Comparison of Microleakage and Compressive Strength of Different Base Materials

Eunyeong Jang[1], Jaesik Lee[1], Soonhyeun Nam[1], Taeyub Kwon[2], Hyunjung Kim[1]

[1]*Department of Pediatric Dentistry, School of Dentistry, Kyungpook National University*
[2]*Department of Dental biomaterials, School of Dentistry, Kyungpook National University*

Abstract

This study compared the microleakages and compressive strengths of various base materials.

To evaluate microleakages, 50 extracted permanent premolars were prepared. The teeth divided into 5 groups of 10 each according to the base materials. Cavities with a 5.0 mm width, 3.0 mm length, and 3.0 mm depth were formed on the buccal surfaces of the teeth. After filling the cavities with different base materials, a composite resin was used for final restoration. Each specimen was immersed in 2% methylene blue solution and then observed under a stereoscopic microscope (× 30). To evaluate the compressive strength, 5 cylindrical specimens were prepared for each base material. A universal testing machine was used to measure the compressive strength.

The microleakage was highest in the Riva light cure™ group and lowest in the Biodentine™ and Well-Root™ PT groups. For the compressive strengths, in all groups, acceptable strength values for base materials were found. The highest compressive strength was observed in the Fuji II LC™ group and the lowest strength in the Well-Root™ PT group.

Key words : Base material, Glass ionomer cement, Mineral trioxide aggregate, Tricalcium silicate-based material, Microleakage, Compressive strength

Ⅰ. Introduction

Restorative treatment of large carious lesion has been a challenge for dentists because of pulp sensitivity, microleakage, and secondary caries. Cavity bases can be used to reduce postoperative sensitivity and secondary caries in restoration of extensive carious lesions[1]. The cavity bases are used to provide a barrier or protective layer between the exposed dentin and final restoration[1]. Anusavice[2] defined a base as a layer of insulating, sometimes medicated, cement placed in the deep portion of the cavity preparation to protect the pulp from thermal and chemical injury. Ferracane[3] suggested that bases should be placed in a thick layer and must be strong enough to support a restorative material during its placement and function. Craig and Powers[4] stated that the cavity bases should protect the pulp from heat, mechanically support the restoration, and in many cases, play a role in replacing the dentin that was destroyed by caries or damaged during cavity preparation.

There are many studies on the properties of each base material, but there are only a few studies comparing the various base materials together. The aim of this study was to evaluate and compare the microleakages and compressive strengths of 5 base materials; Fuji II LC™ (FLC), Riva light cure™ (RLC), Pro-

Root™ white MTA (WMTA), Biodentine™ (BD), and Well-Root™ PT (WRPT). And it was discussed whether each base material would be acceptable as cavity bases.

Ⅱ. Materials and Methods

The protocol was approved by the Institutional Review Board of Kyungpook National University Dental Hospital (IRB No. KNUDH-2020-03-05-00).

1. Subjects

In this study, 5 types of cavity base materials, FLC, RLC, WMTA, BD, and WRPT, were used, and composite resin(Filtek Z250, 3M ESPE™, USA) was used as a restorative material. Before restoration with the composite resin, Scotchbond™ (3M ESPE™, USA) was used as an etchant and Adper™ Single Bond 2 (3M ESPE™, USA) was used as an adhesive agent. Details of the study materials are described in Table 1.

2. Methods

1) Microleakage

(1) Specimen preparation

A total of 50 permanent premolar teeth with no dental caries and no discoloration were prepared. After removing all soft tissue and debris with an ultrasonic scaler, the teeth were cleansed with pumice and distilled water. After washing, all teeth were immersed in saline, and stored at room temperature. Cavities with a 5.0 mm width, 3.0 mm length, and 3.0 mm depth were formed on the buccal surfaces of the teeth with a #330 carbide bur for high speed engines. The depth of the cavities was confirmed using a thin rod marked with the length and a head length of the bur. The teeth with the cavity were classified into 5 groups according to the type of material used for the cavity bases, and the type of cavity bases was chosen randomly.

