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Comparison of Fluoride Release and Microhardness between Restorative Materials

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Purpose: Research comparing and evaluating the properties of various dental materials is an important topic in the field of dentistry. This study aims to evaluate the fluoride release and microhardness properties of various fluoride-containing restorative materials used in dental treatments. **Materials and Methods:** Thirty specimens of four restorative materials were prepared (5 mm × 2 mm, cylindrical): alkasite-based material (Cention N, CN), Self-cure glass Ionomer (Riva self cure, RS), Resin-modified glass ionomer cement (Fuji LC II, FL) and composite resin (Filtek Z350XT, FZ). Fluoride release measurements were conducted on 25 specimens at intervals of 1, 2, 6, 13, 20, and 27 days with a fluoride electrode connected to the pH/ISE Meter (Orion Star A214, Thermo Scientific, USA) and cumulative fluoride release was calculated. Vickers microhardness measurements were performed on five specimens from each material with microhardness tester (DM2D, AFFRI, Italy). **Results:** As a result of measuring the amount of fluoride release over 27 days, the amount of fluoride release in CN showed a gradual increase, while the amount of fluoride release in RS, FL, and FZ gradually decreased. The cumulative fluoride release amount for 28 days was significantly higher in CN and FL than in RS ($P < 0.05$). FZ and RS demonstrated significantly higher microhardness compared to CN and FL ($P < 0.05$). FZ and RS showed similar microhardness, and FL showed the lowest microhardness. **Conclusion:** Cention N (CN) exhibited superior fluoride release compared to Glass Ionomer Cement (RS), making it a promising option for preventing secondary caries. However, it displayed a lower microhardness than the composite resin (FZ), indicating potential limitations in terms of mechanical strength. Therefore, if an anti-caries action is required, Cention N may be considered first; however, it appears to be difficult to use in posterior permanent teeth. [J Korean Dent Sci. 2024;17(3):105-11]

Key Words: Fluoride release; Microhardness; Cention N

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Introduction

Dental caries is a disease in which the minerals on the tooth surface are dissolved by acids produced in the dental plaque, destroying the tooth structure. Teeth affected by dental caries are treated by removing the carious area and filling it with restorative materials[1]. However, the incidence of secondary caries is high in patients with high caries activity, and fluoride-containing restorative materials are widely used to prevent caries.

Fluoride, which is known to be effective in preventing dental caries, not only prevents demineralization of enamel but also enables restoration of tooth structure by remineralizing demineralized enamel[2]. Compared to methods using agents such as fluoride gel or fluoride varnish, the release of fluoride through restorative materials enables continuous action over a long period of time[3].

Glass ionomer cement (GIC) is a representative restorative material that releases fluorides. GIC is a material that is capable of releasing and refilling fluoride ions in the oral cavity[4]. However, owing to its high solubility, low strength, and wear resistance, it is not suitable as a restorative material in the posterior region, where a high mechanical load is applied[5]. To supplement this physical strength, materials such as resin-modified glass ionomers and compomers have been developed and used; however, limitations still exist as sufficient physical strength is not achieved and fluoride emissions are reduced[6,7].

Recently, alkasite-based restorative materials, classified as compomers, have been introduced. This restorative material contains an alkaline filler composed of calcium fluorosilicate glass that releases fluoride, calcium, and hydroxide ions[8]. In addition, it has suitable physical strength and can be used as a restorative material for the posterior teeth[9,10].

In this study, we aimed to compare the fluoride release behavior of alkasite restorations and other types of restorations, and further confirm the microhardness of the materials. The null hypothesis states that there is no difference in the fluoride release behavior and microhardness between alkali-restorative materials and other restorative materials.

Materials and Methods

1. Specimen production

The materials used in this experiment were alkasite-based materials (Cention N, CN; Ivoclar Vivadent, Chicago, USA), self-cured glass Ionomer Cement (Riva Self Cure, RS; SDI, Victoria, Australia), resin-modified glass ionomer cement (Fuji II LC, FL; GC, Tokyo, Japan), and composite resin (Filtek Z350, FZ; 3M ESPE, Maplewood, USA). These components are summarized in Table 1. Thirty specimens for each material were produced with molds of 2.5 mm height and 5 mm diameter. These specimens were created using a mold with a cover glass applied to both sides. CN, RS, and FL were prepared according to the manufacturer's instructions. The FZ was light-cured on each side for 20 s using a B&L ite (B&L Biotech, Seoul, Korea) in normal mode (800 mW/cm^2).

