Inhibition of artificial caries around bioactive glass-ursolic acid containing composite resin

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감사의 글

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언제나 변함없이 큰 사랑을 주고 지켜보며 응원해 주는 나의 든든한 버팀목 부모님과 동생 수현이에게 무한한 감사와 사랑을 전하며 글을 마칩니다.

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김 현

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Abstract

Inhibition of artificial caries around bioactive glass-ursolic acid containing composite restorations

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1. Objective

Recurrent caries formation around existing restorations represents the primary reason for replacement of composite resin restorations. Use of the antimicrobial restorative material to inhibit the bacterial biofilm formation can be one way to prevent the recurrent caries around restoration. The aim of this study is to assess the inhibitory effect of experimental composite resins containing BAG and/or UA on artificial caries model.

2. Materials and methods

Four antibacterial composites containing bioactive glass (BAG) filler, BAG filler coated with ursolic acid (UA BAG), ursolic acid was added to the resin matrix (BAG + UA Monomer), ursolic acid was added both BAG filler and resin matrix (UA BAG + UA Monomer) were developed. Conventional composite (OX50) were used as control groups.

Standard cavities (3.5 mm × 2 mm × 2 mm) were prepared on the buccal and lingual surfaces of fifty extracted human third molars and restored with these composite resins (n=10). Artificial caries lesions were produced on the experimental teeth using *S. mutans*-induced artificial caries system. Demineralized area of dental enamel around the restorations were analyzed with quantitative light-induced fluorescence (QLF). The demineralized specimens were photographed with QLF-D Biluminator™ 2 (Inspektor Research Systems bv, Amsterdam, Netherlands) and the fluorescence images of white spot area 1mm around the restorations were analyzed using image analysis software QA2 (Inspektor Research Systems bv, Amsterdam, Netherlands).

3. Result

Mean fluorescence loss (ΔF) and the total fluorescence loss (ΔQ) of experimental groups significantly decreased than control group, but there was no significant difference among experimental groups.

4. Conclusion

The experimental composite resins containing bioactive glass and/or ursolic acid can inhibit the artificial caries induced by *S. mutans* biofilm around the restoration

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Key words : bioactive glass, ursolic acid, antibacterial composite, QLF.

Inhibition of artificial caries around bioactive glass-ursolic acid containing composite restorations

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I. Introduction

Secondary caries is the main reason of the restoration failure of dental restoratives including resin composites (Opdam et al., 2007). This often occurs at the interface between the restoration and the cavity margins, and primarily caused by the acid produced from plaque bacteria. Although several species of bacteria have been isolated from dental plaque associated with caries lesions,

there is evidence that *Streptococcus mutans*, *Streptococcus sobrinus* and *Lactobacilli* are the major pathogens (Loesche, 1986). There are various methods to induce dental caries artificially, but to evaluate anticariogenic materials, a method using oral flora needs to be utilized. A method using *S. mutans* is most commonly used. Because of resin composites posses no ability to prevent or inhibit these bacteria growth, there are several trials to provide composites with antibacterial effects have been reported. These include attempts in which the antimicrobials were incorporated and the materials showed antibacterial effects by release of the agents added (Syafiuddin et al., 1997; Yamamoto et al., 1996; Yoshida et al., 1999).

Bioactive glass (BAG), first introduced by Hench et al, are surface-active glasses that bond chemically to bone minerals. This material is used in dental implants, bone cement, bone and periodontal fillers. Although bioactive glass was originally developed as a bone conductive material, some previous studies have emphasized the remineralizing effect of bioactive glass materials on tooth structures (Efflandt et al., 2002; Marending et al., 2009; Vollenweider et al., 2007). Sauro and others recently used Raman spectroscopy and energy-dispersive x-ray spectroscopy (EDS) to show that a bioactive glass reacts with artificial saliva to deposit hydroxycarbonate apatite (HCA) within the demineralized collagen fibrils (Sauro et al., 2011). In an in vivo study showed that BAGs have a broad antibacterial effect on oral microorganisms, including *S. mutans* (Stoor et al., 1998).