After making with a marking pen at a depth of 1mm of the cavities, the materials were used to fill 10 teeth in each group to a depth of 1.0 mm. The overfilled part was removed before a initial setting of the base materials using a cotton pellet and an explorer. FLC and RLC were mixed according to the manufacturer's instructions and light-cured for 20 seconds at 1200 mW/cm2 using an LED light curing unit (VALO LED, Ultradent, USA). WMTA and BD were mixed according to the manufacturer's instructions. After filling, WMTA was wrapped with wet gauze and cured at 37°C and 100% humidity for 72 hours. BD was cured at 37°C for 15 minutes. WRPT was cured at 37°C for 30 minutes. The composite resin was then applied to a depth of 2.0 mm on top of the cavity base materials (Fig. 1). After
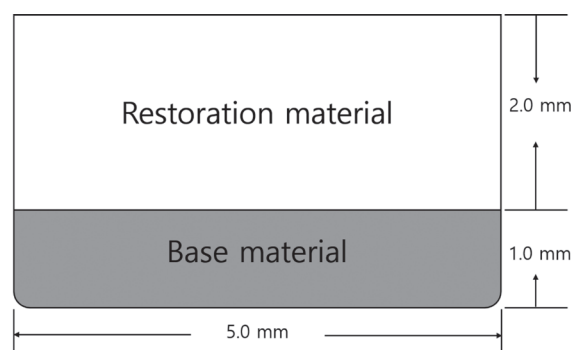

Fig. 1. Schematic representation of the filling method.

Table 1. Base materials used in this study

Material	Manufacturer		Composition
Fuji Ⅱ LC™	GC Corp, Japan	Powder	Fluoro-alumino-silicate glass
		Liquid	Water, copolymer of acrylic acid-maleic acid, tartaric acid
Riva light cure™	SDI, Australia	Powder	Fluoro-alumino-silicate glass, silica
		Liquid	Polyacrylic acid, tartaric acid, HEMA, Camphoroquinone
ProRoot™ white MTA	Dentsply, USA	Powder	Tricalcium silicate, bismuth oxide, dicalcium silicate, tricalcium aluminate, calcium sulfate dehydrate or gypsum
Biodentine™	Septodont, France	Powder	Tricalcium silicate, dicalcium silicate, calcium carbonate, calcium oxide, zirconium oxide
		Liquid	Calcium chloride, water-reducing agent
Well-Root™ PT	Vericom Co., Korea	Paste	Calcium aluminosilicate compound, zirconium oxide

setting of the base materials, all cavities were etched with 35% phosphoric acid for 15 seconds and rinsed for 10 seconds. Adper™ Single Bond 2, a fifth generation adhesive system, was applied and light-curing was carried out with a LED light curing machine (VALO LED, Ultradent, USA) with an intensity of 1200 mW/cm² for 20 seconds. Then, Filtek™ Z250 was applied for final restoration of the rest of the cavity at a depth of 2.0 mm and light-curing was carried out with the same method for 20 seconds.

(2) Microleakage evaluation

After final restoration, all specimens were placed in deionized water for 24 hours and stored in a thermostat at 37℃. For thermocycling, all specimens were immersed in water baths at 5℃ and 55℃ for 30 seconds and a total of 500 rounds were performed.

To prevent dye penetration through the apical foramen, the apical foramen area was sealed with a composite resin. A nail varnish was applied on the entire surface of the tooth excluding the restoration surface and the surrounding 1.0 mm. For the evaluation of microleakages, all specimens were immersed in 2% methylene blue solution for 24 hours, rinsed, and dried.

To facilitate specimen observation, each tooth was cut into two parts: the crown and root. The crown part was then sectioned buccolingually using a TechCut 4™ Low Speed Saw (Allied, USA) to obtain two specimens for each tooth. The obtained specimens were observed under a stereoscopic microscope (× 30). Dye penetration of each specimen was scored from 0 to 3, and then classified and measured according to the following criteria. Two specimens obtained from one tooth were observed, and the higher score was recorded (Table 2, Fig. 2).

