Experimental brush wear pattern and cariostatic effect of Biscover

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Objective: The aim of this study was to investigate the experimental brush wear pattern of a light cured surface sealant, Biscover (Bisco, Schaumburg, IL), and to evaluate its cariostatic effect. **Methods:** Caries-free human premolars were used for the Biscover coating group (n = 90) and the control group (n = 10). The Biscover coating group was randomly assigned to nine subgroups of 10 each and the control group was assigned to two subgroups of 5 each according to the number of brushing strokes. An experimental 3-body wear test was conducted under different strokes of wear test. Tooth-brushing was accomplished with movement of each brush head set at a frequency of 100 rpm under a force of 1.5 N. Surface roughness was tested before, and after Biscover coating, and after brushing. Then, each of the 10 teeth of both groups were placed in artificial caries inducing solution for 7 days. All tooth surfaces were assessed using scanning electron microscopy. **Results:** Biscover coated surfaces showed a smoother texture than enamel surfaces. The roughness was increased after experimental brushing and after 10,800 brushing strokes, the whole layer of Biscover wore out. However, teeth in the Biscover coating group had a cariostatic effect in cariogenic conditions. **Conclusions:** We suggest that white lesions in orthodontic patients can be suppressed by topical applications of Biscover. **(Korean J Orthod 2008;38(3):214-222)**

Key words: Surface sealant, Wear test, Cariostatic effect, Biscover

INTRODUCTION

Composite resins are predominantly used to bond orthodontic brackets to teeth.[1] However, despite advances, surfaces that had orthodontic brackets bonded with composite resin exhibited micro-irregularities that inherently lead to material wear, deterioration, and marginal infiltration. Far too often a less-than-optimal esthetic result occurs after orthodontic treatment due to demineralization of enamel adjacent to fixed orthodontic appliances in patients with inadequate oral hygiene.[2]

Although a thin layer of orthodontic bonding monomer prevents bacterial plaque from making direct contact with the enamel surface, its low wear resistance after prolonged tooth brushing would ultimately enhance bacterial plaque accumulation.

The so-called surface sealant was developed to increase the wear resistance of resin restorations[3,4] and to enhance surface smoothness.[5] This approach is assumed to provide a more uniform, regular surface, thereby enhancing surface smoothness.[6,7] In addition, the coating resin would be capable of penetrating deeply into the interfacial micro-gaps, thus providing improved marginal sealing.[1,8,9] Biscover, a newly devel-

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oped material, is a light cured surface sealant used to seal restorations while leaving a smooth polished surface. Biscover has the general properties of surface sealants such as improved wear resistance and smooth surface texture, and it cures without leaving a sticky oxygen inhibited layer. Therefore better resistance for plaque accumulation would be expected than the traditional bonding monomer.

Recently, Song[10] evaluated the bonding strength of metal orthodontic brackets applied with Biscover as a substitute bonding monomer. Shear or tensile bonding strength of Biscover was significantly higher than Transbond XT monomer. Biscover was proved to be useful as an orthodontic bonding monomer.

However, to replace the orthodontic bonding monomer used in bracket bonding procedures to Biscover, it must be proved first that the Biscover coated surface has a sufficient hardness against wear out, and that it still has a smooth surface texture after wearing out under tooth brushing conditions. Moreover, even after the Biscover coating layer is worn out by tooth brushing, the altered tooth surface should not be more susceptible to dental caries than natural enamel surfaces under cariogenic circumstances.

Table 1. Composition of Biscover

Ingredients	Content (weight %)
Ethoxylated bisphenol-a-diacrylate	20 - 50
Urethane acryl ester	20 - 40
Polyethleneglycol diacrylate	20 - 40

The objectives of this study were to study the in vitro brush wear behavior of Biscover and to evaluate the cariostatic effect of Biscover by examining the surface sealing potency to the enamel surface in artificial caries solution.

MATERIAL AND METHODS

The material used for this study was a light cured surface sealant, Biscover (Bisco Schaumburg, IL, USA). Biscover cures without leaving a sticky oxygen inhibited layer by using a special polymerization initiator (Table 1).