2. Fluoride release measurement

Fluoride release measurements were conducted on 25 specimens at intervals of 1, 2, 6, 13, 20, and 27 d using a fluoride electrode connected to a pH/ISE meter (Orion Star A214, Thermo Scientific, Waltham, USA). Each specimen was placed in a polyethylene vial containing 3.0 ml of deionized water and stored in a constant-temperature chamber at 37℃. On the day of measurement, the TISAB II solution (3.0 mL) was added to the polyethylene vial containing the specimen. At every 10th measurement, the electrode was standardized using 1 ppm and 10 ppm fluoride standard solutions at the same temperature as that of the specimen. On measurement completion, the specimen and vial were rinsed with flowing water for 30 s and

Table 1. Materials used in this study

Group	Material	Category	Manufacturer
I	Riva self cure	Self cure glass Ionomer	SDI, Victoria, Austrailia
II	Fuji II LC	Resin modified glass ionomer cement	GC Co., Tokyo, Japan
III	Cention N	Alkasite restorative material	Ivoclar Vivadent , Schaan , Liechtenstein
IV	Filtek Z350XT	Composite resin	3M ESPE, St. Paul, USA

then stored in a new batch of deionized water. The cumulative fluoride release was calculated.

3. Vickers Hardness test

Of the 30 specimens, the remaining 5 specimens from all groups were used for the microhardness test. For each selected sample, the surface microhardness was assessed using a microhardness tester (DM2D, AFFRI, Induno Olona, Italy). Three indentations were created, and measurements were obtained at different points on each specimen, with 200 gm load for a 15 s dwell time. The distances between the indentation points and disc borders were not less than 1 mm. The mean value was calculated and considered as the Vickers hardness number (VHN).

4. Statistical analysis

The Kruskal-Wallis and Mann-Whitney U tests were used, and all statistical analyses were performed at a significance level of 0.05, using IBM SPSS Statistics software (version 26.0; IBM, Armonk, NY, USA).

Results

As a result of measuring the amount of fluoride released over 27 d, the amount of fluoride released in CN gradually increased, whereas the amount of fluoride released in RS, FL, and FZ gradually decreased. In the remaining groups, except for CN, the amount of fluoride released was highest on the first day of measurement. This is presented in Table 2 and Fig. 1.

Table 3 summarizes the cumulative fluoride release by measurement day for each group, and Fig. 2 shows this in a chart. The cumulative amount of fluoride released over 28 d was significantly higher in the CN and FL groups than in the RS group (P<0.05).

FZ and RS compared to CN and FL demonstrated significantly higher microhardness values (P<0.05). FZ and RS had similar microhardness values, whereas FL had the lowest microhardness value. Table 4 summarizes the microhardness of each group, and Fig. 3 shows this in a diagram.

Table 2. Fluoride release for 27days

Experimental period	Fluoride release (Mean±SD, μg/cm^2) (ppm)			
	Group I	Group II	Group III	Group IV
1st day	15.60±3.47	28.76±6.24	4.29±1.20	0.034±0.00
2nd day	6.30±2.36	25.8±6.10	4.12±1.16	0.016±0.00
6th day	12.90±4.34	26.2±6.26	11.07±2.24	0.026±0.00
13th day	11.10±4.38	23.76±6.11	26.88±7.42	0.000±0.00
20th day	6.10±2.44	22±6.1	35.32±11.71	0.000±0.00
27th day	4.01±1.63	15.02±3.93	35.36±8.66	0.000±0.00

Group I: Riva Self Cure; Group II: Fuji II LC; Group III: Cention N; Group IV: Filtek Z350XT.