2) Compressive strength

(1) Specimen preparation

A total of 25 split stainless steel molds capable of producing cylindrical (6.0 mm high × 4.0 mm internal diameter) specimens were prepared. FLC, RLC and WMTA were mixed according to the manufacturer's instructions and were placed in split stainless steel molds at 5 pieces each (Fig. 3). Then, specimens were cured according to the same methods which were used in microleakage evaluation. BD was mixed according to the manufacturer's instructions, applied to the other 5 split molds, and stored at 37℃ for 48 hours. The remaining 5 split stain-
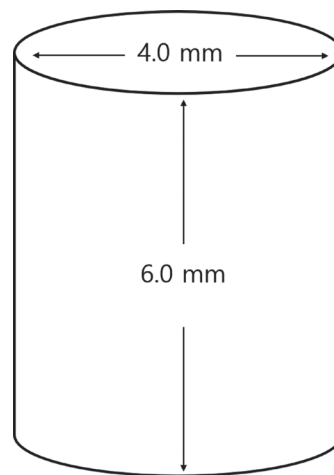
Table 2. Criteria for extent of dye penetration

Score	Criteria
0	No dye penetration
1	Dye penetration into the enamel part of the cavity wall
2	Dye penetration into the dentin part of the cavity wall
3	Dye penetration including the pulpal floor of the cavity

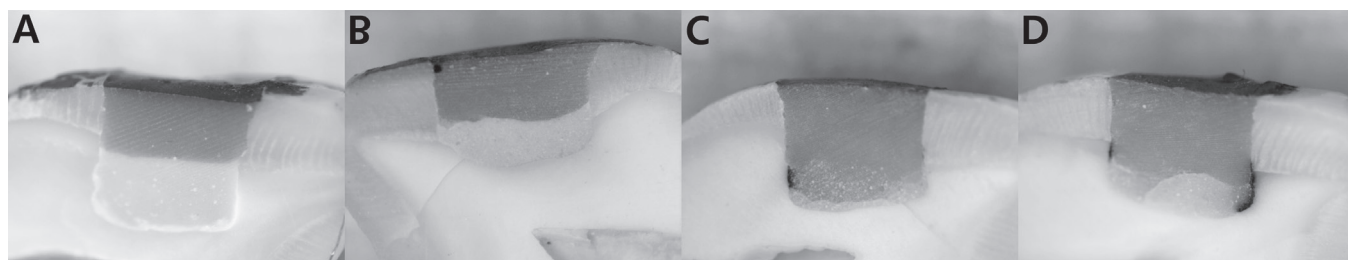**Fig. 3.** Schematic representation of the specimen for a compressive strength test.

Fig. 2. Photographs of extent of dye penetration. (A) Score 0, (B) Score 1, (C) Score 2, (D) Score 3.

less steel molds were filled with WRPT and then stored at 37°C for 48 hours. After that, each specimen was separated from the split stainless steel mold.

(2) Compressive strength test

A universal testing machine (Instron 3366, Instron Corp., UK) was used to measure the compressive strength. The specimen was placed in a universal testing machine so that the load could be applied to the long axis of the specimen. The load was applied at a speed of 1.0 mm/min until a fracture occurred, and the maximum load value was applied until the specimen fracture was recorded.

3) Statistical analysis

Data were analyzed using SPSS software (ver. 25.0, SPSS Inc., Chicago, IL, USA). Fisher's exact test was used to analyze microleakages statistically. To compare compressive strengths, an One-way ANOVA was performed and the Scheffe test was performed as a post hoc test.

Ⅲ. Results

1. Comparison of microleakages

In this study, after evaluating the degree of microleakages according to the base materials, the highest microleakage was observed in the RLC group and the lowest microleakage in the BD and WRPT groups (Table 3). The results of comparison among the 5 groups regarding microleakages are shown in Table 4.

2. Comparison of compressive strength

1) Mean value for compressive strength

Table 5 shows the compressive strength of the base materials measured in this study. The FLC group showed the highest compressive strength with an average of 189.04 ± 12.79 MPa. The WRPT group showed the lowest compressive strength with an average of 44.55 ± 6.55 MPa.

2) Comparison of compressive strength

The FLC group showed significantly higher compressive strength than all other groups (Table 6).