Teeth preparation

One hundred extracted caries-free human premolars were obtained. Only the buccal segments were embedded in orthodontic acrylic resin using a mold (Fig 1), then the teeth were divided into two groups: Biscover coating group (n = 90) and Control group (n = 10) (Table 2).

Biscover coating group

Teeth in the Biscover coating group were polished with a mixture of nonfluoride pumice and water, rinsed copiously, then randomly assigned to nine subgroups of 10 each (B1 - B9) according to the number of brushing strokes (B1, 0; B2, 450; B3, 900; B4, 1,800; B5, 2,700; B6, 5,400; B7, 8,100; B8, 10,800; B9, 21,600 strokes).

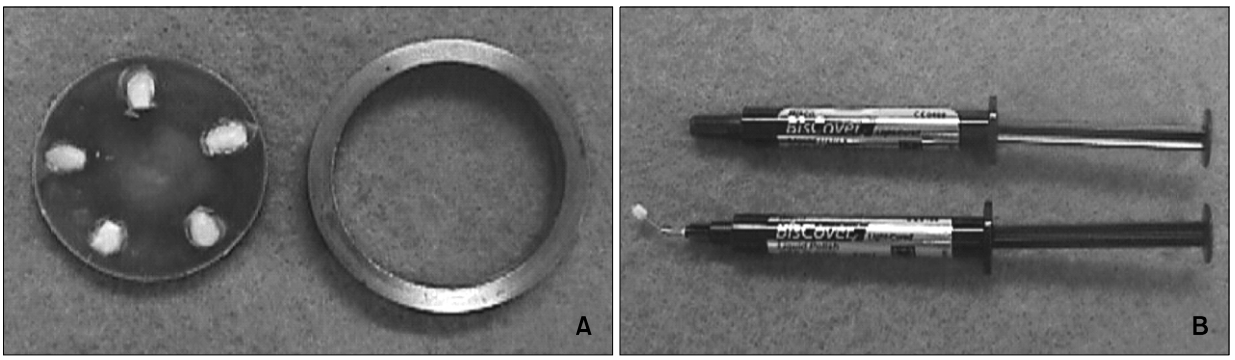

Fig 1. Specimens and Biscover. **A,** Teeth in resin block and mold (diameter, 50 mm; height, 10 mm); **B,** Biscover syringe type.

Table 2. Classification of specimen

	Groups	N	Brushing strokes	Cycles	Months
Biscover coating	B1	10	0	0	0
	B2	10	450	150	0.5
	B3	10	900	300	1
	B4	10	1,800	600	2
	B5	10	2,700	900	3
	B6	10	5,400	1,800	6
	B7	10	8,100	2,700	9
	B8	10	10,800	3,600	12
	B9	10	21,600	7,200	24
Controls	C1	5	10,800	3,600	12
	C2	5	21,600	7,200	24

10 brushing strokes per tooth/after meal; 30 brushing strokes/day (10 × three meals = 30 strokes); 900 brushing strokes/month (30 × 30 day = 900 strokes); 10,800 brushing strokes/year (900 × 12 months = 10,800 strokes); 3 brush strokes = 1 cycle rotation.

Teeth in the Biscover coating group were etched with a 37.5 % phosphoric acid gel for 15 seconds and rinsed thoroughly for 15 seconds and excess water removed with a mild oil free air stream for 10 seconds. A uniform layer of Biscover was applied over the etched area using a 22 gauge needle brush-tip for 10 seconds, gently air-thinned for 5 seconds and light cured for 15 seconds. Curing light was held 1 - 2 mm away from the surface to be cured, as recommended by the manufacturer's instructions, using a visible light curing unit with a 500 mW/cm^2 output (Optilux, Demetron, Danbury, CT, USA). The specimens were then stored in distilled water at room temperature for 7 days.

Control group

Teeth in the control group were also prophylactically polished with a mixture of nonfluoride pumice and water, rinsed copiously, then assigned to two subgroups of 5 each (C1 and C2) according to the number of brushing strokes (C1, 10,800; C2, 21,600 strokes).