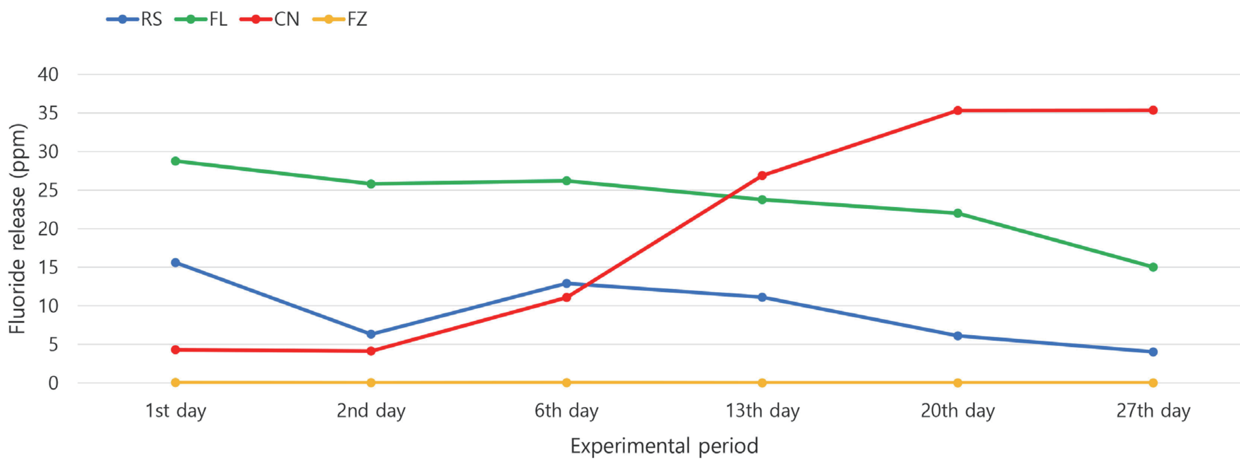

Fig. 1. Daily fluoride release.
When comparing within rows, different superscript letters indicate significant differences (*P*<0.05).
Group I: Riva Self Cure; Group II: Fuji II LC; Group III: Cention N; Group IV: Filtek Z350XT.

Table 3. Cumulative fluoride release for 27days

Experimental period	Cumulative fluoride release (Mean±SD, μg/cm²) (ppm)			
	Group I	Group II	Group III	Group IV
1st day	15.60±3.47[a]	28.76±6.24[b]	4.29±1.20[c]	0.03±0.00[d]
2nd day	21.89±5.73[a]	54.56±12.0[b]	8.41±2.28[c]	0.05±0.01[d]
6th day	34.78±9.93[a]	80.76±17.49[b]	19.49±4.41[c]	0.07±0.01[d]
13th day	45.88±14.25[a]	104.52±22.98[b]	46.37±11.73[a]	0.07±0.01[c]
20th day	51.99±16.64[a]	126.52±27.95[b]	81.69±23.35[c]	0.07±0.01[d]
27th day	56.00±18.24[a]	141.54±30.51[b]	117.05±31.94[b]	0.07±0.01[c]

When comparing within rows, different superscript letters indicate significant differences (*P*<0.05).
Group I: Riva Self Cure; Group II: Fuji II LC; Group III: Cention N; Group IV: Filtek Z350XT.

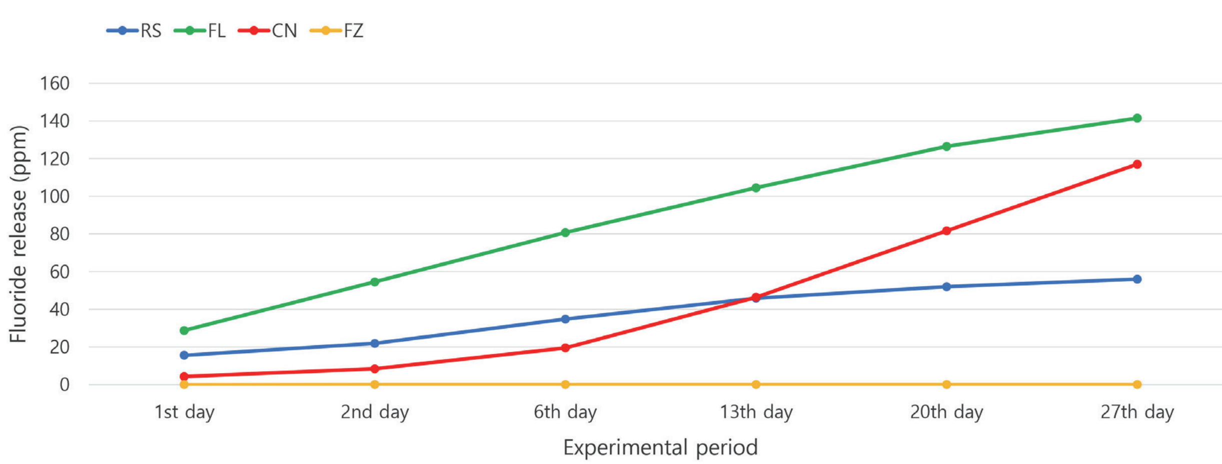

Fig. 2. Cummulative fioride release.
When comparing within rows, different superscript letters indicate significant differences (*P*<0.05).
Group I: Riva Self Cure; Group II: Fuji II LC; Group III: Cention N; Group IV: Filtek Z350XT.

Table 4. The mean of Vickers microhardness value (HV)

	Group I	Group II	Group III	Group IV
Mean HV	50.68±6.91[a]	35.08±3.09[b]	41.6±9.00[c]	51.04±6.69[a]

When comparing within rows, different superscript letters indicate significant differences (*P*<0.05).
Group I: Riva Self Cure; Group II: Fuji II LC; Group III: Cention N; Group IV: Filtek Z350XT.