Table 3. Frequency of microleakage score of restoration with different base materials

	Score 0	Score 1	Score 2	Score 3
FLC	1 (10%)	1 (10%)	5 (50%)	3 (30%)
RLC	0 (0%)	0 (0%)	6 (60%)	4 (40%)
WMTA	3 (30%)	5 (50%)	1 (10%)	1 (10%)
BD	6 (60%)	4 (40%)	0 (0%)	0 (0%)
WRPD	6 (60%)	4 (40%)	0 (0%)	0 (0%)

FLC: Fuji Ⅱ LC[TM], RLC: Riva light cure[TM], WMTA: ProRoot[TM] white MTA, BD: Biodentine[TM], WRPT: Well-Root[TM] PT

Table 4. Comparison of microleakage score

	FLC	RLC	WMTA	BD	WRPT
FLC	-	-	-	-	-
RLC	1.000	-	-	-	-
WMTA	0.075	0.003	-	-	-
BD	0.003	0.000	0.484	-	-
WRPT	0.003	0.000	0.484	1.000	-

p value from Fisher's exact test
FLC: Fuji Ⅱ LC[TM], RLC: Riva light cure[TM], WMTA: ProRoot[TM] white MTA, BD: Biodentine[TM], WRPT: Well-Root[TM] PT

Table 5. Mean of compressive strength

Group	Mean ± SD of Compressive strength (MPa)
FLC	189.04 ± 12.79
RLC	64.14 ± 9.34
WMTA	53.38 ± 7.10
BD	57.04 ± 9.34
WRPT	44.55 ± 6.66

SD: Standard deviation
FLC: Fuji Ⅱ LC[TM], RLC: Riva light cure[TM], WMTA: ProRoot[TM] white MTA, BD: Biodentine[TM], WRPT: Well-Root[TM] PT

Table 6. Comparison of compressive strength

	FLC	RLC	WMTA	BD	WRPT
FLC	-	-	-	-	-
RLC	0.000	-	-	-	-
WMTA	0.000	0.516	-	-	-
BD	0.000	0.830	0.982	-	-
WRPT	0.000	0.055	0.691	0.371	-

p value from Scheffe test
FLC: Fuji Ⅱ LC[TM], RLC: Riva light cure[TM], WMTA: ProRoot[TM] white MTA, BD: Biodentine[TM], WRPT: Well-Root[TM] PT

IV. Discussion

In the treatment of the large carious lesions, the cavity bases can be used to reduce postoperative sensitivity and secondary caries[1]. There are many characteristics required for the base materials. Sealing ability and compressive strength are one of them. In this study, the microleakages and compressive strength of 5 base materials were evaluated.

The marginal leakage is the precursor of secondary caries, staining of restoration, tooth discoloration, postoperative sensitivity, and pulpal pathology[5]. So, it is important to have a good marginal seal for the longevity of restorative material, thereby reducing the marginal leakage[5]. In this study, microleakages with 5 base materials was evaluated. In previous studies, BD exhibited less microleakage than conventional glass ionomer cement and MTA[6,7]. In this study, BD and WRPT showed the lowest microleakage and RLC showed the highest microleakage (Table 3). And the BD and WRPT groups showed significantly less microleakage than the FLC and RLC groups ($p < 0.05$). And the WMTA group showed significantly less microleakage than the RLC groups ($p < 0.05$). The consistency and handling property of the mixed materials might be one of the factors that affect these results.

The handling property is important for the convenience of the procedure in pediatric dentistry. The materials used in this study had different handling properties. FLC showed a high viscosity and good handling property so that it was possible to condense the material with an instrument. RLC showed low viscosity and poor handling property; therefore dense restoration was difficult. WMTA showed a sandy consistency and initial looseness after mixing, revealing a poor handling property[8]. BD can be well-aggregated and it easily adheres to the tooth surface; thus, it has a good handling property and sealing ability[7,9]. WRPT showed a good handling property so that it could be condensed using instruments during the filling process. In this study, BD and WRPT showed the lowest microleakage (Table 3). BD can achieve constant properties through auto-mixing and it has excellent handling property and sealing ability[7,9]. Auto-mixing method is not under the control of the operator, and the mixing regime is standardized by the manufacturer so that the functional properties of the mixed materials are constant[10,11]. WRPT is a pre-mixed type material that shows constant physical properties, and it is provided in the form of a syringe. Therefore, it can be easily applied to the desired area[6]. Moreover, WRPT has excellent handling property.

