Influence of Primers Containing Cupric Ion on Bonding of Dentin Treated with Phosphoric Acid

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A primer containing cupric [Cu (II)] ions that promoted the interfacial initiation of polymerization from dentin surfaces was studied. Bovine dentin surfaces were treated with 10% phosphoric acid, then with a Cu primer consisting of aqueous 35% 2-hydroxyethyl methacrylate (HEMA) containing 0.03% cupric salt, and finally bonded with 4-META/MMA-PMMA resin initiated with oxidized tributylborane (TBBO). The use of the Cu primer resulted in a mean bond strength of 12.5 MPa compared with 3.8 MPa without the primer and 6.3 MPa using a 35% HEMA primer without Cu. The Cu primer produced a bond strength of 13.5 MPa even without 4-META in the resin system. Use of the Cu primer should simplify the bonding procedure since enamel and dentin can be etched simultaneously with 10% phosphoric acid.

Key words: Dentin bonding, Primer, Phosphoric acid

INTRODUCTION

There is considerable interest and activity in dentin bonding systems and many products are available. However, adhesion to dentin requires further research to improve clinical performance¹⁾. Most studies of dentin bonding systems have been directed to adhesion-promoting monomers, treatment agents such as etchant, cleanser, and conditioner, as well as primers. The role of polymerization initiator systems in bonding has been studied to a lesser degree, but we and others have stressed the importance of polymerization initiator systems and the interfacial initiation of polymerization to achieve effective adhesion to dentin and to reduce marginal gap and microleakage²⁾.

We have proposed two approaches for causing interfacial initiation of polymerization from the dentin surface. These are the use of metal ions such as ferric or cupric ions adsorbed onto dentin as a component of redox-type initiators and of initiators, having high affinity for dentin.

We investigated the influence of primers containing cupric ions [Cu (II)], that initiate and promote polymerization at the dentin interface, upon dentin bonding after etching with phosphoric acid.

MATERIALS AND METHODS

Materials

The following were used without purification*: 2-hydroxyethyl methacrylate (HEMA), methyl methacrylate (MMA), phosphoric acid, citric acid, ferric chloride, and cupric salts [Cu (II)] of acetate, acetylacetonate, chloride, and nitrate. Cupric methacrylate was prepared from sodium methacrylate and cupric chloride. Oxidized tributylborane (TBBO), 4-methacryloyloxyethoxycarbonylphthalic acid anhydride (4-META), and poly (methylmethacrylate) (PMMA) powder were commercially available**.

Two resin cement formulations (4-META/MMA-PMMA and MMA-PMMA) were prepared: a 1 : 1 (w/w) mixture (this ratio was established by means of the brush-on-technique used in the present resin system) of PMMA and MMA containing 10 wt% TBBO with or without 5 wt% 4-META. The cement containing 4-META was practically the same as the commercially available material#.

Reagents

These included 5, 7, 10, 15, and 40 wt% phosphoric acid and a mixture of 10 wt% citric acid and 3% ferric chloride.

Primers

Five primers containing Cu (II) ions were prepared by adding 0.03 wt% Cu (II) acetate, acetylacetonate, chloride, methacrylate and nitrate in aqueous 35 wt% HEMA as a control primer.

SEM examination of tooth structures

One drop (about 0.05 mL) of 5, 7, 10, 15, or 40 wt% phosphoric acid was applied to the finished tooth surfaces described below for 15, 30, or 60 s. Immediately thereafter, the surface was rinsed with a stream of water for 20 s, dried under compressed air for 20 s and then *in vacuo*. The specimens were sputtercoated with gold and examined under a scanning electron microscope##.