Ursolic acid (UA) is triterpenoid compounds which exist widely in natural plants in the form of free acid or aglycones for triterpenoid saponins. Recently,

it is known that it has various pharmacological effects; hepato-protection, antiinflammation, antitumor-promotion, and antihyperlipidemia activity. UA and its derivatives also have been shown to have antimicrobial activity, such as growth inhibition of *S. aureus*, gram-negative organisms and *M. lenosum*, food-associated bacteria and yeast (Liu, 1995). Due to its hydrophobic nature, it can be mixed with the resin matrix and expected to maintain its antibacterial effects longer than hydrophilic or hydrolytic materials. In the previous studies of our lab (Kim et al., 2013; Won, 2013) ursolic acid could suppress the bacterial growth of *S. mutans* when they were added to the matrix of commercial nanofilled composite (Filtek Z350, 3M ESPE, St Paul, MN, U.S.A.). In the previous research in our lab showed the composites containing BAG and UA in the various methods had inhibitory effect on the *S. mutans* biofilm formation on the experimental composite surface (Kim, 2013). Among them experimental composites containing BAG and UA in the matrix group showed more significant reduction of the biofilm formation. In a study by Won, it was found that quantitative light-induced fluorescence (QLF) is useful in quantitative analysis of caries lesion around restoration with UA-containing composite resin (Won, 2013).

The aim of this in vitro study was to figure out that these experimental composites containing BAG and/or UA which had the biofilm inhibitory effect can also inhibit the formation of the artificial caries lesion around the composite restoration the caries inhibitory effect.

II. Materials and Methods

1. Preparation of experimental composite resin

Four antibacterial composites containing bioactive glass (BAG, 62 mol% SiO_2, 31 mol% CaO, 4 mol% P_2O_5, and 3 mol% F) filler were prepared. Filler and matrix compositions of experimental groups are as described in Table 1. Four experimental groups were prepared: BAG group (BAG filler replaced the nanosilica filler), UA BAG group (UA coated BAG filler replaced the nanofiller), BAG + UA Monomer group (BAG filler was added and UA was dissolved in the matrix), UA BAG + UA Monomer group (UA coated BAG was added and UA was dissolved in the matrix). Conventional composite (10% wt OX50 silica nanofiller instead of BAG) were used as control group. BAG used in this experiment was synthesized by sol-gel methods, then ball milled, sieved, and micronized as an average particle size ranged from 0.04 to 3.0 μm (Sturtevant, Hanover, MA, USA).

Coating of ursolic acid to BAGs was conducted using vacuum methods. Ursolic acid (U6753, Sigma Aldrich, St. Louis, MO, U.S.A.) dissolved in 70% ethanol and mixed with BAG powder. Then, the solvents were evaporated under negative pressure in vacuum condition, and complete evaporation of solvents was confirmed by comparing the weight of BAG before and after the treatment. The BAG fillers or UA coated BAG fillers were incorporated into the matrix as 10% of total weight of filler content.

To incorporate the ursolic acid into resin matrix, the ursolic acid was dissolved

with TEGDMA then BisGMA was added as 50:50 ratio in UA Monomer groups (BAG + UA Monomer group and UA BAG + UA Monomer group).

Table 1. Filler and matrix compositions of experimental groups

Groups	Filler (%)				Matrix (%)
	Glass	OX50	BAG	UA	
Control	61	10	0	0	29
BAG	61	0	10	0	29
UA BAG	61	0	9.5	0.5	29
BAG + UA Monomer	61	0	10	0	29 (0.5% UA included)
UA BAG + UA Monomer	61	0	9.75	0.25	29 (0.25% UA included)

The composition of matrix used in this study was 49.38% of BisGMA, 49.38% of TEGDMA, 0.40% of CQ, 0.80% of EDMAB, and 0.05% of MEHQ.

Control : silica nanofillers

BAG : bioactive glass

UA : ursolic acid

BisGMA : bisphenol A diglycidyl methacrylate

TEGDMA : triethylene glycol dimethacrylate

CQ : camphorquinone

EDMAB: amine-ethyl-4-dimethylaminobenzoate

MEHQ: monoethyl ether hydroquinone

UA BAG group : Ursolic acid was coated to BAG fillers

BAG + UA Monomer group : Ursolic acid was dissolved in resin matrix

UA BAG + UA Monomer group : Ursolic acid was added both BAG filler and resin matrix