Thus, it can be densely restored to the cavity. It is thought that these factors contributed in part to BD and WRPT showing the lowest microleakage. From the results of microleakage evaluation in the present study, it was confirmed that BD and WRPT were the base materials that have an excellent sealing ability. FLC showed significantly higher microleakage than BD and WRPT in this study ($p < 0.05$). FLC might show a difference in physical properties each time because it is a power/liquid type material and is mixed by hand. The physical properties of materials that use a traditional hand-mixing method may vary depending on the skill of the operator and mixing environments[11]. Also, because FLC is not available in syringe form, there is high possibility of the presence of voids inside the material during the filling process[12]. RLC is an auto-mixing and syringe-type material. Therefore, it can achieve constant properties and is easy to apply to the cavity. But, it showed the hightest microleakage in this study (Table 3). This result was attributed to the fact that RLC was difficult to condense in the cavity due to its low viscosity and poor handling property. The voids could have been present during the process of adjusting the base material to 1.0 mm height with a cotton pellet. This was supported by Nomoto *et al*.[10], who stated that a low-viscosity material encouraged more voids to be formed during mechanical mixing. From this result, it could be suggested that the material in the form of auto-mixing does not always show lower porosity and good properties. Therefore, when selecting a material, it is necessary to simultaneously consider other factors, such as the viscosity and handling property of the material and the environment in which the material is being used.

Products applied as a cavity bases require sufficient strength to withstand condensing stresses during filling of the restoration[13]. Compressive strength is one of the main physical properties of base materials. When used as a base material, the cement should have the capacity to withstand masticatory stress[5]. In this study, FLC showed significantly higher compressive strength than the rest of the groups. No statistical significance was observed among the other groups (Table 5, 6). According to the International Organization for Standardization (ISO) 3107, when zinc oxide eugenol is used as cavity bases, the compressive strength should be at least 25 MPa[14]. In ISO 9917-1, the compressive strength of glass ionomer cement, used for a cavity base/lining material, is specified to be at least 50 MPa[15]. In this compressive strength test, FLC had 189.04 ± 12.79 MPa and RLC had 64.14 ± 9.34 MPa, which satisfied the requirements. BD had a compressive strength of

57.04 ± 9.34 MPa, WMTA 53.58 ± 7.10 MPa, and WRPT 44.55 ± 6.55 MPa. Although there are no requirements presented in the international standard for calcium silicate-based materials, the experimental results satisfied the requirements as seen in the standards of ISO 3107 or ISO 9917-1[14,15]. Therefore, all materials in this study can be used as cavity bases. But, if the tooth receives large masticatory stress, such as a permanent molar, a base material with sufficiently high compressive strength would be more recommended[5]. Thus, it can be suggested that if the treated tooth receives large masticatory stress, the material that showed higher compressive strength, such as FLC, is more recommended. In this study, FLC showed the highest compressive strength. The compressive strength of BD in this study was 57.04 ± 9.34 MPa, which was lower than the value reported in previous studies[16]. It is presumed that there was a possibility for the existence of voids inside the specimen due to insufficient operator skills. It was reported that the compressive strength might differ due to the presence of the voids[17]. Grech *et al*.[18] reported that BD had low fluid uptake, low setting time, and superior mechanical properties. Camilleri *et al*.[19] reported that BD is more dense and less porous than MTA. According to these results, BD could be also considered as a base material in areas requiring high strength.

Due to the characteristics of pediatric dentistry, it is important to shorten the operation time when treating patients. Therefore, when using the base materials, the materials that have a short setting time and make it possible to complete the whole procedure in a single appointment are recommended. Among the materials used in this study, RMGICs, which can be light-cured immediately, can be used for 1-visit treatment. WMTA has a long setting time, so it cannot be used for 1-visit treatment. BD and WRPT have been promoted as having relatively short setting times, each 12 minutes and 25 minutes, respectively, according to the manufacturers. Although BD and WRPT have relatively short setting times than WMTA, the setting times of these materials are not short enough to be used for a 1-visit treatment.