Measurement of bond strength

Bovine anterior teeth were ground on a model trimmer to expose adequate enamel or dentin surface for bonding. The exposed surfaces were then finished with 600-grit abrasive paper, treated with a drop (approximately 0.05 mL) of 5, 7, 10, 15, or 40 wt% phosphoric acid or the mixture of 10% citric acid and 3% ferric chloride for 30 s, rinsed with water for 20 s and air-dried for 20 s. Adhesive masking tape with a 5-mm diameter hole was attached to the surface to control the adhesion area. The Cu primer was applied with a small brush to the tooth surface and left for 30 s. An acrylic rod, having 8-mm diameter, 30-mm length, and a hole in one end through which a metal pin was passed to attach it to a testing machine, was bonded perpendicularly to the surface with the 4-META/MMA-PMMA or MMA-PMMA resin cement. The specimen was left for 15 min in air at room temperature, stored in distilled water at 37°C for 24 h, then tensile failure was tested on an Instron-type universal

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* Nacalai Tesque Co., Kyoto, Japan

** Sun Medical Co., Moriyama, Shiga, Japan

Super-Bond C&B, Sun Medical Co., Moriyama, Shiga, Japan

Model 2300, Hitachi Co., Tokyo, Japan

Fig. 1 Assembly used to test tensile bond strength.

testing machine* with a crosshead speed of 2 mm/min. The assembly used for the test is schematically shown in Fig. 1.

After the bond tests, the fracture surfaces were examined to identify the mode of failure. Failure at the tooth/resin interface constituted adhesive bond failure. That which occurred within the resin cement and/or tooth substrate constituted cohesive failure, whereas that partly at the interface and partly within the cement was termed mixed failure.

Five specimens were tested in each group. The data were evaluated by means of the analysis of variance and Duncan's multiple range test at the 5% level of significance.

RESULTS

Bovine tooth surfaces finished with 600-grit abrasive paper were treated with 5, 7, 10, 15 or 40% phosphoric acid (PA) for 15, 30, or 60 s and examined under a scanning electron microscope (SEM). The scanning electron micrographs revealing the effects upon the enamel and dentin surfaces exposed to this procedure for 30 s, are shown in Figs. 2 and 3. The enamel surfaces were etched to various degrees that were almost proportional to the PA concentration and the length of exposure. The dentin surfaces exhibited a gradual decrease in the amount of plug material in the tubules and gradual widening of the tubule orifices, as the strength of the acid and the length of treatment increased.

The effect of the PA concentration used to pretreat the enamel surface on the bond strength of 4-META/MMA-TBBO resin is shown in Table 1. The mean bond strength ranged from 12.0 to 16.8 MPa, which was not significantly different at the 0.05 level. With or without Cu primer, the bond strength to surfaces etched with 10% PA were 19.2 and 16.8 MPa, respectively, which were not statistically different.

Table 2 shows the effects of the Cu primer and the concentrations of PA on the bonding

* Autograph AGS 1000A, Shimadzu Co., Kyoto, Japan

Fig. 2 Enamel surfaces exposed to 5, 7, 10, 15, or 40% phosphoric acid for 30 s.

Fig. 3 Dentin surfaces exposed to 5, 7, 10, 15, or 40% phosphoric acid for 30 s.

Table 1 The bond strength of 4-META/MMA-TBBO resin to enamel treated with various concentrations of phosphoric acid

Treatment		Bond strength (MPa)			CV** (%)
		Mean*	(SD)**	Range	
5%	phosphoric acid	12.0 a	(2.7)	9.3-15.2	23
7%	phosphoric acid	15.1 ab	(1.8)	12.7-17.5	12
10%	phosphoric acid	16.8 ab	(3.6)	13.7-22.7	21
15%	phosphoric acid	14.5 ab	(3.7)	10.0-19.9	26
40%	phosphoric acid	14.9 ab	(4.6)	9.5-22.1	31
10%	phosphoric acid#	19.2 b	(2.0)	17.2-22.2	10
10%	citric acid/3% FeCl ₃	15.9 ab	(4.1)	11.4-20.4	26

* Means with the same letters were not significantly different at the level of 0.05

** SD, standard deviation ; CV, coefficient of variation

35% HEMA primer containing 0.03% cupric chloride was used thereafter

of 4-META/MMA-TBBO resin to dentin. The mode of failure of the bonding test specimens varied dependent upon bond strength. When the bond strength of each specimen was below 4 MPa, between 4 and 9 MPa, and above 9 MPa, the failure mode was mostly adhesive, mixed, and cohesive, respectively.