2. Preparation of experimental teeth

Twenty-five freshly extracted human third molars, free of caries and structural defects, were selected for this study. Immediately following extraction, the teeth were placed in saline and the teeth were not allowed to be dried during any stage of the experiment. After the roots of each teeth were cut off, the crown portions were cut in halves mesiodistally and trimmed the cutting plane to adjust for height of specimen at 4mm. Rectangular cavities (3.5 mm × 2 mm × 2 mm) were prepared in the middle third of the buccal or lingual surfaces of all specimens, with a cylindrical plain cut diamond bur (838RM.314.007; Komet Dental, Lemgo, Germany) with high speed handpiece under copious water spray. To standardize the dimension of cavities, all the preparation were performed with prefabricated stainless steel molds.

The prepared specimens were soaked in 70% ethyl alcohol for 24 hours (Dummer et al., 1982) and ultrasonicated for 30 seconds, washed with distilled water.

All cavities were cleaned with water and air dried. Enamel cavity margins were selectively etched with 37% phosphoric acid gel (ETCH-37^{TM}; Bisco Inc, Schamburg, IL, USA) for 15 seconds then washed for 30 seconds and dried thoroughly. Clearfil SE bond (Kuraray Medical, Inc., Tokyo, Japan) was applied on the cavities of the specimens. According to the manufacturer's instructions, the primer agent was applied to the cavity for 20 seconds and gently air-dried. The bonding agent was then applied, gently air-dried, and light-cured for 10 seconds.

Afterwards, the specimens were randomly divided into five groups (n=10) and restored with experiment composites. Resin composite was inserted into the cavity in one increment and light-cured for 40 seconds. The filled cavity was finished and polished with Soflex (3M, St Paul, MN, USA) to remove the overlying composite on the margin. All preparation and restoration procedures were performed under the operating microscope (OPMI PICO; Carl Zeiss, Göttingen, Germany) at 10 times magnification.

3. Lesion production

Each tooth surface was coated with acid-resistant nail varnish except for the restoration and 1 mm peripheral zone around the restoration. Before starting lesion production, all the specimens were sterilized with ethylene oxide gas (Fontana et al., 1996).

Prior to start the artificial caries model, medium and artificial saliva for the incubation were prepared. 37g of BHI and 10g of sucrose were dissolved into the distilled water to manufacture one liter of culture medium of which carbohydrate concentration to be 1%. The composition of manufactured artificial saliva was as follows. One liter of distilled water contained 2.2g Gastric musin, 0.381g NaCl, 0.213g $CaCl_2$, 0.738g KH_2PO_4, 1.114g KCl (Sigma Aldrich, St. Louis, MO, U.S.A.) and was adjusted to a pH of 6.8 (Hae-Sun Kim, 2011). Manufactured media and saliva were sterilized by autoclaving and kept in cold storage.

S. mutans biofilm induced artificial caries model was used to create carious-

like lesions around composite restorations of the experimental teeth (Guggenheim et al., 2001; Guggenheim et al., 2004). The specimens were incubated in vitro with the cariogenic bacteria *S. mutans* in a mixture of artificial saliva and medium containing 1% carbohydrate for 5 days. The microorganism used for this study was *Streptococcus mutans* ATCC 25175.

The experiment, including the preparatory phase, lasted for 5 days. The summarized diagram of the experimental steps is shown in Figure 1.

