Studies on Color Analysis of Dental Porcelains

II. Effect of Covering Non-precious Alloys with Opaque Porcelain Materials

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We fixed by firing opaque porcelain materials (Uni bond, Vita VMK 68 Paint-on 88) and margin porcelain materials of varying thicknesses on to non-precious alloys (Bio cast of the Co-Cr system, Uni metal of the Ni-Cr-Be system, and Nichrome bond of the Ni-Cr system).

The effect of covering oxide films with porcelain materials is discussed.

Key Words: Color Analysis, Non-precious Alloy, Opaque Porcelain

INTRODUCTION

The porcelain bond casting crown technique is now the best method for approaching natural tooth color. However many aesthetic problems occur because porcelain bond casting crowns are often used for anterior teeth. For example, there are problems involving color harmony with teeth in the opposite jaw, neighboring teeth, gingiva, and the facial tone.¹⁻¹¹⁾ These problems arise because the color tone of the oxide film on the metal surface varies with different metals used for firing. The oxide film color of precious alloys is gray, and that of non-precious alloys is dark blue or dark green.¹²⁾

Here we report the effect, as evaluated by color analysis, of covering oxide films on non-precious alloys with various thicknesses of porcelain materials by firing.

MATERIALS AND METHODS

Three kinds of non-precious metal alloys for firing (Bio cast of the Co-Cr system, Uni metal of the Ni-Cr-Be system, and Nichrome bond of the Ni-Cr system)¹³⁾ were cast (10 mm×10 mm) by the ordinal method (Table 1). The surface of the casting metal was made smooth by sand blast treatment using 25 μ m particles of aluminum oxide. Only the surface of Bio cast was made smooth by using the bonding agent itself.

Opaque porcelain materials for bonding and margin porcelain materials are shown in Table 2. For opaque porcelain materials, seven specimens of Uni bond and six of Vita VMK 68 Paint-on 88 were used. For margin porcelain material, which is naturally used over fired opaque porcelain materials, it was fired in seven specimens directly on to non-precious metal surfaces used for firing. The firing schedule for opaque and margin porcelain

Table 1 Percentage Composition of Non-precious Alloys¹³⁾

	Co	Cr	Ni	Mo	Si	Mn	Al	Mg	Be
Bio cast	62.29	31.31	—	2.57	2.42	0.84	—	—	—
Uni metal	—	12.62	79.33	4.75	—	—	1.21	0.25	2.11
Nichrome bond	—	21.92	58.47	13.09	2.03	1.76	1.84	0.51	—

(%)

Table 2 Porcelain and Margin porcelain materials used for firing

SHADE	I	Lot No.	II	Lot No.	III	Lot No.
A1	A ₁ O	118018	510	79	—	—
A2	—	—	—	—	A ₂ M	108203
A4	A ₄ O	108011	514	928	A ₄ M	108202
B1	B ₁ O	118002	515	705	—	—
B2	—	—	—	—	B ₂ M	108202
B4	B ₄ O	108014	—	—	B ₄ M	078201
C1	C ₁ O	108013	517	790	—	—
C2	—	—	—	—	C ₂ M	078201
C4	C ₄ O	108013	519	177	C ₄ M	078201
D2	—	—	—	—	—	—
D3	D ₃ O	108015	563	41	D ₃ M	078201

I: Uni bond

II: Vita VMk 68 Paint-on 88

III: Uni bond Margin porcelain

materials as suggested by the manufacturers were followed. For color analysis of the samples, the Value (L), Hue (a), and Chroma (b) were measured on R.S. Hunter.*

RESULTS AND DISCUSSION

Figure 1 and Table 3 show the relationship between porcelain thickness and L, a, and b values when porcelain materials A₁O, A₄O, 510, and 514 were fired on to the Bio cast. For the L value, A₄O was brightest, and 510, 514, and A₁O were gradually darker in the order given. Especially on the Bio cast, the L value of the alloy surface was 35.44 (3.614) by surface treatment, which is a low value. But A₁O at a thickness of 0.07 mm showed a value of 69.76. The a values for A₄O tended to indicate a slight red color, and the a values for 514 tended to change from slightly green to slightly red as thickness increased. A₁O tended to show a slight green color, which was different from the others. The b values tended to indicate a yellow color in all cases.

Figure 2 and Table 4 show the relationship between porcelain thickness and L, a, and b values when porcelain materials B₁O, B₄O, and 515 were fired on to the Bio cast. For the L values, at a 0.08 mm thickness, B₁O was 69.67 (1.218), 515 was 66.95 (1.309), and B₄O

*: MICRO MULTI PHOTOMETER, MODEL MMP-1001 DP (NIPPON DENSHOKU IND. Co., LTD.).

Figure 1 Relationship between porcelain thickness and L, a, and b values when A₁O, A₄O, 510, and 514 porcelain materials were fired on to the Bio cast alloy.