Without the Cu primer, the resin alone resulted in a bond strength of 1.7-4.4 MPa. When the dentin was treated with 7-40% PA, the Cu primer increased the bond strength significantly to 11.3-13.7 MPa. These values were about three times as high as those without the primer and were comparable to the bond strength (11.4 MPa) obtained in bonding to dentin treated with standard citric acid containing ferric chloride as recommended by the manufacturer. The strength of the bonding to dentin treated with 5% PA and Cu primer was only 6.2 MPa ($p < 0.05$), which was not significantly different from the value without the primer

Table 2 The effect of Cu primer on the strength of the 4-META/MMA-TBBO resin bonding to dentin treated with various concentrations of phosphoric acid

Treatment	Primer	Bond strength (MPa)			CV** (%)
		Mean*	(SD)**	Range	
5% phosphoric acid	No	3.7 ab	(1.1)	2.6- 5.3	30
7% phosphoric acid	No	4.4 ab	(3.6)	0.8- 9.2	82
10% phosphoric acid	No	4.2 ab	(2.1)	1.0- 6.5	50
15% phosphoric acid	No	3.9 ab	(2.8)	0.6- 8.1	72
40% phosphoric acid	No	1.7 a	(0.8)	0.9- 2.7	47
10% phosphoric acid	35% HEMA	6.3 b	(3.7)	1.7-10.8	60
5% phosphoric acid	Cu/HEMA#	6.2 b	(2.4)	3.0- 9.1	39
7% phosphoric acid	Cu/HEMA#	11.3 c	(4.5)	7.1-16.2	40
10% phosphoric acid	Cu/HEMA#	12.5 c	(3.4)	8.4-18.5	27
15% phosphoric acid	Cu/HEMA#	12.9 c	(4.1)	9.7-20.1	32
40% phosphoric acid	Cu/HEMA#	13.7 c	(3.1)	9.1-18.0	23
10% citric acid/3% FeCl ₃	No	11.4 c	(4.1)	5.9-16.4	36
10% citric acid/3% FeCl ₃	35% HEMA	13.7 c	(5.9)	6.4-20.2	43
10% citric acid/3% FeCl ₃	Cu/HEMA#	11.8 c	(6.3)	5.3-20.2	53

* Means with the same letters were not significantly different at the level of 0.05

** SD, standard deviation ; CV, coefficient of variation

35% HEMA primer containing 0.03% cupric chloride

Table 3 The effect of 4-META on the strength of the MMA-TBBO resin bonding to dentin

Treatment	Primer	4-META	Bond strength (MPa)			CV** (%)
			Mean*	(SD)**	Range	
10% phosphoric acid	No	No	3.3 a	(2.4)	0.2- 5.7	73
10% phosphoric acid	No	Yes	3.8 a	(2.2)	1.0- 6.5	58
10% phosphoric acid	35% HEMA	No	5.4 a	(2.3)	2.0- 7.8	43
10% phosphoric acid	35% HEMA	Yes	6.3 ab	(3.7)	1.7-10.8	60
10% phosphoric acid	Cu/HEMA#	No	13.5 c	(5.3)	8.1-21.2	39
10% phosphoric acid	Cu/HEMA#	Yes	12.5 c	(3.4)	8.4-18.5	27
10% citric acid/3% FeCl ₃	No	No	11.0 bc	(4.1)	4.0-14.3	37
10% citric acid/3% FeCl ₃	No	Yes	11.4 c	(4.1)	5.9-16.4	36

*, **, # See Table 2

Table 4 The effect of cupric salts in HEMA primer on the strength of 4-META/MMA-TBBO resin bonding to dentin etched with 10% phosphoric acid

Primer	Bond strength (MPa)			CV** (%)
	Mean*	(SD)**	Range	
No	3.8 a	(2.2)	1.0- 6.5	58
35% HEMA	6.3 a	(3.7)	1.7-10.8	60
Cupric acetate/HEMA#	8.7 ab	(6.9)	3.2-17.1	79
Cupric acetylacetonate/HEMA#	9.5 ab	(4.1)	5.0-15.6	43
Cupric nitrate/HEMA#	12.3 b	(3.1)	7.9-15.1	25
Cupric chloride/HEMA#	12.5 b	(3.4)	8.4-18.5	27
Cupric methacrylate/HEMA#	14.2 b	(4.2)	9.3-19.6	30

*, ** See Table 2

35% HEMA primer containing 0.03% cupric salt.