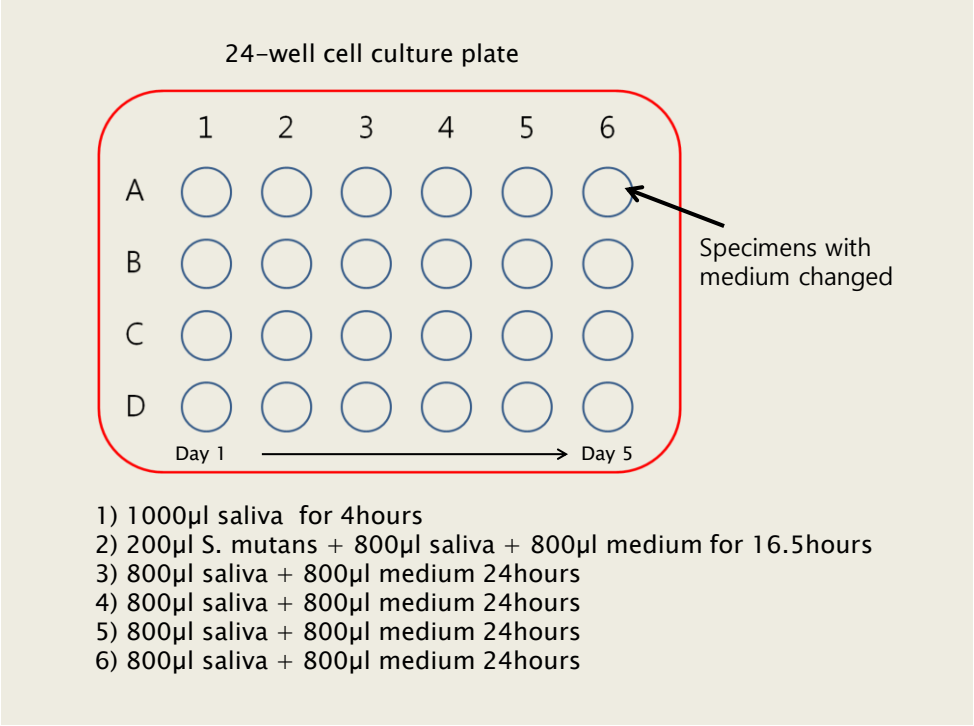

Fig. 1. Schematic presentation of experimental procedures used for biofilm induced artificial caries model.

24-well cell culture plates were used for incubating the specimens. The specimens were preconditioned with 1000 μL of artificial saliva for 4 hours, at

37°C and then they were transferred to new wells containing a fresh mixture of saliva (800 μL) + medium (800 μL). At this time, the wells were also inoculated with the pooled *S. mutans* species (200 μL) and incubated in CO_2 chamber at 37°C for 16.5 hours. After 16.5 hours, specimens were transferred to new wells containing a fresh mixture of saliva (800 μL) + medium (800 μL) and again incubated in CO_2 chamber at 37°C for 24hours. This process was repeated three times, renewing saliva and medium at 24 hour intervals, so that by the end of the experimental period the teeth had been subjected to four days of challenge. Above procedures were conducted twice to confirm the reproducibility of the model.

4. Lesion examination and measurement

All the specimens were examined and recorded by quantitative light-induced fluorescence (QLF) before and after the lesion formation. All the specimens were previously confirmed that are free of any crack or defects using QLF examination. During the intervals for examination, the specimens were individually mounted on wet sponge jig which enabled the specimens to be stored in a humidified environment.

At the end of the experiment for artificial caries formation, the teeth were removed from the well plates and cleaned of adherent microbial deposit. Macroscopic examination of the exposed enamel border around each restoration revealed a white, opaque region resembling that observed in early natural white spot caries lesions. For QLF analysis, the demineralized specimens were gently

dried for 15 seconds with an air syringe and photographed with QLF-D Biluminator™ 2 (Inspektor Research Systems bv, Amsterdam, Netherlands) (Figure. 2) on a black background. The distance between the tooth surface and camera sensor was fixed equally for all specimens.

An image analysis software QA2 (Inspektor Research Systems bv, Amsterdam, Netherlands) was used for display, storage, and subsequent analysis of images. To quantify the fluorescence losses of white spot lesions, the area of interest was defined as 1mm outside the restorations excluding composite restorations. The lesion area was selected using a user-defined patch with borders placed on sound enamel surrounding the lesion. The sound fluorescence radiance values inside the patch were reconstructed through two-dimensional linear interpolation of sound enamel values on the patch borders. The decrease in fluorescence is determined by calculating the percentage difference between actual and reconstructed fluorescence surface.