In the treatment of the teeth affected by extensive caries, cavity bases can be used to reduce postoperative sensitivity and secondary caries. When selecting the base material to be used, many factors, such as the sealing ability, biocompatibility, and physical properties, should be considered. At the same time, in pediatric patients, other factors, such as patient cooperation, the convenience of the procedure and visit times for treatment, should also be considered. In this study, when considering the ease of handling and microleakages of the materials, BD and WRPT showed good results. But, when considering the visit times for treatment and mechanical properties, FLC was more suitable than other materials.

From the findings of this study, it was found that BD and WRPT showed little microleakages and good handling properties as base materials. And it was found that FLC has a short setting time and large compressive strength. But there are many other things that should be considered when selecting a base material. The clinician should know the characteristics of the material and be able to select the appropriate material according to the situation.

This study has some limitations. First, this study would not completely reproduce the oral environment. In this study, WRPT was not cured within 25 minutes, the time indicated by the manufacturer. So, the final restoration was proceeded after 30 minutes. It is thought to be because the environment in which the material is cured is not the same as the clinical conditions. Second, the effect of the final restoration was not considered when evaluating the microleakages. The microleakage on the enamel may be the effect of the final restoration, not the base materials, but this was not considered in this study. Although the composite resin was restored in the form of a single bulk filling to minimize the effect of the final restoration, the effect of the final restoration on the microleakage evaluation was not completely controlled. Third, due to insufficient skills to prepare specimens for the compressive strength evaluation, the experimental results of BD were lower than those of previous studies. Fourth, only the microleakages and compressive strengths of the base materials were evaluated in this study. There are many other factors that should be considered for selecting materials, such as biocompatibility, solubility, and sealing ability. Further studies on other factors that should be considered for selecting materials are needed.

Ⅴ. Conclusion

As a result of comparing and evaluating the microleakages and compressive strengths of 5 base materials. The lowest microleakage was observed in the BD and WRPT groups and the highest compressive strength was observed in the FLC group. Regarding compressive strength, all 5 base materials satisfied the international requirements.

From the findings of this study, it was found that BD and

WRPT showed the lowest microleakage and good handling properties as base materials. And it was found that FLC has a short setting time and highest compressive strength. But there are many other things that should be considered when selecting a base material.

All materials used in this study can be used as the cavity bases, but each material has different properties. The clinician should know the characteristics of the material and be able to select the appropriate material according to the situation.

Authors' Information

Eun-Yeong Jang *https://orcid.org/0000-0003-0448-5925*
Jae-Sik Lee *https://orcid.org/0000-0001-5514-4595*
Soon-Hyeun Nam *https://orcid.org/0000-0002-8309-7658*
Tae-Yub Kwon *https://orcid.org/0000-0002-9998-3099*
Hyun-Jung Kim *https://orcid.org/0000-0001-6568-9687*

References

1. Weiner RS : Liners, bases, and cements: a solid foundation. *Gen Dent*, 50:442-446, 2002.

2. Anusavice K : Phillip's Science of Dental Materials, 11th ed. WB Saunders, Philadelphia, 2003.

3. Ferracane JL : Materials in dentistry: principles and applications, 2nd ed. Lippincott Williams and Wilkins, Philadelphia, 2001.

4. Craig RG, Powers JM : Restorative dental materials, 11th ed. Mosby, St Louis, 2002.

5. Masih S, Thomas AM, Joshi JL, *et al*. : Comparative evaluation of the microleakage of two modified glass ionomer cements on primary molars. an in vivo study. *J Indian Soc Pedod Prev Dent*, 29:135-139, 2011.

6. Ragu VG, Venumbaka NR, Elangovan A, *et al*. : Comparative evaluation of shear bond strength and microleakage of tricalcium silicate-based restorative material and radiopaque posterior glass ionomer restorative cement in primary and permanent teeth: An in vitro study. *J Indian Soc Pedod Prev Dent*, 32:304-310, 2014.

7. Samuel A, Asokan S, Thomas S, *et al*. : Evaluation of sealing ability of BiodentineTM and mineral trioxide aggregate in primary molars using scanning electron microscope: A randomized controlled in vitro trial. *Comtemp Clin Dent*, 7:322-325, 2016.