(3.7 MPa) ($p > 0.05$). Without the cupric salt in the HEMA primer, the strength of the bonding to dentin treated with 10% PA was significantly lower (6.3 MPa *vs* 12.5 MPa) ($p < 0.05$). No additional effect of the Cu primer was noted on the strength of the bond to the dentin treated with the citric acid mixture (11.8 MPa *vs* 11.4 MPa).

Table 3 summarizes the effect of 4-META in the MMA resin upon bond strength. There were no significant effects of 4-META. Using the Cu primer, the bond strength was 13.5 MPa even without 4-META in the resin.

The effect of anions of cupric salts on the bond strengths is compared in Table 4. Cupric methacrylate, chloride, and nitrate increased the bond strength significantly ($p < 0.05$) (6.3 MPa *vs* 12.3-14.2 MPa), but Cu acetate and acetylacetonate had no significant effect at the level of 0.05.

DISCUSSION

In principle, the new Cu primers could be applied to any treated dentin surface regardless of the agents, in a resin using TBBO initiator. Therefore, we studied how to establish a reasonable and practical treatment procedure. Most current dentin bonding systems contain mild acid cleansers or conditioners. However, enamel bonding systems usually require etching with phosphoric acid (PA) and, therefore, the tooth preparation is a two-step procedure. To prepare enamel and dentin simultaneously would greatly simplify the clinical procedures.

Although aqueous maleic acid, nitric acid, or a mixture of 10% citric acid and 3% ferric chloride effectively etch or condition both dentin and enamel for bonding, PA is the preferred agent. This is because phosphate anions would be more physiologically beneficial for the tooth than maleate, nitrate, citrate, and ethylenediamine tetraacetate anion (which are used as mild pretreatment agents in present dentin bonding systems), since they are components of apatite and therefore could be a source of remineralization of the tooth. We therefore selected PA for etching.

Before bonding, we studied changes in the tooth surface after exposure to PA at several concentrations and for various periods. Scanning electron microscopy of the enamel sur-

faces revealed the gradual progression of etching with an increase in the exposure period and PA concentration. However, 40% PA for 30 and 60 s caused considerable destruction of the enamel surface.

Exposure to 5% PA for 15 s completely removed the smear layer from the dentin surface and fully opened the tubule orifices. However, the smear plug material in the tubules remained after 60 s. With 10 and 40% PA, dentin tubules were almost entirely stripped free of the plugs. Considering the surface changes in enamel and dentin, a 30-second exposure to 10% phosphoric acid seems optimal for simultaneously etching enamel and dentin. When etched with 7, 10, 15, and 40% PA, there were no significant differences in the bond strength to enamel (14.5–16.8 MPa) and dentin with or without the Cu primer (11.3–13.7 MPa or 1.7–4.4 MPa, respectively) (Tables 1 and 2). As long as the bond strength is the same, a lower concentration of PA would be desirable from the standpoint of pulpal irritation. Thus, etching enamel and dentin simultaneously with 10% PA for 30 s seemed optimal. Recently, these conditions have been adopted and recommended in one commercial bonding system³⁾.

The direct application of PA to dentin remains controversial^{3,4)}. Adverse pulpal responses have been studied using high concentrations of PA (30–50%). However lower concentrations of PA could result in different effects. Recent clinical studies have shown a lack of postoperative sensitivity, even when 37% PA was used to etch dentin^{5,6)}. The histologic pulpal response of PA-etched dentin was minimal when the teeth were restored with an appropriate dentin bonding system^{7,8)}.

