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Biocompatibility of White Portland cement Mixed Sodium Hypochlorite 2.2% Gel

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Abstract

Introduction: Mixing Portland cement with NaOCl improved its antibacterial activity, which may have some positive reflection on dental practice. This study was designed to evaluate the biocompatibility of white PC mixed with NaOCl 2.2% gel.

Materials and Methods: Histological analysis was performed on 22 sections dyed with Hematoxylin and Eosin stains. Studied materials were implanted in the bucco-mandibular gingival sulcus of 11 rabbits, one in each side: PC + sterile water (control), PC + NaOCl 2.2% gel (study). Scarifications were performed after 15 days (n=5), and 45 days (n=6). Finally, histological changes were compared with Chi-square accomplished by Fisher's exact test on SPSS 17. Package.

Results: PC mixed with distilled water has shown a stage 3 histological reaction after 15 days that has receded after 45 days significantly ($P<0.05$). Whereas, PC mixed with NaOCl remained a stage 3 histological reaction in the two periods of the study without any significant improvement by time ($P>0.05$).

Conclusion: Mixing white Portland cement with sodium hypochlorite 2.2% gel resulted in unstable vital tissue reaction, and must be prohibited from use.

Keywords: Biocompability, NaOCl, Portland cement, Sodium hypochlorite.

Introduction

Dental pulp system management by various approach's such as direct capping, indirect capping, pulpotomies, pulpectomies, regenerative pulp therapies, and open apex handling are some of the main reasons of patient presence to the dental office [1,2]. Through the years different tactics using a great variation of dental materials were suggested until the appearance of MTA which changed the patterns of daily practice for the best [2–5]. However, its price has suppressed many patients of low income background

from the right for normal dental remedies in modern dentistry [2,6,7].

Portland cement (PC) has been suggested as cheaper alternative in dental business [3,8–12]. MTA consists of 75% of PC in addition to bismuth oxide [13–18]. PC of various origins proved to be biocompatible and good for use in humans by several researchers [19–22].

Sodium hypochlorite (NaOCl) and is regarded as the gold antibacterial standard in dentistry [23–26]. It is used in different concentrations especially 5.25%, 2.2% and <1% to eliminate bacteria and dissolve unwanted soft tissues [26,27]. It is available in several viscosities from liquid to gel, while preserving its antimicrobial activity in all its variations [26–30].

NaOCl allows a complete setting of MTA without significant effect on its characteristics [31]. It was suggested that mixing MTA with NaOCl gel minimized its setting time, retained its mechanical properties, with a controversial cytotoxic reflection in contact to isolated tissues [32–35]. Furthermore, adding NaOCl to PC improved its antimicrobial abilities [36].

This study was designed to assess whether mixing white PC with NaOCl 2.2% gel is biocompatible in direct contact with soft tissue, prior to any clinical trials to ever be completed on humans.

Materials and Methods

Pathological study (in vivo study): that was conducted to determine the biological receptivity of fresh mixture of white PC with NaOCl 2.2% gel implanted in direct contact with vital tissues in bucco-mandibular gingival sulcus of white experimental rabbits. The study sample consisted of 22 tissue sections taken from 11 experimental animals, a material in each site. Scarifications were done after 15 days and 45 days, and histological examination were performed after staining the biopsies with Hematoxylin and Eosin (Vector Laboratories, Maravai LifeSciences, 10770 Wateridge Circle Suite).

Sodium hypochlorite (NaOCl) with white Portland cement (PC) were mixed in comparison to sterile water and PC as a control group (Table 1). They were blended in ratio of 0.4g PC to 0.12ml. of gel and 0.10ml. of liquid determined by consistency test of Vicat's Apparatus (H-3050 Vicat Consistency Apparatus/ Humboldt Mfg. Co., Illinois 60176 U.S.A.).

Inclusion criteria

1- Homogeneous mixture, the ratio of the solution to the cement is constant and within the ideal viscosity limits of the mixture.

2- New Zealand white adult experiment rabbits with a weight of not less than 1600 g.

3- Ideal surgical; conditions and sterile working tools.

4- Observance of animal rights in accordance with NIH and NENT instructions for the care of laboratory animals.

Exclusion criteria

1-Malformation of the slice taken from the rabbit.

2-The death of the animal before the expiration of the required period of custody of the transplanted materials.