Brushing schedule

An in vitro 3-body wear test was conducted on each specimen under different wear test cycles (Fig 2) and a pin-on-disk type wear tester (Model KD-WT02, Kwangduck FA. Gwangju, Korea) was used to simulate tooth brushing.

As an abrasive agent, a suspension of dentifrice and deionized water was prepared in a 2 : 1 ratio at room temperature. Both slurry and tooth brush heads were replaced for every new sample, every 3,600 cycles. Tooth-brushing was accomplished at a frequency of 100 rpm with movements of the tooth brush heads under a force of 4.5 N (each brush head under 1.5 N). Each group of specimens was subjected 450, 900, 1,800, 2,700, 5,400, 8,100, 10,800, and 21,600 strokes.[11,12,16-18]

Roughness examination

Initially, teeth in the Biscover coating group were subjected to a surface roughness reading to determine the initial enamel roughness in a roughness meter (Form Taly surf, Rank Tayler-Hobson Co, England) before Biscover coating. Each tooth was carefully fixed on a metallic support, with the needle situated at the extremity of the equipment's arm positioned on the sample surface and programmed to trace a course of 0.8 mm, with a cut-off value of 0.25 mm. Subsequently, the average surface roughness (Ra, μm) and peak surface roughness (Ry, μm) of enamel surface, Biscover

coating surface, and brushed surface were examined.

The collected data were analyzed by using SPSS (ver 10.0) program.

Artificial caries examination

After evaluation of roughness, every 5 teeth that had the same brushing cycle performed was randomly chosen from C1, C2, B8, and B9 groups. After that they were placed in artificial caries solution (2.2 mM Ca^{2+}, 2.2 mM PO_4, 50 mM acetic acid, PH 4.4, at 37°C) for 7 days.[21,22]

SEM examination

The teeth in the Biscover coating group were sectioned buccolingually along the axis of the tooth with a microtome (ISOMETTM, Beuhler, Lake Bluff, IL, USA) under running water. Section faces were polished with #1000, #2000 grit SiC polishing paper and 1 μm, 0.3 μm alumina (Beuhler, Lake Bluff, IL, USA). The cross sections and surfaces of the teeth were as-