8. Noh YS, Chung SH, Rhee SH, *et al*. : Mechanical properties and microstructure analysis of mineral trioxide aggregate mixed with hydrophilic synthetic polymer. *J Biomed Mater Res B Appl Biomater,* 103:777-782, 2015.

9. Butt N, Talwar S, Bali A, *et al*. : Comparison of physical and mechanical properties of mineral trioxide aggregate and Biodentine. *Indian J Dent Res*, 25:692-697, 2014.

10. Nomoto R, Komoriyama M, Hirano S, *et al*. : Effect of mixing method on the porosity of encapsulated glass-ionomer cement. *Dent Mater*, 20:972-978, 2004.

11. Nekoofar MH, Aseeley Z, Dummer PMH : The effect of various mixing technique on the surface microhardness of mineral trioxide aggregate. *Int Endod J,* 43:312-320, 2010.

12. Mitchell CA, Douglas WH : Comparison of the porosity of hand-mixed and capsulated glass-ionomer luting cements. *Biomater*, 18:1127-1131, 1997.

13. Kayahan MB, Nekoofar MH, Dummer PMH, *et al*. : Effect of acid etching procedures on the compressive strength of 4 calcium silicate-based endodontic cements. *J Endod*, 39:1646-1648, 2013.

14. International Organization for Standardization : Dentistry-Zinc oxide/eugenol cements and zinc oxide/non-eugenol cements. ISO 3107, 2011.

15. International Organization for Standardization : Dentistry-Water-based cements-Part 1: Powder/liquid acid-base cements. ISO 9917-1, 2007.

16. Govindaraju L, Neelakantan P, Gutmann JL : Effect of root canal irrigating solutions on the compressive strength of tricalcium silicate cements. *Clin Oral Investig*, 21:567-571, 2017.

17. Nomoto R, McCabe JF : Effect of mixing methods on the compressive strength of glass ionomer cements. *J Dent*, 29:205-210, 2001.

18. Grech L, Mallia B, Camilleri J : Investigation of the physical properties of tricalcium silicate cement-based root-end filling materials. *Dent Mater*, 29:20-28, 2013.

19. Camilleri J, Sorrentino F, Damidot D : Investigation of the hydration and bioactivity of radiopacified tricalcium silicate cement, Biodentine and MTA angelus. *Dent Mater*, 29:580-593, 2013.

국문초록

여러 치과 와동 기저재용 재료들의 미세누출 및 압축강도 비교

장은영[1]·이제식[1]·남순현[1]·권태엽[2]·김현정[1]

[1] 경북대학교 치의학대학원 소아치과학교실
[2] 경북대학교 치의학대학원 치과생체재료학교실

이 연구는 깊은 와동에서 기저재로 사용되는 5개의 기저재용 재료를 대상으로 미세누출 및 압축강도 평가를 시행하였다.

미세누출 평가를 위해 발거된 영구 소구치 50개를 준비하여 베이스 재료에 따라 10개씩 군을 나누었다. 치아의 순면에 가로 5.0 mm, 세로 3.0 mm, 높이 3.0 mm 크기의 와동을 형성하였다. 형성된 와동에 1.0 mm 두께로 각 베이스 재료를 충전하였다. 이후 와동의 상방부를 composite resin으로 최종수복 시행하였으며, 시편을 2% 메틸렌블루 용액에 침적시킨 후 치아를 절삭하였고 실체현미경 (× 30)을 이용해 미세누출 정도를 평가하였다. 압축강도 평가를 위해 각 재료 별로 5개씩의 원통형 시편을 제작하였다. 이후 만능시험기를 이용해 압축강도를 평가하였다.

미세누출 평가에서 Riva light cure[TM]가 가장 큰 미세누출을 보였으며, Well-Root PT와 Biodentine이 가장 적은 미세누출을 보였다. 압축강도는 모든 군이 베이스 재료로서 받아들일 만한 강도를 보였다. Fuji II LC가 가장 높은 압축강도를 보였으며 Well-Root PT가 가장 낮은 강도를 보였다.