Whereas the high concentrations of PA (30–40%) usually used to etch enamel cause considerable destruction of the natural dentin structure, low concentrations (5–10%) do not⁹⁾. Even at 5–10% PA, the bond strength to enamel is comparable to that obtained with higher concentrations^{10–12)}. In dentin, with either of the PA concentrations used, the bond strength is not significantly different^{9,13)}, but the contraction gap between the dentin and the resin is minimized at the lower concentrations⁹⁾. These reported results together with those obtained here indicate that treating teeth with 10% PA will become more widely accepted.

In the 4-META/MMA-TBBO resin system, which is supplied commercially in Japan® and the USA[§], preparation with PA for enamel and a mixture of 10% citric acid and 3% ferric chloride for dentin are usually recommended. However, Tables 1 and 2 show that adding a Cu primer to the dentin eliminated the need for the citric acid/ferric chloride procedure. Therefore, dentin and enamel can be simultaneously etched. Even if enamel contacts or is contaminated by the primer, it does not seem to cause any adverse effect on the bonding to enamel; the bond strength to enamel with and without the primer was 16.8 MPa and 19.2 MPa, respectively, after treatment with 10% PA.

When dentin was treated with PA, the bond strength was increased remarkably by the Cu primer. In contrast, the bond strength to dentin treated with citric acid/ferric chloride was the same regardless of the Cu primer (11.4 MPa *vs* 11.8 MPa). This was reasonable, since ferric ions, which are essential for obtaining strong bond in the present system²⁾, had already been supplied from the treatment mixture to dentin collagen. Hence, Cu (II) ions supplied from the primer showed no additional effect.

® Super-Bond C&B, Sun Medical Co., Moriyama, Shiga, Japan

[§] Amalgambond, Parkell Co., Farmingdale, NY, USA

When the Cu primer was applied to 10% PA-treated dentin, a high bond strength of 13.5 MPa was obtained without 4-META. This value was comparable to that of 11.4 MPa obtained by the standard or recommended bonding procedure for 4-META/MMA resin. A comparison of the bond strengths in the presence and absence of 4-META indicated that adding of 4-META to the MMA-TBBO resin did not significantly improve the bond strength in 4 samples (Table 3). These results again demonstrated the major role of the metal ions and the minor role of 4-META in this dentin bonding system²⁾, although Nakabayashi¹⁴⁾ has maintained that 4-META improves the bond strength by infiltrating the dentin and forming a dentin-resin hybrid layer.

Adding cupric salts to the HEMA primer markedly improved the bond strength, and no significant difference was indicated among various cupric salts ($p > 0.05$). However, there was a difference in the minimum bond strength and coefficient of variation between the methacrylate, chloride, and nitrate groups, and the acetylacetonate and acetate groups, in which the bond strength was statistically the same as those without primer or with 35% HEMA primer (9.5 and 8.7 MPa *vs* 3.8 and 6.3 MPa) (Table 4). A higher minimum bond strength and lower coefficient of variation are clinically desirable to increase the reliability of the bonding. Not only the variety of anions, but also the concentration of cupric salts should affect the bond strength, though a concentration of 0.03% was adopted in this study based upon preliminary findings. A detailed study of the effect of concentration of cupric salts has revealed that $0.5\text{--}3.0 \times 10^{-4}$ mol/w% is optimal, resulting in statistically similar bond strengths¹⁵⁾. The 0.03 w/w% concentration of cupric salts corresponds to $1.15\text{--}2.23 \times 10^{-4}$ mol/w% and hence was within the optimal range.

The present study supports our interfacial initiation of polymerization concept, and that the combination of TBBO and metal ions adsorbed on dentin plays a more important and decisive role than 4-META in the bonding to dentin of 4-META/MMA-TBBO resin. Without the metal ions, high bond strength was unobtainable regardless of the presence or absence of 4-META (Table 3).