After choosing the healthy white male New Zealand experiment rabbits, they were kept and looked after in special incubators, each rabbit in an incubator with adequate food and drink, cleaning the place and taking care of making the nursing conditions as suitable as possible.

The surgery was performed under deep sedation of the animal after examining the general condition of the rabbit by the veterinarian. It was sedated using 3.5 mg/kg of intramuscular Ketamine and intramuscular 5 mg/kg of Xylazine. After 10 minutes, the rabbit's condition allowed to start the surgery for about half an hour.

After the gingival fold was located on both sides of the vestibular groove of the mandible, the workplace was

disinfected with Povidone 10%, then local anesthesia was applied to the workplace with 0,5 ml of lidocaine 2% & Adrenaline 1:80000, a minor incision was made with tissue dissection to provide an entrance to transfer the studied material to it and implant it, then a stitch was performed using absorbable Vicryl 0x3 sutures using the horizontal mat technique without tightening the thread in order to allow the transfer of the studied material to the target place. Materials were transferred within a clean amalgam cannon and intensified by pressing it on the glass plate to give a cylinder with a height of 3 mm of the studied cement. The researcher planted the fresh mixture into the prepared incision and pushed it into it and then intensified it using a scaling tool, after that a suture was tied and the surgical incision was closed. The same steps mentioned above were done in the other side of the mandible and the second studied material was injected with blinding the researcher until the statistical work was done.

Then, two antibiotics, one is a wide broad spectrum and the other is against anaerobes, were injected intramuscularly to ensure absence of sepsis in the studied rabbit: Amoxicillin at a dose of 0.1 ml/kg, and Gentamicin at a dose of 0.1 ml/kg, and 0.5 ml of Ketoprofin for each rabbit for postoperative analgesia, then fluids were replaced through infusion saline solution for an hour before the animal was left to wake up and returned to its cage afterwards).

During the following days, animals were provided with the required nutrition from food and water. After 24 hours and 48 hours, an intramuscular injection was made using an insulin syringe containing 0.1 ml/kg Amoxicillin. The wound was checked and any abnormal manifestations of infection or discoloration of the gingiva and the surrounding tissues were recorded. Rabbits were divided into two groups according to the time of sacrifice chosen for each of them. To alleviate the animal's pain when sacrificed, a sedation was performed using the substances and concentrations mentioned previously in the surgical procedure. After that a tissue biopsy was taken from the connective tissue deep into the bone, dissected and stained.

Histological examination was done under a light microscope (Optical Microscope Olympus\Japan) at x10, x20, and x40 magnifications.

After determining the location of the implanted compound within the slide, and the inflammatory status in each slide, the final value was recorded according to the highest value wherever found as follows:

0= no inflammation (no signs of an inflammatory condition observed).

1= mild inflammation (scattered leukocytes).

2= moderate inflammation (a dense positioned collection of the white blood cells).

3= severe inflammation (a thick scattered collection of white blood cells).

Cases of dystrophic calcification and coagulation necrosis have been documented with there is or there is not.

Therefore, histological reactions were given one of four stages:

Stage 0: no signs of inflammation.

Stage 1: mild inflammation not associated with dystrophic calcification or coagulation necrosis

Stage 2: moderate to severe inflammation, or mild inflammation associated with dystrophic calcification.

Stage 3: inflammation associated with dystrophic calcification and coagulation necrosis.

Finally, the potential clinical applications and biocompatibility were determined by comparing the changes of inflammatory values, fibrosis and histological changes between samples of each group at both stages of the study.

Table 1: Showing the tested materials.

Material	Production
White Portland cement	Royal White Portland Cement C150 White. El Minya Cement Co./ 7 Moustafa Refaat St. – Complex 1135/ Sheraton Buildings, Cairo, Egypt.
NaOCl 2.2% gel	Clorox® Bleach Whitening Gel CX0063HU/ Broadway Oakland CA 94612, USA

Eventually, statistical analysis was performed with SPSS 17 (Statistical Package for Social Science, SPSS, version 17.0, SPSS, Chicago, IL, USA). Chi-Square accomplished by Fisher's exact test were carried out at the confidence level of 95%.