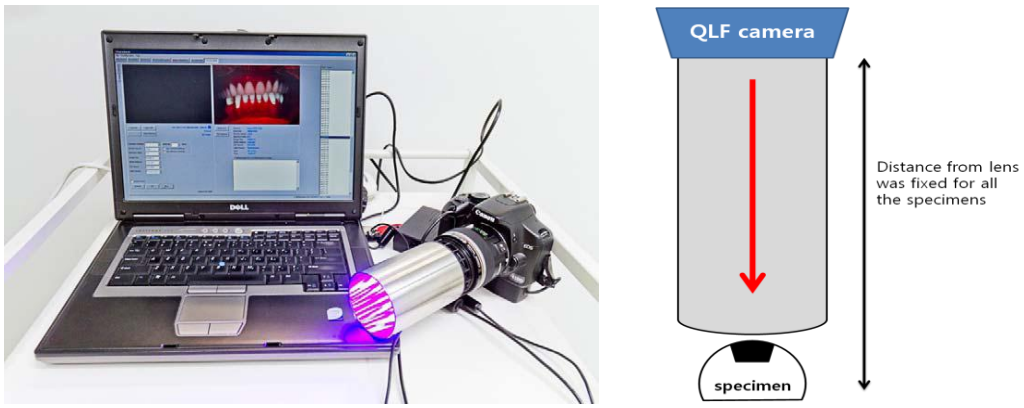

Fig. 2. The device and analyzing software of QLF-D Biluminator™ 2.

5. Statistical analysis

One-way ANOVA followed by the Bonferroni correction were used to statistically analyze the data. Statistical analyses were performed using SAS software version 9.2 (SAS Institute Inc., Cary, NC, USA). The adjusted P value less than 0.05 was considered to be statistically significant.

III. Result

After 5 days of incubation, all the specimens showed the white, opaque appearance on enamel surface around the restorations resembling natural white spot lesions. They showed fluorescence radiance drop of more than 5% which was considered caries (van der Veen and de Josselin de Jong, 2000).

The mean fluorescence loss of the specimens are summarized in Table 2, Figure 3 and 4. QLF can measure the fluorescence radiance loss (-%) and lesion size (pixel) as well as total fluorescence loss (-%·Px) to describe lesion severity. ΔF (-%) represents the mean loss of fluorescence radiance and ΔQ (-%·Px) represents total fluorescence loss integrated over the lesion area and calculated as multiplication of the lesion area (pixel) and the mean change in fluorescence radiance (-%). As shown in figure 3 and 4, mean fluorescence loss (ΔF) and the total fluorescence loss (ΔQ) of experimental groups significantly decreased than control group, but there was no significant difference among experimental groups. Based on ΔQ results, the BAG + UA Monomer group showed the lowest value, but there was no significant difference among other

experimental groups.

Table 2. Distribution of ΔF and ΔQ for experimental groups

Group	ΔF (Mean ± SD)	ΔQ (Mean ± SD)
Control	20.04 ± 1.26[a]	9730 ± 2164.66[c]
BAG	16.62 ± 2.25[b]	3754 ± 1281.72[d]
UA BAG	15.18 ± 1.00[b]	3492 ± 1054.13[d]
BAG + UA Monomer	15.46 ± 1.50[b]	2490 ± 705.62[d]
UA BAG + UA Monomer	16.06 ± 1.75[b]	3564 ± 747.71[d]

ΔF : The mean fluorescence loss over the artificial lesion area

ΔQ : The total fluorescence loss over the artificial lesion area

The values with the same letter in each category were not significantly different (P > 0.05).