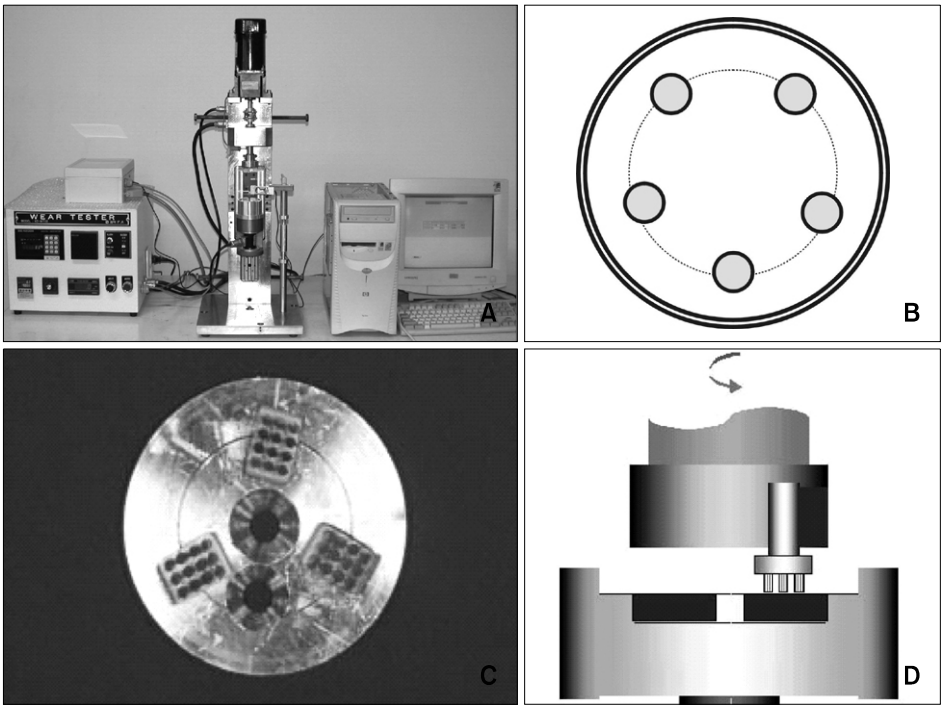

Fig 2. Wear tester. **A**, wear tester, pin on disk type (Model KD-WT02, Kwangduck FA. Gwangju, Korea); **B**, five teeth were subjected to wear tester simultaneously; **C**, tester brush, 3-raw brushes with soft bristles (Gum 311, Jone O Butler, Chicago, IL). Three tester brushes were positioned at 120° intervals; **D**, an illustration of wear test and tooth paste (Perio A+ Total effect tooth paste; LG Chemical Co, Seoul, Korea).

Table 3. Mean and standard deviations of surface roughness

Roughness (μm)	Enamel	Biscover coating	After brushing
Ra	0.190 ± 0.092*,‡	0.019 ± 0.006*,†	0.062 ± 0.017†,‡
Ry	1.022 ± 0.445*,‡	0.116 ± 0.033*,†	0.373 ± 0.089†,‡

Ra, average surface roughness, Ry, peak surface roughness; *statistically significant difference between enamel and Biscover coating ($p < 0.001$); †statistically significant difference between Biscover coating and after brushing ($p < 0.001$); ‡statistically significant difference between enamel and after brushing ($p < 0.001$).

sessed using scanning electron microscopy (SM-350, Topcon, Tokyo, Japan) (× 500, × 2,000) after gold coating (IB-3, Eikoengineering, Ibaraki, Japan) to explore the nature of the wear pattern of Biscover under cyclic loading conditions and to assess the caries protecting ability of Biscover.

RESULTS

Surface roughness

The average surface roughness (Ra) of the enamel surface was 0.190 0.09 μm and the peak surface roughness (Ry) was 1.022 0.445 μm. After Biscover coating, Ra (0.019 0.006 μm), Ry (0.116 0.033 μm) values were significantly diminished. After brushing, Ra (0.062 0.017 μm), and Ry (0.373 0.089 μm) values were increased ($p < 0.001$) (Table 3).

There were statistically significant differences among the test stages (enamel, after Biscover coating, after brushing). One-way analysis of variance (ANOVA) indicated that the initial Biscover coating surface had a significantly lower roughness than the enamel surface ($p < 0.001$), the brushed surface after Biscover coat-

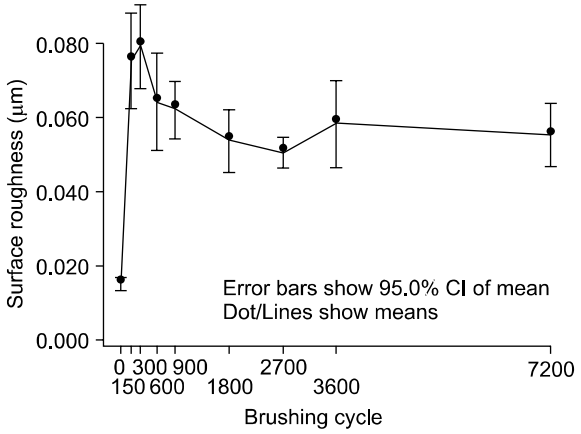

Fig 3. Surface roughness of Biscover coating groups according to the brushing cycle.