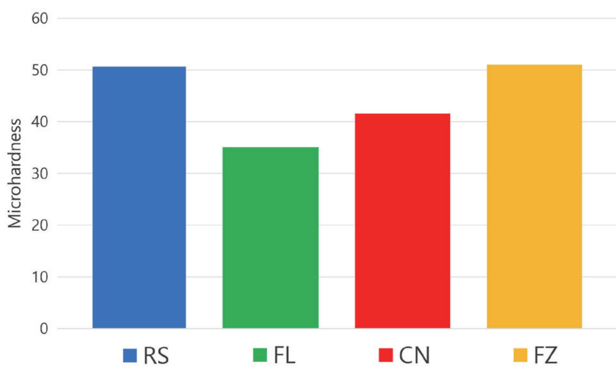

Fig. 3. Mircrohardness.
RS: Riva Self Cure, FL: Fuji II LC, CN: Cention N, FZ: Filtek Z350.

Discussion

The experiment showed that CN released significantly more fluoride than the other materials, except FL and exhibited intermediate performance in terms of microhardness. Accordingly, the null hypothesis that there is no difference in the fluoride release and microhardness between the materials was rejected.

In general, the amount of fluoride released in the GIC series was the highest during the first 24 h after polymerization. This is a phenomenon in which a large amount of fluoride is rapidly released from the surface of a material and is referred to as the burst effect[11]. Subsequently, the amount of fluoride released gradually decreased and switched to a bulk diffusion process. The decreasing amount of fluoride released later reached a plateau and low concentrations of fluoride were continuously released. Our research also showed this pattern in cases of RS and FL.

However, in the case of CN, the amount of fluoride released was small at first, and the amount of fluoride released continued to increase. Another study evaluating the amount of fluoride released in CN showed that the highest amount of fluoride release occurred in the first 24 h and then decreased over time[12,13]. The difference in the results from previous studies appears to be due to the use of the self-cure mode. It appeared that the alkaline restorative material was bonded less tightly than when light-cured, thus increasing its ability to release fluoride ions.

It has been reported that the amount of fluoride released from CN changes rapidly and depends on pH[14]. In a neutral environment, the amount of fluoride release from CN was less than that of GIC, whereas in an acidic environment of pH 4.0, the amount of fluoride release from CN was similar to that of GIC. Cention N showed a higher fluoride release under acidic conditions than under neutral pH. This behavior indicates its potential efficacy in caries-prone environments, where low pH levels are common. However, the fluoride release under neutral conditions is comparatively low, which may affect its performance in less acidic environments.

In this experiment, there was no significant difference between the CN and FL groups in the cumulative fluoride levels over 27 days. In a study by Lee et al., FL compared to CN showed significantly higher fluoride emissions after 28 days, there was no significant difference after 42 days, and CN compared to FL released significantly more fluoride after 84 days[15]. This shows a similar trend to that found in our research; however, the reason for the difference in the period appears to be the differences in the size and shape of the specimen. In addition, the short measurement period in this experiment appears to be a limitation because the plateau state of fluoride emission was not confirmed.

Surface hardness is the most important mechanical property of restorative materials and provides information on wear resistance. Surface hardness is affected by various factors such as the material matrix, amount and size of filler particles, and manner of filler distribution[16].

In the microhardness experiments, FZ and RS showed similar values, CN showed an intermediate value, and FL showed the lowest value. Existing studies have shown conflicting results. In a study comparing RMGI and CN, CN showed a significantly higher microhardness[17]. However, in research by Lee et al., RMGI compared to resin and Cention N showed higher microhardness[18]. The reason for this difference is that the RMGI was measured using a Fuji IX. Fuji IX is designed for bulk-fill applications and has a high compressive strength, making it suitable for load-bearing areas. In addition, Fuji II has a dual-cure system and uses an acid-base reaction, whereas FUji IV uses only an acid-base reaction. Therefore, the microhardness appears to have improved compared to that of Fuji II.

As a result of the study, Cention N showed lower microhardness than composite resin. However, several other studies have reported that composite resins and CN have similar microhardness[16,19]. The increased microhardness of CN was probably related to the nanoparticle size and concentration of the inorganic filler[20]. It includes a special patented filler (partially functionalized by silanes) that minimizes shrinkage stress. This isofiller acts as a shrinkage stress reliever that minimizes the shrinkage force, whereas the organic/inorganic ratio and monomer composition of the material are responsible for low volumetric shrinkage[21].

The most-studied mechanical properties of materials are their flexural resistance and hardness as they approximate the forces involved in mastication and those supported by the material[22]. In this study, only the microhardness was measured, and further research on flexural resistance when using posterior teeth is required.

Conclusion

In this study, Cention N (CN) exhibited superior fluoride release compared to Glass Ionomer Cement (RS), making it a promising option for preventing secondary caries. However, it displayed a lower microhardness than the composite resin (FZ), indicating potential limitations in terms of mechanical strength. Therefore, if an anti-caries action is required, Cention N may be considered first; however, it appears to be difficult to use in posterior permanent teeth.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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