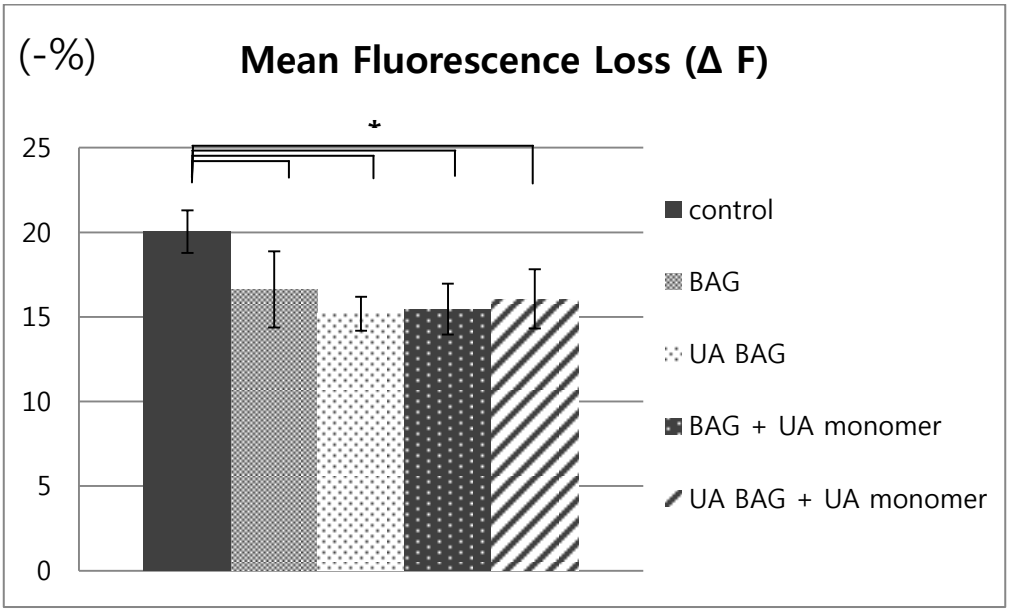

Fig. 3. Mean fluorescence loss (−%).

Significant differences between groups at the 95% level are indicated by *.

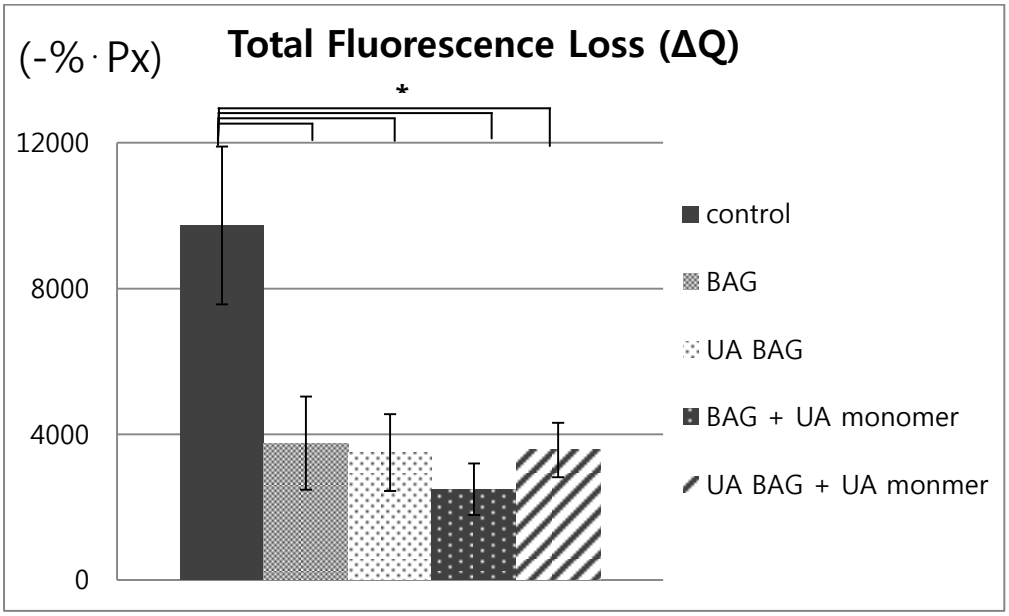

Fig. 4. The total fluorescence loss over the artificial lesion area (−%·Px).

Significant differences between groups at the 95% level are indicated by *.

IV. Discussion

In the previous study (Kim, 2013), experimental BAG groups had initial antibacterial effect against *S. mutans* biofilm formation comparing to control, and UA showed additional effects on reducing biofilm formation. Therefore, the purpose of this study was to evaluate these materials have a possibility of preventing the recurrent caries around the restorations in natural teeth. For this purpose, artificial caries lesions were induced on teeth specimens by *S. mutans* biofilm.

Artificial caries models can be achieved by very simple and cost-effective chemical models which use an acidic environment to demineralize the tooth (Silverstone et al., 1988a, 1988b). However their applicability is limited to factors which directly influence the de- and remineralization process and they do not simulate the in vivo situation. Since it is widely accepted that *S. mutans* plays an important role in both the development of primary and secondary caries, it has been utilized in in vitro bacterial systems for the production of caries-like lesions (Deng and ten Cate, 2004; Noorda et al., 1985). Bacterial systems where the mixed natural flora are controlled by in vitro environmental and nutrient conditions provide a means for studying complex microbial ecosystems such as dental plaque and its effect on the development of dental caries. Recent developments of artificial caries models seem to be easy to handle, reliable and reproducible (Guggenheim et al., 2004). Therefore, in this study, the artificial caries lesion was induced by the Zurich biofilm model.