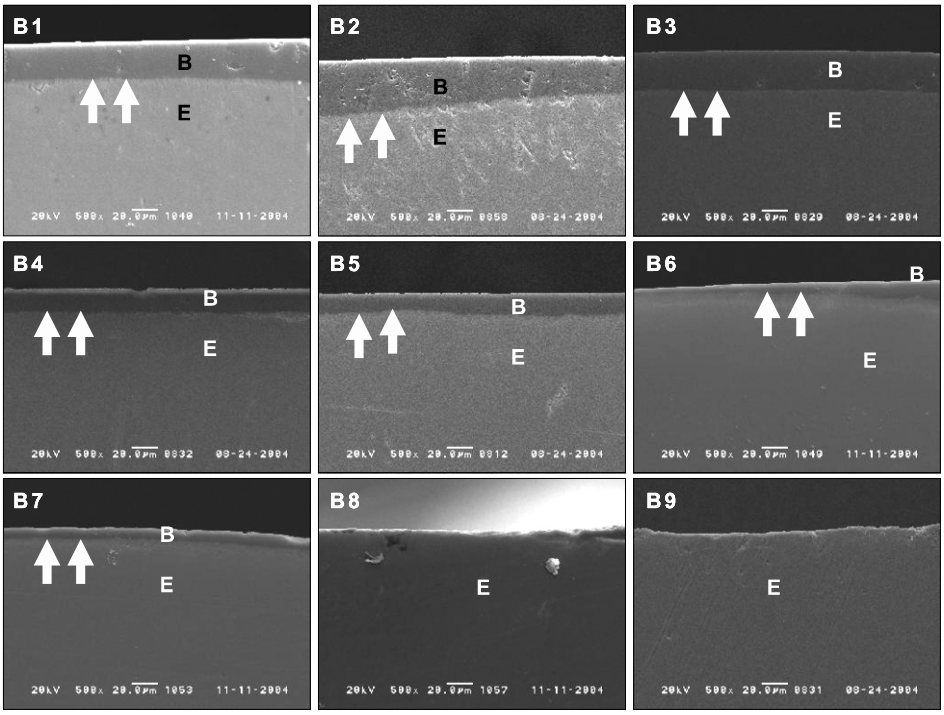

Fig 4. SEM micrographs of the section faces of Biscover coated teeth. Before brushing & after brushing (× 500). **B1**, no brushing strokes (0 month); **B2**, 450 brushing strokes (0.5 month); **B3**, 900 brushing strokes (1 month); **B4**, 1,800 brushing strokes (2 months); **B5**, 2,700 brushing strokes (3 months); **B6**, 5,400 brushing strokes (6 months); **B7**, 8,100 brushing strokes (9 months); **B8**, 10,800 brushing strokes (12 months); **B9**, 21,600 brushing strokes (24 months). Abbreviations, B, Biscover; E, enamel; arrow, border line between Biscover and enamel.

ing had significantly higher roughness than the initial Biscover coating surface ($p < 0.001$), and the brushed surface after Biscover coating had a significantly lower roughness than the enamel surface ($p < 0.001$) (Table 3).

However, there was no statistically significant difference in roughness among the Biscover coating groups after brushing (Fig 3).

SEM examination of the cross-section surface

The Biscover coating layer was gradually worn away by tooth brushing. As brushing strokes increased, the thickness of the Biscover layer diminished. After 3,600 cycles (10,800 brushing), almost all the Biscover layer was worn out, and the enamel surface was exposed (Fig 4).

SEM examination of the brushed surface

The Biscover coating surface showed luster. After brushing, the surface had a scale-shaped appearance which followed the brushing pathway. After 3,600 cycles (10,800 brushing), the enamel surface was exposed (Fig 5).

Artificial caries examination

After 7 days, formation of early white lesions could be seen on the natural tooth with the naked eye. A clear difference was seen between the luster surface of the Biscover coating group tooth and chalky surface of the control group tooth.

On surface observation by SEM, all teeth in the Biscover coating group (3,600, 7,200 cycled) showed a smooth surface. All teeth in the control group (3,600, 7,200 cycled) showed a rough surface similar to a phosphoric acid etched surface (Fig 6).