An adequate amount of metal ions, which can promote polymerization, has to be supplied to dentin before MMA-PMMA-TBBO resin or a similar commercial resin^{§§} to develop strong bonding. The presence of Cu (II) or Fe (III) ions adsorbed onto dentin collagen is a prerequisite for obtaining high bond strength in the present bonding system using TBBO as a polymerization initiator. The roles of Cu (II) or Fe (III) ions in promoting the TBBO-initiated polymerization of MMA in the presence of collagen and in increasing the bond strength have been discussed in our earlier papers^{2,16)}. Essential metal ions can be supplied by using a treatment mixture or primer containing therein. Currently, the primer would be preferable to the treatment solution when the advantage of treating enamel and dentin at the same time with PA is considered. In the future, however, the feasibility of a treatment mixture containing of PA and metal ions remains to be studied.

The Cu primer that was effective in MMA-TBBO resin should be equally so in other resins, depending on the type of initiator used in each bonding system and resin. Cupric chloride/35% HEMA primer is effective for two composite resins⁺¹⁷⁾.

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§§ Super-Bond C&B, Sun Medical Co., Moriyama, Shiga, Japan

+ Photo bond/Photo Clearfil resin and New bond/Clearfil FII resin, Kuraray Co., Osaka, Japan

The advantage of interfacial initiation is obvious. Polymerization shrinkage of composite resins causes stress on the bonding system¹⁸⁾. Therefore, to resist the contraction force of polymerizing resins, polymerization should be initiated rapidly from the dentin interface. Even if the collagen layer is infiltrated by a primer and/or a resin system and a collagen-resin hybrid layer is formed, it does not necessarily lead to strong bonding without interfacial initiation of polymerization, although high bond strength has been discussed in relation to the hybrid layer. A hybrid layer or resin-impregnated dentin, which is clearly present in any bonding system in the range of 0.1-2.5 μm ¹⁹⁾, is undoubtedly necessary, but it does not ensure high bond strength. Despite the presence of a hybrid layer, there is a wide range of bond strength for various bonding systems.

The recent findings that moistened dentin was more favorable than dry dentin for improving the bond strength of some dentin bonding systems²⁰⁾, would also be better understood on the basis of our concept of interfacial initiation of polymerization. An adequate amount of water in dentin could promote polymerization. In fact, water promoted the polymerization of HEMA in the presence of N-phenylglycine²¹⁾. Detailed studies are now in progress in our laboratory, and will be reported in the near future.

CONCLUSION

Primers consisting of HEMA and cupric [Cu (II)] salts capable of promoting the interfacial initiation of polymerization from dentin surfaces, were very effective in bonding dentin etched with 10% phosphoric acid to 4-META/MMA-TBBO resin. Even without 4-META, the Cu primer resulted in high bond strength that was comparable to that obtained with the recommended bonding procedure for the resin. Use of the Cu primer could simplify the bonding procedure by simultaneously treating enamel and dentin with 10% phosphoric acid.

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2種の結晶を含有するキャストブルガラスセラミックスの機械的強さに及ぼす結晶化の影響

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アパタイトとチタン酸マグネシウムの2種の結晶が析出するキャストブルガラスセラミックスの機械的性質に及ぼす結晶化（セラミシング）の影響を検討するため、結晶化処理温度を変化させ、曲げ強さ、破壊靱性および硬さなどを調べた。その結果、結晶化処理したガラスセラミックスの曲げ強さは結晶相の増加につれて高くなることがわかった。ガラスセラミックス中に析出するチタン酸マグネシウムは同量のアパタイトの析出に比較し、強

さに対して効果的であることが示唆された。破壊靱性はアパタイト結晶だけを析出させた試験片で、アズキャストの場合に比較して、2倍の値が得られた。このことは硬さの低いアパタイト粒子でもクラックのピン止め効果を持つものと考えられた。本材料は市販のボディー用陶材より高い機械的性質が得られたことから、審美補綴材料として使用できる可能性が示唆された。