QLF was used for quantifying changes in mineral content in artificial caries

model. When the caries developed on the tooth surface, the fluorescence radiance at the lesion decreased. The fluorescence image of enamel with caries lesions can be digitized and then the fluorescence loss in the lesion can be quantified in comparison to the fluorescence radiance level of sound enamel, and relates it directly to the amount of mineral loss during demineralization. The validity, reproducibility and sensitivity of the QLF technique for detection and quantification of caries in enamel have previously been assessed by others comparing to the other caries quantification techniques (Ando et al., 2001; Cochrane et al., 2012; Gmur et al., 2006). Comparative studies in relation to micro-digital-photography (MDP) have been investigated, and both MDP and QLF are able to measure enamel lesion severity in vitro if the surface is intact. But QLF correlated more strongly with the lesion depth measured by polarized light microscopy (PLM) (Meharry et al., 2012).

For QLF analysis, enamel hydration level is considerable factor. These effects are probably due to the changed light scattering in the lesion, which is also demonstrated in the well-known clinical observation that an early white spot lesion can be more easily distinguished from sound enamel when the tooth is air-dried. Pretty et al. showed that the greater the demineralization existing in a lesion, the greater the drying time was needed to get a reliable assessment with QLF (Pretty et al., 2004). The protocol for drying time used in this study was determined to be adequate at 15 s with an air syringe at a distance of 3.4 cm (Meharry et al., 2012)

In the present study, all types of experimental BAG containing composite reins (BAG, UA BAG, BAG + UA Monomer, UA BAG + UA Monomer) show

significantly lower mean fluorescence loss (ΔF) and the total fluorescence loss (ΔQ). This result is similar to the tendency of previous research for antibacterial effect of BAG filler against *S. mutans* biofilm formation (Kim, 2013). However, in a study by Kim, although the difference wasn't considerably large, the lowest CFU value was shown in group 4 (BAG + UA Monomer), and in this study, there was no significant difference in experimental groups.

Stoor et al. showed the powdered BAG possessed a broad antibacterial effect on microorganisms of both supra- and subgingival plaque (Stoor et al., 1998). However when BAG is incorporated in the composite resin, its antibacterial effect can be reduce because the exposed surface area of the BAG was reduced.

The antimicrobial effect of BAG is largely a function of their ability to raise the pH in aqueous suspension. The release of Ca^{2+} ions from and the incorporation of H_3O^+ protons into the corroding BAG results in a high pH environment. This change interferes with microbial viability (Waltimo et al., 2007), and acts as a buffer against the acidic products from carbohydrate metabolism by *S. mutans.* (Takahashi and Nyvad, 2011). Furthermore, the release of silica, Ca, and P ions, which allowed the BAG to mineralize the bacteria i.e. from Ca/P precipitates on their surface, thereby destroying their cellular integrity (Zehnder et al., 2006). Additionally, the BAG used in this study has fluoride and another mechanism of antibacterial effect can be induced by fluoride-releasing. This property can reduce the biofilm formation on the composite surface also (Kim, 2012).

Besides its antibacterial effect, ion exchange and release from BAG has been studied in simulated body environments. These ions will increase the level of super saturation with respect to apatite. The remineralization process induced

by the BAG used in this study were probably due to a bioactive reaction characterized by Silica ion release. A subsequent polycondensation reaction induced by precipitation of calcium and phosphates. The reaction of polycondensation forms H_2O which remains physically bonded with the SiO. Si surface forming the hydrated silica rich layer. The polycondensated silicon rich layer (Si-gel) then precipitates into an amorphous $CaO.P_2O_5$ by the incorporation of soluble Ca and PO_4 ions. The further incorporation of various mineral ions from artificial saliva helps the amorphous $CaO.P_2O_5$ to convert into apatite (Wang et al., 2011). Under these conditions, apatite can be expected to form at the interface on the BAG surface and in the demineralized zone created by *S. mutans*.