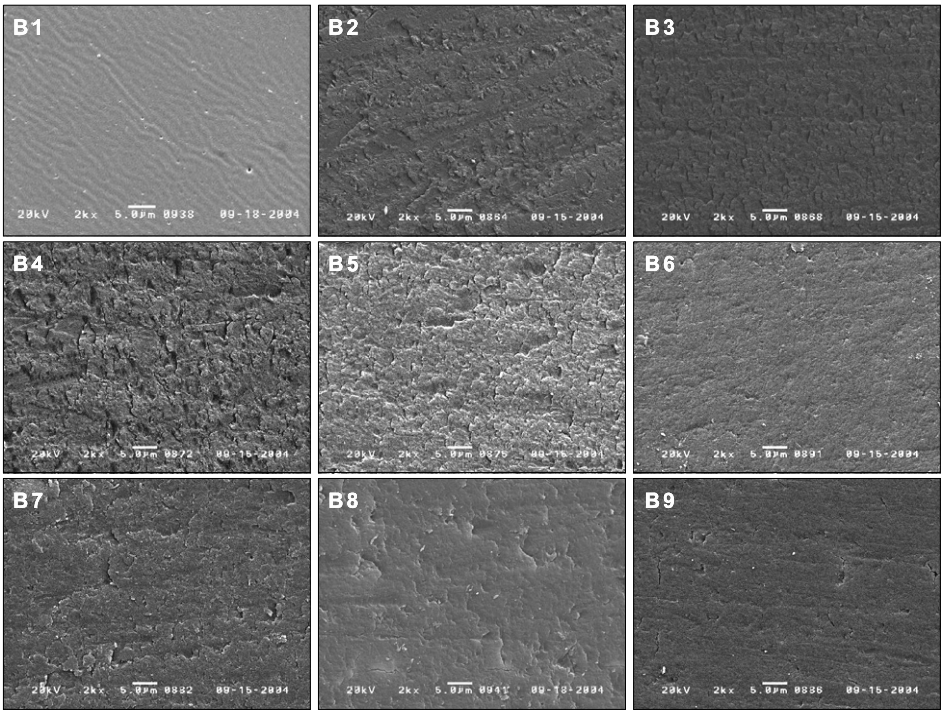

Fig 5. SEM micrographs of the surface of Biscover coated teeth. Before brushing & after brushing (× 2,000). **B1**, no brushing strokes (0 month); **B2**, 450 brushing strokes (0.5 month); **B3**, 900 brushing strokes (1 month); **B4**, 1,800 brushing strokes (2 months); **B5**, 2,700 brushing strokes (3 months); **B6**, 5,400 brushing strokes (6 months); **B7**, 8,100 brushing strokes (9 months); **B8**, 10,800 brushing strokes (12 months); **B9**, 21,600 brushing strokes (24 months).