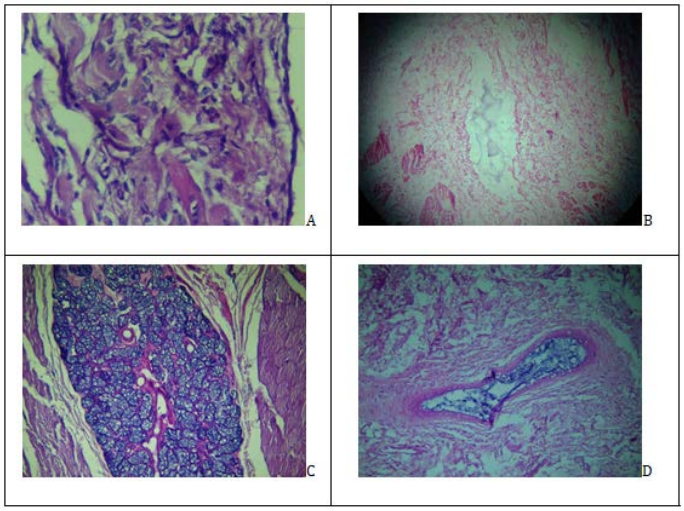

Figure 1: Shows histological Hematoxylin and Eosin stained sections of the implanted studied materials: (A) Control group mixture $_X$40, after 15 days, a moderate inflammation is seen,(B) Control group mixture $_X$10, after 45 days, a mild inflammation with dystrophic calcification is observed, (C) Studied group mixture $_X$10, after 15 days, a mild inflammation with dystrophic calcification and necrosis are obvious, (D) Studied group mixture $_X$10, after 45 days, a mild inflammation with dystrophic calcification and necrosis are seen in addition to the material remains inside the vessel.

Results:

In control group after 15 days a moderate inflammation and dystrophic calcification were observed in all five cases. In addition to four cases of coagulant necrosis. Histological reaction was of the third stage for all (Figure 1, A). After 45 days the inflammation retracted to mild one in five cases, and no inflammatory reaction was observed in the sixth case. Dystrophic calcification regressed up to 50%, and necrosis was not observed in any of them. Histological reaction ranged from stage zero up to stage three (Figure 1, B) with a significant improvement by the time ($p<0.05$) (Table 2).

In the studied mixture of PC and NaOCl 2.2% gel, after 15 days a mild inflammation was seen in three cases, the other two presented with moderate one. Dystrophic calcification and coagulant necrosis were visible in four cases. Histological reaction was of the third stage for four out of five cases (Figure 1, C). After 45 days the inflammation remained in similar pattern. While dystrophic calcification and necrosis hit all the studied cases. Histological reaction was of the third stage three for all cases (Figure 1, D). There was no significant difference between the stages of the study ($p>0.05$) (Table 2).

In comparison between the two groups at the 15th day no significance difference was observed ($p>0.05$).

After 45 days a significant difference was observed on the level of the necrosis and histological reaction ($p<0.05$), in which the studied group revealed worse results.

Table 2: Represents the counts of each group at both of studied stages for inflammatory process, dystrophic calcification, coagulant necrosis and histological reaction.

		Implanted Cement Mixture			
		PC+H2O (Control)		PC+NaOCl2.2% (Study)	
		15 days	45 days	15 days	45 days
Inflammatory Process	No inflammation	0	1	0	0
	Mild inflammation	0	5	3	4
	Moderate inflammation	5	0	2	2
	Severe inflammation	0	0	0	0
Dystrophic Calcification	Absent	0	3	1	0
	Exist	5	3	4	6
Coagulant Necrosis	Absent	1	6	1	0
	Exist	4	0	4	6
Histological reaction	Stage 0	0	1	0	0
	Stage 1	0	2	1	0
	Stage 2	0	3	0	0
	Stage 3	5	0	4	6

Discussion

Biocompatibility tests (In-Vitro, and In-Vivo) are essential in determining new materials and their modifications viability, before they can be used in practice [37] . MTA was mixed with NaOCl by several researchers resulting contradictious cytotoxic findings [33–35]. In-Vivo histological sensitivity examination was conducted in this work to respond this inconsistency.

Rabbits are rodent of choice in 3.12% of medical studies [38]. To sedate the animals and minimize the pain during surgical procedures they were exposed to Ketamin and Xylazine [39]. Then the surgical region was anesthetized by Lidocaine 2% to insure a comfortable operation. Materials were implanted in the bucco-mandibular gingival sulcus of the rabbit as long as this region is similar to the periapical one, easy to recognize and take a biopsy of [40,41].