In the present study, there are no advantageous effects of ursolic acid were seen when these powders were added with a filler or matrix of composite resins. In the study by Won(Won, 2013), UA alone showed anticariogenic effect without BAG. However, in comparison with the result obtained in this study, the effect of BAG was more effectively worked than UA during the early period of restoration. Thus, it may seem that the UA-containing group rarely has any effect on preventing caries. However, when the long-term anticariogenic effect is evaluated, the addition of hydrophobic UA may be of advantage after the total release of BAG ions. Although ursolic acid has antibacterial effect, this study evaluated not antibacterial effect but anticariogenic effect on artificial caries model. The experimental composites with the immobilized ursolic acid have been demonstrated to show antibacterial effects against *S. mutans* after being cured without releasing any antibacterial components. Unlike BAG, ursolic acid has no

effect of remineralization of demineralized zone around restoration. Therefore, in this study, ursolic acid represented a minimal effect for demineralization compared to the BAG.

There are several limitations in present study. Artificial caries were induced for 10 days in this study. However, long term ability of ursolic acid-containing composite resin needs to be evaluated in further study. Although this model used bacterial biofilm to produce carious lesions in well plates, it cannot be an optimal simulation of the oral environment. For instance, this experiment was carried only with a single bacterium *S. mutans* not considering the microbial interactions between oral bacteria. Attempts are required to mimic the diverse conditions present in the oral cavity which may affect dental caries development. This study evaluated the degree of outer lesion formation in the enamel around the restorations of composite resin containing ursolic acid. However, the secondary caries lesion consists of outer lesion as well as wall lesion, which is a narrower defect in the enamel or dentin along the cavity wall-restoration interface. Further investigation about the wall lesion around the restoration will allow the direct effect of ursolic acid-containing composite on inhibiting secondary caries to be understood.

V. Conclusion

Within the limitation of this study, the experimental composite resins containing bioactive glass and/or ursolic acid can inhibit the artificial caries induced by *S. mutans* biofilm around the restoration.

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국문 요약

Bioactive glass 와 ursolic acid 가 포함된 복합레진 수복물 주변의 인공 우식 억제 효과

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김 현

1. 서론

복합레진 수복 실패의 주된 원인은 수복물 주변의 이차 우식 형성이다. 수복물 주변 이차 우식 형성을 예방하기 위한 한 방법으로 세균 피막 형성을 억제하는 항균성 수복물질을 사용할 수 있다.

이 연구의 목적은 항균물질로 알려진 생활성(生活性) 유리와 우르솔릭산이 첨가된 복합레진이 수복물 주변의 인공 우식 형성을 억제하는 효과가 있는지 알아보는 것이다.

2. 본론

충진재로 생활성 유리를 첨가한 복합레진 4 가지를 제작하였다. 생활성 유리군과 생활성 유리 충진재에 우르솔릭산을 첨가한 군, 레진 기질에 우르솔릭산을 첨가한 군,

그리고 생활성 유리 충진재와 레진 기질 양쪽 모두에 우르솔릭산을 첨가한 군을 실험군으로 하여 대조군의 일반 복합레진과 비교하였다. 50 개의 인간 발거 대구치의 시편에 표준와동 (3.5 mm × 2 mm × 2 mm)을 형성하고 항균 물질을 함유한 각 군의 실험 레진으로 수복하였다. Streptococcus mutans 에 의한 인공 우식 모델을 이용하여 실험 시편상에 인공 우식 병소를 유발하였다. Quantitative light-induced fluorescence (QLF)를 이용하여 수복물 변연 주변의 법랑질 탈회를 정량적으로 분석하였다. 탈회 시편을 QLF-D BiluminatorTM 2 (Inspektor Research Systems bv, Amsterdam, Netherlands)로 촬영하고, Image analysis software QA2 (Inspektor Research Systems bv, Amsterdam, Netherlands)를 이용하여 촬영된 상의 형광 소실 정도를 비교하였다.

3. 결과

실험군 레진의 평균 형광 소실량 (ΔF)과 총 형광 소실량 (ΔQ)은 대조군에 비해 낮았으며 실험군 간의 통계적 유의차는 없었다.

4. 결론

본 실험연구의 결과에 의하면, 생활성 유리와 우르솔릭산을 첨가한 복합레진 수복물은 수복물 주위로 S. mutans 에 의해 유발되는 우식 형성의 억제효과를 기대할 수 있다.

Key words : bioactive glass, ursolic acid, antibacterial composite, QLF