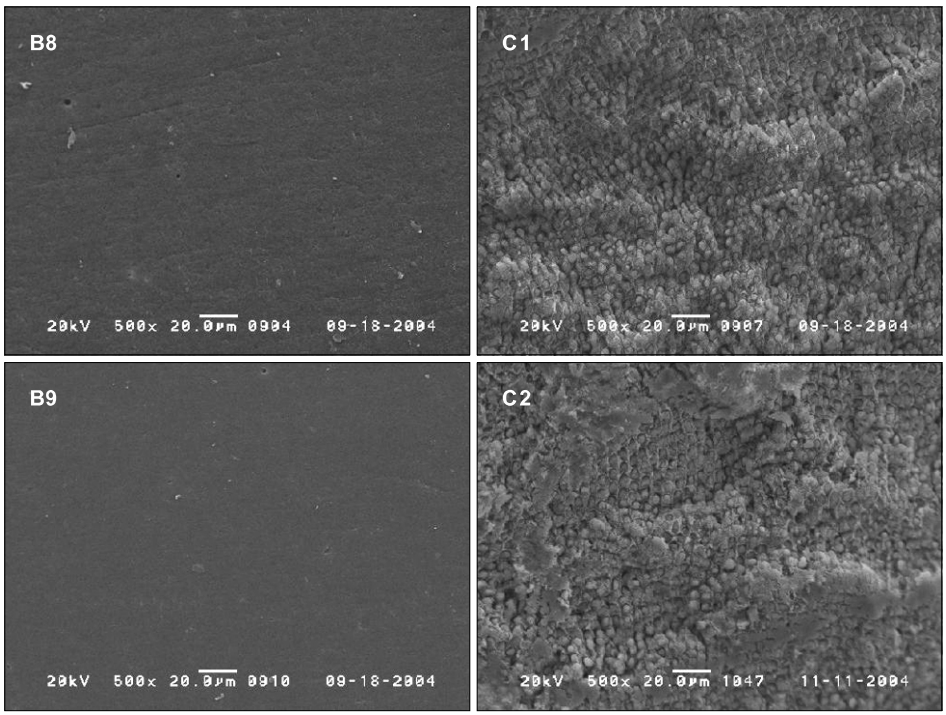

Fig 6. SEM micrographs of the surface of Biscover coating group & control group after artificial caries examination (× 500). **B8** and **C1**, 10,800 brushing strokes (12 months); **B9** and **C2**, 21,600 brushing strokes (24 months).

DISCUSSION

SEM showed a more noticeable improvement in the surface texture on the Biscover coated surface than the enamel surface. Also the roughness meter showed an enhancement of surface smoothness after Biscover coating. After brushing, the roughness increased but was lower than the enamel surface. This observation is supported by the works of Bertrand et al[3], who used SEM and reported that surface penetrating sealant enhanced surface smoothness, and dos Santos et al[7], who used a roughness meter and reported that surface penetrating sealant effectively decreased the surface roughness.

The arbitrary number of brushing strokes and months have to be considered. In this study 10,800 brushing strokes corresponded to a one-year brushing exposure. Lee[11] calculated the 10,000 brushing strokes correspond to an one-year brushing exposure. But, Takeuchi et al[12] used 17,800 brushing per year. Takeuchi et al[12] used a back-and-forth reciprocating device, but Lee[11] used a rotary device.

For brushing force, our study used 1.5 N per brush. Recently, McCracken et al[13] observed in a range from 0.75 to 3.0 N that the improvement in plaque removal using a power toothbrush with forces in excess of 1.5 N was negligible. Van der Weijden et al[14,15] reported that mean brushing forces in 35 subjects were 1.75 ± 0.6 N. They also said that no brushing lesions were observed in those individuals that had a brushing force equaling 2 N. If the brushing force was $>$ 2 N co-factors such as brushing time, brushing method and frequency of brushing appeared to be associated with respect to acute brushing lesions. Heasman et al[16] concluded that toothbrush forces are unaffected by placing fixed orthodontic appliances in children. So 1.5 N in this study was an adequate load for the brushing test. For brushing speed, this study used 100 rpm. A number of studies used various speeds ranging from 80 rpm to 5,000 rpm.[12,17,18] In the next study, this must be a point to be considered.

The wear loss increased in a roughly linear relationship with applied length of time. Although the layer of Biscover wore out after 10,800 or 21,600 brushing

strokes, the exposed enamel surface showed a lower roughness than natural enamel surface.

Although roughness was increased by partial exposure of enamel surface after 10,800 strokes, there was no significant difference in roughness from the tooth brushing cycle. Moreover, it also showed lower surface roughness than natural enamel.

Davidson and Bekke-Hoekstra[19] demonstrated that resin tags were present in the remaining surface enamel after partial mechanical removal of the sealant. It can be suggested that the lower roughness value of the exposed enamel surface is related to the remaining Biscover tag.

There was no statistically significant difference in roughness among the brushing strokes. Takeuchi et al[12] showed that the use of a dentifrice and toothbrush resulted in significant alterations to the surface smoothness. Roughness after brushing in this study was the result of the unique dentifrice particle and brushing force combination.[20] So, no linear relationship was shown between roughness and brushing strokes.

In artificial caries test, Vorhies et al[21] and Todd et al[22] used caries solution supplemented with 2.2 mM Ca^{2+}, 2.2 mM PO_4, 50 mM acetic acid, and a pH of 4.4.[23] Both the Biscover coating group and the control group were brushed for the same period. The Biscover coated layer was removed and the enamel surface exposed after 10,800 or 21,600 brushing strokes. Except for the effect of fluoride component in toothpaste, teeth in the Biscover coating group were protected to some degree from caries. Davidson and Bekke-Hoekstra[19] proved that teeth can be resistant to carious attack as long as the resin tags were present. It can be surmised from these results that Biscover penetrated deeply into the micro-gaps of etched irregular enamel rods. So after 10,800 or 21,600 brushings (12 or 24 months later), although the outer layer of Biscover was worn out, the Biscover tags inserted into the enamel rods remained and prevented caries formation in enamel. Therefore, there was no necessity for re-coating of Biscover, during the average of two years of orthodontic treatment period.