Scarifications were accomplished after two weeks when the inflammatory process is still in progress, so it can be compared to the later results of implantations [42]. Whereas, after 45 days is the needed period for both the blood flow returning to its norm and the inflammatory process raced [43].

Hematoxylin and Eosin are stains of choice to determine inflammatory process, Dystrophic calcification and Coagulant necrosis [41,42].

It appears that adding NaOCl improves an antibacterial characteristics of PC [36]. In addition to reducing setting time of MTA, without affecting its physical properties [32,33].

In this study the histological reaction of PC mixed with distilled water regressed by time, which indicates that vital tissues recovered and regenerated [44], returning to normal stages and suggesting a biocompatible reaction similar to calcium hydroxide [42]. In contrary to the mixture with NaOCl 2.2% gel, which had worsened by the study period leading to irreversible reaction that cannot be used in contact with vital tissues [42].

AlAnezi et al. studied the harden mixture of MTA and NaOCl 3% gel in contact with the osteoblasts and fibroblasts of rat tissues, and observed actin growth in addition to nucleus survival around the mixture similar to the traditional one. But suggested further studies In-Vivo before using it in daily practice [33]. As long as it was set not fresh, which contrasts the vivid situation in contact with body tissues, this was solved in this work.

Similarly, Jafarnia et al. revealed that vitality of this mixture in both cases set and fresh could be accepted. They suggested that recovery occurs by time [34]. Here the results diverged when it was implanted in vital tissues. Which might be assigned to the possible high Alkalinity of the mixture, that in its role might inhibit calcium ions release preventing normal healing of the body [45].

Whereas, Karygianni et al. studied the mixture in contact with isolated human osteoblast tissue and detected an inhibition in its growth. They disclosed that it was related with high concentrations of Metalloprotine 1 &3 leading to irritation and inflammation by the chloramine. Later the healing was repressed by low concentrations of Interleukin 6 [35]. The results of this study has fallen in with Karygianni, and both of those works suggested the elimination of mixing NaOCl with calcium silicate materials.

After all, mixing NaOCl 2.2% with white PC resulted in irreversible reaction and must be excluded from use, even though it has a high antibacterial activity.

Conclusion

Mixing white Portland cement with sodium hypochlorite 2.2% gel resulted in unstable vital tissue reaction, and must be prohibited from use in the studied concentrations and higher. However, the antibacterial activity of the mixture may suggest further In-Vitro studies in lower concentrations of the mixture in the future.

References

1 John MT, Sekulić S, Bekes K et al. Why Patients Visit Dentists – A Study in all World Health Organization Regions. J Evid Based Dent Pract 2020; 20. doi:10.1016/j.jebdp.2020.101459.

2 Torabinejad M, Parirokh M, Dummer PMH. Mineral trioxide aggregate and other bioactive endodontic cements: an updated overview – part II: other clinical applications and complications. Int. Endod. J. 2018; 51: 284–317.

3 Petel R, Ziskind K, Bernfeld N, Suliman H, Fuks AB, Moskovitz M. A randomised controlled clinical trial comparing pure Portland cement and formocresol pulpotomies followed from 2 to 4 years. Eur Arch Paediatr Dent 2021; 22: 547–552.

4 Stringhini Junior E, dos Santos MGC, Oliveira LB, Mercadé M. MTA and biodentine for primary teeth pulpotomy: a systematic review and meta-analysis of clinical trials. Clin Oral Investig 2019; 23: 1967–1976.

5 Torabinejad M, Hong CU, McDonald F, Pitt Ford TR. Physical and chemical properties of a new

root-end filling material. J Endod 1995; 21: 349–353.

6 Islam I, Kheng Chng H, Jin Yap AU. Comparison of the physical and mechanical properties of MTA and portland cement. J Endod 2006; 32: 193–197.

7 Wiltbank KB, Schwartz SA, Schindler WG. Effect of Selected Accelerants on the Physical Properties of Mineral Trioxide Aggregate and Portland Cement. J Endod 2007; 33: 1235–1238.

8 Reddy N V, Srujana P, Daneswari V, Konyala HR, Mareddy AR. Sealing Ability of MTA vs Portland Cement in the Repair of Furcal Perforations of Primary Molars : A Dye Extraction Leakage Model — An In Vitro Study. 2019; : 0–4.

9 da Silva SR, da Silva Neto JD, Veiga DF, Schnaider TB, Ferreira LM. Portland cement versus MTA as a root-end filling material. A pilot study. Acta Cir Bras 2015; 30: 160–4.

