2	1.3640	.71248	15
	3	1.8140	1.18899	15
	Total	1.4973	.83957	45
Gr B	1	1.09067	.292293	15

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	2	3.00933	1.049071	15
	3	2.17240	.583961	15
	Total	2.09080	1.056768	45
Gr C	1	1.53067	.807766	15
	2	2.65927	.972773	15
	3	2.85233	1.145468	15
	Total	2.34742	1.128568	45

Table 4. Comparison of mean solubility of different root repair materials (one-way ANOVA)

		Sum of Squares	df	Mean Square	F	Sig.
Gr A	Between Groups	2.275	2	1.137	1.662	.202
	Within Groups	28.740	42	.684		
	Total	31.015	44			
Gr B	Between Groups	27.759	2	13.880	27.269	.000
	Within Groups	21.378	42	.509		
	Total	49.137	44			
Gr C	Between Groups	15.289	2	7.645	7.879	.001
	Within Groups	40.752	42	.970		
	Total	56.041	44			

Table 5. Descriptives (Mean, SD) for each group at each time point (Penetration of materials into dentinal tubule)

	PENETRATION OF MATERIALS	Mean	Std. Deviation	N
V2	1	108.5800	12.49572	10
	2	362.6980	57.99667	10
	3	154.1850	56.91222	10
	Total	208.4877	121.47659	30
V3	1	363.8400	109.94024	10
	2	591.3820	114.08303	10

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	3	310.8300	78.46849	10
	Total	422.0173	158.18453	30
V4	1	1015.9400	59.66662	10
	2	940.1830	371.82517	10
	3	612.9438	166.25164	10
	Total	856.3556	290.21503	30

Table 6. Comparison of mean Penetration of materials into dentinal tubule w.r.t different root repair materials (one-way ANOVA)

		Sum of Squares	df	Mean Square	F	Sig.
V2	Between Groups	367111.484	2	183555.742	81.475	.000
	Within Groups	60828.819	27	2252.919		
	Total	427940.303	29			
V3	Between Groups	444316.155	2	222158.078	21.321	.000
	Within Groups	281331.882	27	10419.699		
	Total	725648.037	29			
V4	Between Groups	917435.181	2	458717.590	8.121	.002
	Within Groups	1525083.009	27	56484.556		
	Total	2442518.190	29			

Table 7.Comparison of chemical characterization (weight %) in 6 months between different treatments

Treatments Chemical	MTA	Biodentine	RCS	P-value
carbon	4.83± .26[b]	6.36± .15[b]	8.13± .73[a]	.001**
oxygen	29.0680±1.4	28.4800±3.01	29.1360±1.59	.972
sodium	.7550±.08[b]	.8500±.08[a]	1.0010±.0	.031**

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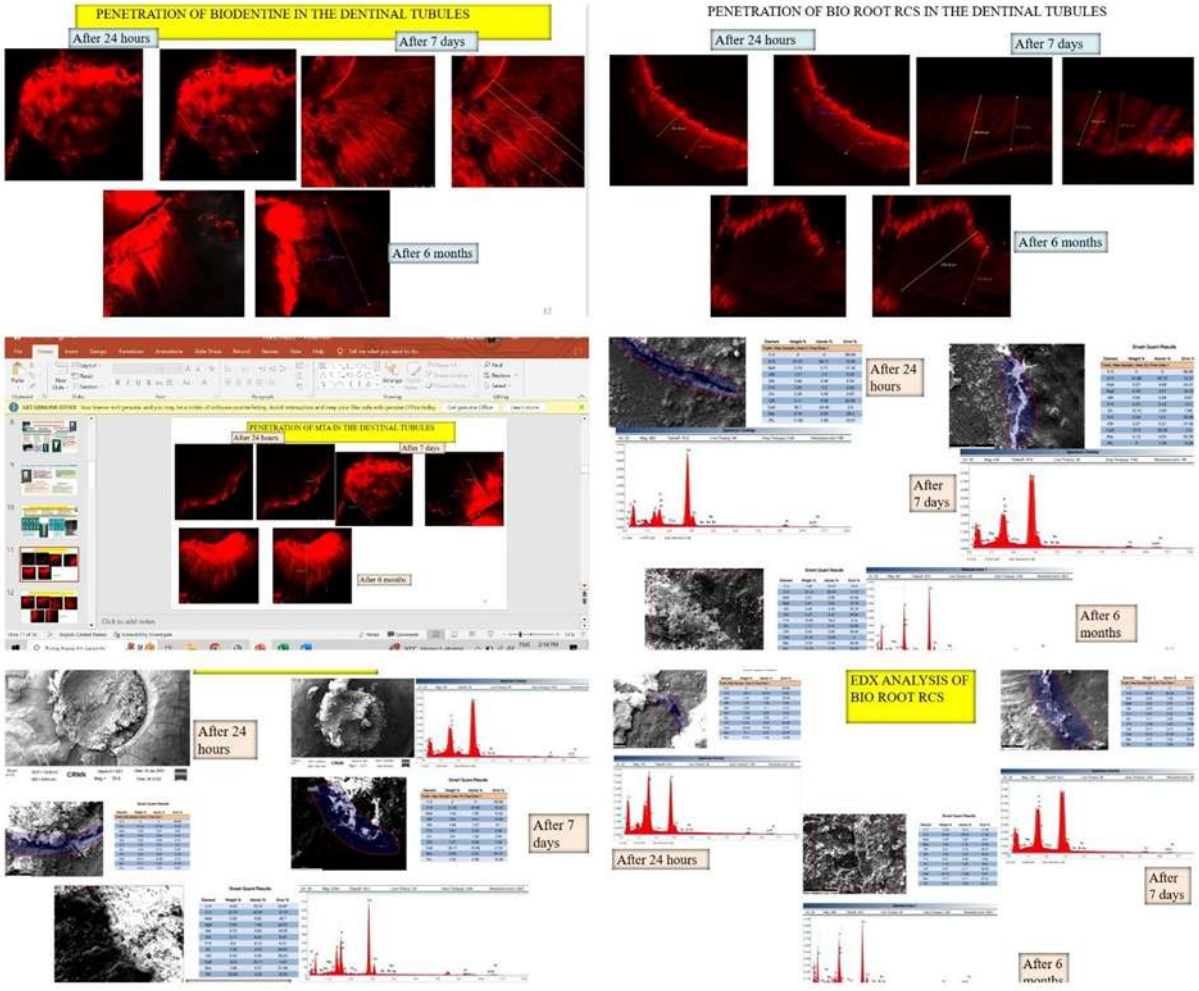
		[b]	4[a]	
magnesium	1.3850±.22[a]	.7360±.06[b]	1.0120±.09[ab]	.011
aluminium	.9190±.21[a]	2300±.02[b]	.2520±.021[b]	<.001**
silica	6.1680±1.24[a]	.6600±.19[b]	1.3±.16[b]	<.001**
phosphorus	9.3020±.77	11.0550±.83	9.8350±.57	.238
zirconium	.8610±.22[b]	1.5210±.15[ab]	1.6040±.31[a]	.041*
chloride	.5220±.08	.4770±.06	.5780±.07	.475
calcium	28.4830±1.72[b]	36.1560±1.43[a]	31.4870±.84[b]	.002**
barium	1.1300±.01	1.0020±.17	.8860±.05	.339
platinum	17.9310±1.57	17.1070±2.32	14.3730±1.03	.327



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