O-メタクリロイル-N-アシルチロシンの合成と無処理人歯象牙質に対する接着性

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接着性モノマーの分子構造と接着性との相関を調べることを目的として、種々の長さのアシル鎖を持つO-メタクリロイル-N-アシルチロシン（MAATY）を合成、それらを含むボンディング剤を調製し、その無処理人歯象牙質に対する接着強さについて検討した。その結果は、チロシン骨格のカルボキシル基の自由度の増大が歯質との相互作用にとって好ましく強固な接着の要因であると考えられた。又、立体障害、疎水性といったカルボキシル基近傍の構造、モノマー分子の疎水性-親水性のバラ

ンス、共重合系の重合収縮が重要であることが示唆された。特に、カルボキシル基の隣接基の立体障害がO-メタクリロイル-N-オクタノイルチロシンの場合には極めて重要であった。最大接着強さはO-メタクリロイル-N-ヘキサノイルチロシン（15 mol %）-HEMA（85 mol %）から成るボンディング剤で得られ、その接着強さ（4.75 MPa）はフェニルアラニンを骨格に持つメタクリレートの中で最大であった。

リン酸で処理した象牙質への接着における銅イオン含有プライマーの効果

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象牙質界面での重合を促進することが可能な銅イオンを含むプライマーについて検討した。牛歯象牙質表面を10%リン酸水溶液で前処理した後、0.03%の銅塩を含む35%2-ヒドロキシエチルメタクリレート（HEMA）

水溶液からなるプライマーを塗布し、4-META/MMA-TBBO レジンで接着した。このプライマーを用いることにより、プライマーを用いないときの接着強さ3.8 MPa、あるいは銅塩を含まない35% HEMA プライマ

一使用時の 6.3 MPa に比べ、12.5 MPa の接着強さが、さらにまた、4-META を含まない MMA-TBBO レジンによっても 13.5 MPa という大きな接着強さが得られ、プライマーの有効性が明らかにされた。銅塩含有ブ

ライマーを利用することにより、エナメル質と象牙質を 10 %リン酸で同時に処理することが可能となり、MMA-TBBO 系レジンの接着操作の簡便化、確実化に寄与するものと思われる。

磁性アタッチメントの MRI への影響

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MRI が応用される場合、撮像領域内に金属、とくに磁性合金が存在すると、アーチファクトが大きく生じることが、いろいろな文献により、すでに指摘されている。したがって、磁性アタッチメントの MRI への影響を詳細に調べ、明らかにしておくことは、磁性アタッチメントを、設計、製造し、使用する上で、また、MRI を診断に用いる上でも大切であると思われる。そこで、磁性ステンレス鋼として 447Jl, XM27, 430 の 3 種類を用い磁

気特性、寸法、形状のアーチファクトへの影響を検討した。その結果、それぞれの試料のアーチファクトの中で、447Jl が僅かに大きなアーチファクトを生じる傾向を示し、形状によるアーチファクトへの差は認められなかった。また、寸法とアーチファクトの影響距離は比例していた。今回の場合では、材料の透磁率が MRI 画像のアーチファクトに影響したものと思われる。

タンニン・フッ化物合剤を配合したグラスアイオノマーセメントを作用させた象牙質の F の取り込みと結晶性について

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セメント粉末にタンニン・フッ化物合剤 (HY 剤) を 0 wt % (HY0), 1.5 wt % (HY1.5), 5.0 wt % (HY5) および 10.0 wt % (HY10) 配合したグラスアイオノマーセメント (GIC) を作用させたウシ象牙質への F の層別取り込み量ならびに HY0 および HY10 を作用させた象牙質の結晶性を調べた。配合割合が高いほど F の象

牙質への浸透が深くなり、アパタイトと結合した F の取り込み量が多かった。全 F の取り込みに対して F がアパタイトと安定に結合するのは時間がかかることが示唆された。また、HY 剤を配合した GIC を作用させることで象牙質の結晶性がより向上することが示唆された。

チタン鑄造床作製技法を評価するための実験モデル

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チタン鑄造床作製における各種の鑄造方法を評価し、最適の鑄造法を確立するために、コバルト・クロム鑄造

床の作製に使用されている既製のワックスパターンを用いる実験モデルを検討した。採用したパターンは厚さ