10 Sakai VT, Moretti ABS, Oliveira TM et al. Pulpotomy of human primary molars with MTA and Portland cement: A randomised controlled trial. Br Dent J 2009; 207. doi:10.1038/sj.bdj.2009.665.

11 Brito-Jùnior M, Barbosa de Sá MA, Mota Nobre SA et al. Polymicrobial leakage and retention of MTA and portland cement in a model of apexification. Pesqui Bras Odontopediatria Clin Integr 2019; 19. doi:10.4034/PBOCI.2019.191.108.

12 Rahimi S, Salarinasab S, Ghasemi N et al. In vitro induction of odontogenic activity of human dental pulp stem cells by white Portland cement enriched with zirconium oxide and zinc oxide components. J Dent Res Dent Clin Dent Prospects 2019; 13: 3–10.

13 Tenório de Franca TR, da Silva RJ, Sedycias de Queiroz M, Aguiar CM. Arsenic content in Portland cement: a literature review. Indian J Dent Res 2010; 21: 591–5.

14 Camilleri J, Montesin FE, Di Silvio L, Pitt Ford TR. The chemical constitution and biocompatibility of accelerated Portland cement for endodontic use. Int Endod J 2005; 38: 834–842.

15 Nurdin D, Primathena I, Adang RAF, Cahyanto A. Comparison of chemical composition between indonesian white portland cement and MTA as dental pulp capping material. In: Key Engineering Materials. 2019, pp 34–39.

16 Shanta KN, Bashar AKM, Hossain M, Sheikh MAH, Alim A, Moral AA. Clinical and radiographic efficacy of portland cement as pulpotomy material in human primary molar. Bangladesh Med Res Counc Bull 2017; 43: 71–76.

17 Altan H, Tosun G. The setting mechanism of mineral trioxide aggregate. J Istanbul Univ Fac Dent 2016; 50: 65–72.

18 Nashaat yousra, Roshdy N. Comparative Evaluation of the Push-out bond strength of Nano-formulations of MTA and Portland cement. Egypt Dent J 2020; 66: 2807–2814.

19 Mangala MG, Chandra SMS, Bhavle RM. To evaluate the biocompatibility of the Indian Portland cement with potential for use in dentistry: An animal study. J Conserv Dent 2015; 18: 440–4.

20 Qutieshat AS, Al-Hiyasat AS, Darmani H. Biocompatibility evaluation of Jordanian Portland cement for potential future dental application. J Conserv Dent 2019; 22: 249–254.

21 Mohammed A, Saleh R, Taiema D, Abdel-Hady A-N, Metwally A. In Vivo Biocompatibility of β

Tri-calicum Phosphate Versus White Portland Cement in Mandibular Bone Surgical Defect in Dogs. Egypt Dent J 2019; 65: 3475–3485.

22 Primathena I, Nurdin D, Farah Adang RA, Cahyanto A. Composition and functional groups evaluation of Indonesian Grey Portland cement as material for dental application. Key Eng Mater 2018; 782: 256–261.

23 Plutzer B, Zilm P, Ratnayake J, Cathro P. Comparative efficacy of endodontic medicaments and sodium hypochlorite against Enterococcus faecalis biofilms. Aust Dent J 2018; 63: 208–216.

24 Roshdy NN, Kataia EM, Helmy NA. Assessment of antibacterial activity of 2.5% NaOCl, chitosan nano-particles against Enterococcus faecalis contaminating root canals with and without diode laser irradiation: an in vitro study. Acta Odontol Scand 2019; 77: 39–43.

25 Prada I, Micó-Muñoz P, Giner-Lluesma T, Micó-Martínez P, Muwaquet-Rodríguez S, Albero-Monteagudo A. Update of the therapeutic planning of irrigation and intracanal medication in root canal treatment. A literature review. J. Clin. Exp. Dent. 2019; 11: e185–e193.

26 El Sayed M, Ghanerad N, Rahimi F, Shabanpoor M, Shabanpour Z. Antibacterial Activity of Sodium Hypochlorite Gel versus Different Types of Root Canal Medicaments Using Agar Diffusion Test: An in Vitro Comparative Study. Int J Dent 2020; 2020. doi:10.1155/2020/6483026.

