Improvement of handling characteristics in modified MTA by the addition of spherical silicon dioxide and zirconium oxide particles.

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【Introduction】

Mineral trioxide aggregate (MTA) is a calcium silicate-based endodontic material that has been developed by modification of Portland cement. MTA has a suitable sealing ability, antimicrobial activity, and favorable biocompatibility. MTA was prepared and recommended initially as a root-end filling material and subsequently has been used for pulp capping, pulpotomy, apexogenesis, apical barrier formation in teeth with open apexes, repair of root perforations, and as a root canal filling material.

Although MTA has many excellent properties, there are common problems associated with clinical use of MTA. Some disadvantages with using MTA are its extended setting time and difficult handling.

The aim of this study was to improve handling characteristic of White Portland cement (WPC) by mixing with spherical SiO_2 and ZrO_2.

【Materials and Methods】

1) Preparation of materials

The samples that consist of WPC (from 70 to 100wt%), spherical SiO_2 (from 0 to 30wt%) and ZrO_2 (from 0 to 30wt%) were employed. All samples were hand-mixed at a water-to-powder ratio of 0.25ml/g with distilled water. The consistency of samples was measured spread areas put in mixture cement by glass plates and gave vibration. Setting time, compressive strength and radiopacity of samples were based on the Japanese Industrial Standards Committee (JIS T6609, 6610 and 6522).

A composition of the modified MTA was determined by results of these tests.

2) Measurement of pH

The modified MTA, WPC and ProRoot MTA were mixed and placed into the stainless steel mold (1-mm thickness and 6-mm diameter). The cement in the mold was stored in an incubator at more than 90% relative humidity at 37℃ for 24hours. Each cement disks was placed in 10 ml ultrapure water. The pH value was measured after 1, 3, 6 hours, and 1, 3, 7 days.

3) Evaluation of ion release

The extract water of the cement disks was filtered at 1, 3 and 7 days. Ion concentrations of the extracts were measured by using ICP-AES.

(4) Cell viability

MC3T3-E1 cells were cultured in minimal essential medium alpha (α-MEM) containing 10% fetal bovine serum and 200mM L-gultamine. The disks of the modified MTA and ProRoot MTA was stored in 10 mL α-MEM containing 10% FBS for 3 days to produce the extracts used for the treatment of MC3T3-E1. Cells were seeded in 24-well culture plates at a density of 1×10^4 cells per well and preincubated in growth medium for 24 hours before cells were incubated with the prepared extracts for 24, 48 and 72hours. The cell viability was examined Cell Proliferation Assay Kit.

5) Pulpotomy of rat molar

The rats were used of male Wistar rats of 8 weeks of age. The rats were operated under the general anesthesia giving 16% pentobarbital intraperitoneally, pulp exposure was made in the occlusal surface of the rat maxillary first molar. The exposed pulps were capped with modified MTA, ProRoot MTA and Calvital, and the cavities were sealed with a glass-ionomer cement. The maxillary bone including treated teeth at 7 days after operation was fixed by 4% paraformaldehyde in PBS for 24 hours. The specimens were embedded in paraffin. The sections were performed for Hematoxylin-Eosin staining.

【result】

1) Preparation of materials

Cement mud of samples had moderate consistency by the addition of SiO_2 and ZrO_2 more than 20 wt% in WPC. Setting time of WPC by the addition of SiO_2 or ZrO_2 particles decreased in comparison with ProRoot MTA. In the compressive strength, there were no significant differences between WPC by the addition of SiO_2 or ZrO_2 particles and ProRoot MTA. WPC by adding ZrO_2

more than 20 wt% had radiopacity values greater than or equal to 3.0 mm of the Aluminum scale for all the thicknesses. Therefore, the composition of the modified MTA was decided WPC by the addition of spherical SiO_2 10 wt% and ZrO_2 20 wt%.

2) Measurement of pH

The samples in the modified MTA, WPC and ProRoot MTA were more than pH 9 in the disks stored in an incubator for 1 hour, and all samples were increased up to pH 11 after 7days. The pH of ProRoot MTA was raised sharply compared with the modified MTA.

3) Evaluation of ion release

The amount of released Ca^{2+} and $H_3SiO_4^-$ from the modified MTA was corresponded with ProRoot MTA and WPC. Only ProRoot MTA was released Bi^{3+}, All cement disks were not released Zr^{4+}.

4) Cell viability

Cell viability in the presence of the material extracts evaluated by Cell Proliferation Assay. The modified MTA and ProRoot MTA treated cells had similar cell viability as untreated control cells throughout the experimental period.

5) Pulpotomy of rat molar

There was the formation of a new dentin in the section of pulp in the rat molar capped with the modified MTA or ProRoot MTA by pulpotomy after 1 week. However, the specimen using Calvital showed less new dentin formation. The odontoblast-like cells in the modified MTA sample were polarized and arranged in a palisade pattern, the teeth capped with the modified MTA were observed a layer of new dentin. The specimens using the modified MTA did not have inflammation or showed minor pulpal inflammation. In contrast, the specimens of ProRoot and Calvital were observed chronic inflammatory cells and many hyperemias.

【Discussion】

The modified MTA has improved the consistency due to the bearing effect by the addition of spherical SiO_2 particles. Since, the modified MTA was able to mix with less water, the setting time of the modified MTA decreased as compared with ProRoot MTA. The pH level of the modified MTA was high alkaline pH as well as ProRoot MTA. These results suggest that the strong alkaline is responsible for the antimicrobial ability and the bioactive ability such as dentin-induction.

The modified MTA and ProRoot MTA have not inhibited MC3T3E-1 cells proliferation and both types of cement strongly induced new dentin formation in the section of pulp after pulpotomy in rat molar. The amount of released Ca^{2+} from the modified MTA was identical with ProRoot MTA. These Ca^{2+} releases of the modified MTA or ProRoot MTA play an important role of secondary dentin-induction after pulpotomy.

The modified MTA was improved handling characteristics of White Portland cement by mixing with spherical SiO_2 and ZrO_2, and it strongly induced reparative dentinogenesis.