This study suggests that white lesions from orthodontic patients can be suppressed effectively by topical applications of Biscover. Orthodontists may wish to consider application of Biscover during fixed orthodontic therapy to help reduce the development of enamel white spot lesions.

Nevertheless, further research is necessary to confirm this result. Wear is a complex process that involves several features - masticatory effects, fatigue, friction, erosion and oral health care procedures that interact among themselves. But this study considered only brushing strokes. Therefore, further studies must also be focused on thermocycling,[24] pH cycling, masticatory force, various brushing force and speed, in order to provide the clinician with guidelines for a proper indication and correct handling of Biscover. The abrasion resistance after tooth brushing and the cariostatic effect of Biscover were also evaluated in this study. However no comparisons with conventional orthodontic bonding monomers could be made. Further studies are needed.

CONCLUSION

The results of this study showed that Biscover coated surfaces showed a more noticeable improvement in the surface texture than the enamel surface. After brushing, the roughness increased. There are statistically significant differences among the test stages (enamel, after Biscover coating, after brushing). After 10,800 brushing strokes, although the whole layer of Biscover wore out and the enamel surface was exposed, teeth in the Biscover coating group had a cariostatic effect in cariogenic conditions.

- 국문초록 -

Biscover의 잇솔질에 따른 마모양상과 항우식 효과

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본 연구는 Biscover를 교정학 영역에서 치아우식 예방 목적으로의 활용가능성을 평가하기 위해 Biscover의 잇솔질에 대한 마모 저항성을 평가하였으며, 인공우식용액에서의 치면 변화를 관찰하여 항우식 효과를 평가하였다. 교정치료를 목적으로 발거된 100개의 인간 소구치를 실험에 사용하였으며, 90개의 Biscover coating군과 10개의 대조군으로 분류하였다. Biscover coating 군은 잇솔질 횟수에 따라 무작위로

10개씩 9개의 군(B1 - B9)으로 분류하였으며, 대조군 역시 잇솔질 횟수에 따라 5개씩 2개의 군(C1, C2)으로 분류하였다(B1, 0; B2, 450; B3, 900; B4, 1,800; B5, 2,700; B6, 5,400; B7, 8,100; B8 & C1, 10,800; B9 & C2, 21,600 strokes). 3-body 마모 시험기를 이용해 치아 시편에 대한 잇솔질을 재현하였으며, 100 rpm의 빈도와 1.5 N의 힘을 적용시켰다. Biscover 도포 후 법랑질면의 조도가 유의성 있게 감소되었고, 잇솔질 후에는 증가하였지만, 자연 법랑질보다 낮은 조도를 보였다 ($p < 0.001$). Biscover 도포 후 잇솔질 기간과 표면의 거칠기의 변화 사이에는 상관관계가 없었고, SEM을 이용한 표면과 단면 관찰 시 10,800회 잇솔질 후에 Biscover 층이 모두 마모된 것이 관찰되었다. 그러나, 치아를 인공우식용액에 7일간 침식하여 평가한 결과, 10,800회와 21,600회 잇솔질한 Biscover coating군에서는 매끄러운 표면이 관찰된 반면, 대조군인 자연치면은 심한 탈회가 진행된 소견을 보였다. 이상의 결과를 종합하여, Biscover의 도포는 치면의 활택도를 향상시키며, 적절한 마모저항성을 가지는 것으로 평가되었다. 또한 마모에 의해 Biscover층이 제거된 후에도 자연치면에 비해 우식에 대한 큰 저항성을 가지는 것으로 평가되었으므로, 교정장치의 부착에 있어 이의 적절한 활용이 기대된다.

주요 단어: 표면 실런트, 마모, 항우식 효과, Biscover

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