27 Abu Hasna A, Pereira Da Silva L, Pelegrini FC, Ferreira CLR, de Oliveira LD, Carvalho CAT. Effect of sodium hypochlorite solution and gel with/without passive ultrasonic irrigation on Enterococcus faecalis, Escherichia coli and their endotoxins. F1000Research 2020; 9. doi:10.12688/f1000research.24721.1.

28 Zand V, Lotfi M, Soroush MH, Abdollahi AA, Sadeghi M, Mojadadi A. Antibacterial Efficacy of Different Concentrations of Sodium Hypochlorite Gel and Solution on Enterococcus faecalis Biofilm. IEJ Iran Endod J 2016; 11: 315–319.

29 Al Nesser SF, Bshara NG, Adıgüzel Ö. Antibacterial effect of sodium hypochlorite gel on Enterococcus faecalis in endodontics: A systematic review. Int Dent Res 2020; 10: 22–29.

30 Alkhouli MM, Al Nesser SF, Bshara NG, AlMidani AN, Comisi JC. Comparing the efficacies of two chemo-mechanical caries removal agents (2.25% sodium hypochlorite gel and brix 3000), in caries removal and patient cooperation: A randomized controlled clinical trial. J Dent 2020; 93. doi:10.1016/j.jdent.2020.103280.

31 Neelakantan P, Berger T, Primus C, Shemesh H, Wesselink PR. Acidic and alkaline chemicals' influence on a tricalcium silicate-based dental biomaterial. J Biomed Mater Res - Part B Appl Biomater 2019; 107: 377–387.

32 Kogan P, He J, Glickman GN, Watanabe I. The Effects of Various Additives on Setting Properties of MTA. J Endod 2006; 32: 569–572.

33 AlAnezi AZ, Zhu Q, Wang YH, Safavi KE, Jiang J. Effect of selected accelerants on setting time and biocompatibility of mineral trioxide aggregate (MTA). Oral Surgery, Oral Med Oral Pathol Oral Radiol Endodontology 2011; 111: 122–127.

34 Jafarnia B, Jiang J, He J, Wang YH, Safavi KE, Zhu Q. Evaluation of cytotoxicity of MTA employing various additives. Oral Surgery, Oral Med Oral Pathol Oral Radiol Endodontology 2009; 107: 739–744.

35 Karygianni L, Proksch S, Schneider S et al. The effects of various mixing solutions on the biocompatibility of mineral trioxide aggregate. Int Endod J 2016; 49: 561–573.

36 Al Kurdi S, Bshara N, Khalouf K. Evaluating the Antibacterial Activity of White Portland Cement Mixed with various sorts of Sodium Hypochlorite.,. IJDSIR 2021; 4: 323– 329.

37 Schmalz G. The biocompatibility of non-amalgam dental filling materials. Eur J Oral Sci 1998; 106: 696–706.

38 European Commission. Report from the commission to the council and the European Parliament on the implementation of Council Directive 91/676/EEC. Eur Comm 2018; : 14.

39 Saidon J, He J, Zhu Q, Safavi K, Spångberg LSW. Cell and tissue reactions to mineral trioxide aggregate and Portland cement. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003; 95: 483–489.

40 Abdul Kareem AM, Al-Hashimi W. The biocompatibility and antibacterial action of three endodontic sealers. J Coll Dent 2005; 17: 18–23.

41 Semenoff TADV, Semenoff Segundo A, De Figueiredo JAP. Biocompatibility of different intracanal medications in rat buccal submucosa tissue. J Appl Oral Sci 2008; 16: 12–17.

42 Moretton TR, Brown CE, Legan JJ, Kafrawy AH. Tissue reactions after subcutaneous and intraosseous implantation of mineral trioxide aggregate and ethoxybenzoic acid cement. J Biomed Mater Res 2000; 52: 528–533.

43 Masuda YM, Wang X, Hossain M et al. Evaluation of biocompatibility of mineral trioxide aggregate with an improved rabbit ear chamber. J Oral Rehabil 2005; 32: 145–150.

44 de Oliveira MG, Xavier CB, Demarco FF, Pinheiro ALB, Costa AT, Pozza DH. Comparative chemical study of MTA and Portland cements. Braz Dent J 2007; 18: 3–7.

45 Rajasekharan S, Vercruysse C, Martens L, Verbeeck R. Effect of Exposed Surface Area Volume and Environmental pH on the Calcium Ion Release of Three Commercially Available Tricalcium Silicate Based Dental Cements. Materials (Basel) 2018; 11: 1–14.