Table 3 Measured values for L, a, and b when A₁O, A₄O, 510, and 514 porcelain materials were fired on to the Bio cast alloy

A1O					BIO CAST					510
64.02	66.41	68.55	69.76	74.76	L	63.97	66.95	67.02	69.20	72.98
(2.948)	(1.938)	(1.679)	(0.732)	(0.997)		(1.961)	(1.577)	(1.935)	(0.779)	(1.102)
-0.83	-0.89	-0.95	-1.02	-1.17		-1.90	-1.52	-1.41	-1.21	-0.04
(0.190)	(0.080)	(0.100)	(0.071)	(0.062)	a	(0.091)	(0.257)	(0.172)	(0.156)	(0.244)
3.55	4.51	6.50	8.75	9.19	b	6.53	7.82	9.16	9.48	11.57
(0.629)	(0.352)	(1.077)	(0.483)	(0.560)		(1.232)	(0.862)	(1.105)	(0.513)	(0.681)
A4O						514				
57.80	60.61	60.99	61.29	63.15	L	54.80	56.09	64.44	65.38	70.90
(3.790)	(1.498)	(1.397)	(1.133)	(0.685)		(1.920)	(1.132)	(1.490)	(1.707)	(1.082)
-0.23	0.74	0.96	0.96	1.40		-1.70	-1.60	-1.11	-0.80	0.87
(0.361)	(0.318)	(0.235)	(0.167)	(0.166)	a	(0.098)	(0.109)	(0.138)	(0.160)	(0.191)
8.19	10.05	11.42	11.64	12.47	b	7.88	8.14	11.35	11.35	16.07
(1.503)	(1.023)	(0.675)	(0.460)	(0.383)		(0.416)	(0.430)	(0.578)	(0.639)	(0.504)

Figure 2 Relationship between porcelain thickness and L, a, and b values when B₂O, B₄O, and 515 porcelain materials were fired on to the Bio cast alloy.

Table 4 Measured values for L, a, and b when B₂O, B₄O, and 515 porcelain materials were fired on to the Bio cast alloy

B ₂ O					BIO CAST					515				
55.65	61.60	69.67	71.27	71.90	L a b	52.93	59.65	61.17	66.95	70.67	L a b	52.93	59.65	61.17
(2.727)	(2.379)	(1.218)	(1.836)	(0.863)		(0.936)	(2.878)	(1.675)	(1.309)	(0.641)		(0.936)	(2.878)	(1.675)
-1.05	-1.12	-1.45	-1.61	-1.70		-1.84	-1.65	-1.58	-1.27	-0.69		(0.112)	(0.100)	(0.086)
(0.113)	(0.076)	(0.176)	(0.154)	(0.088)		(0.112)	(0.100)	(0.086)	(0.112)	(0.071)		(0.112)	(0.100)	(0.086)
1.14	2.71	4.97	7.15	8.12		6.05	6.63	6.81	8.28	8.74		(0.723)	(0.408)	(0.815)
(0.313)	(0.380)	(0.421)	(1.032)	(0.442)		(0.723)	(0.408)	(0.815)	(0.592)	(0.200)		(0.723)	(0.408)	(0.815)
B ₄ O														
54.10	59.01	63.18	65.34	67.62	L a b						L a b			
(2.767)	(1.716)	(2.008)	(1.480)	(0.776)										
-0.77	-0.76	-0.72	-0.65	-0.21										
(0.097)	(0.062)	(0.108)	(0.146)	(0.173)										
7.11	7.80	10.85	13.03	14.51										
(0.875)	(0.568)	(0.682)	(0.895)	(0.670)										

() : $\pm$ S. D.

b values when C₁O, C₄O, D₃O, 517, 519, and 563 were fired on to the Bio cast. Only the values of 563 at thicknesses of 0.05–0.17 mm were lower than the others. C₄O tended to be slightly red, and 519 tended to change from slightly green to an achromatic color under thin layer conditions. The b values tended to indicate a yellow color in all cases.

Figure 3 Relationship between porcelain thickness and L, a, and b values when C₁O, C₄O, D₃O, 517, 519, and 563 porcelain materials were fired on to the Bio cast alloy.

Table 5 Measured values for L, a, and b when C₁O, C₄O, D₃O, 517, 519, and 563 porcelain materials were fired on to the Bio cast alloy

C1O					BIO CAST					517
60.71	65.68	68.00	68.48	71.69	L	60.99	63.08	64.25	64.52	69.57
(2.638)	(1.920)	(1.395)	(0.677)	(0.549)		(0.715)	(1.472)	(1.579)	(1.367)	(1.264)
-0.82	-0.52	-0.51	-0.30	0.19		-1.75	-1.58	-1.45	-1.10	-0.85
(0.079)	(0.097)	(0.127)	(0.126)	(0.185)	a	(0.092)	(0.116)	(0.077)	(0.114)	(0.192)
3.40	4.71	6.84	8.15	10.28	b	6.82	7.71	8.40	9.39	9.67
(0.524)	(0.430)	(0.412)	(0.644)	(0.756)		(0.420)	(0.353)	(0.593)	(0.394)	(0.648)
C4O										519
61.69	61.88	61.93	63.80	65.32	L	57.09	61.59	63.07	65.41	67.68
(0.737)	(1.012)	(0.788)	(2.293)	(1.182)		(2.010)	(0.669)	(1.121)	(0.782)	(0.603)
0.40	0.68	1.15	2.51	2.79		-1.41	-0.67	-0.61	-0.07	1.57
(0.265)	(0.184)	(0.197)	(0.417)	(0.272)	a	(0.201)	(0.183)	(0.069)	(0.210)	(0.373)
9.89	10.80	11.23	13.84	14.38	b	8.16	8.68	8.87	10.10	14.31
(0.808)	(0.517)	(0.828)	(0.510)	(0.863)		(1.061)	(0.746)	(0.681)	(0.702)	(0.640)
D3O										563
54.64	61.87	65.98	66.57	67.06	L	32.61	34.94	35.51	35.68	36.28
(1.160)	(1.175)	(1.867)	(2.043)	(0.873)		(0.967)	(0.467)	(0.569)	(0.523)	(0.770)
-0.51	-0.32	-0.26	-0.18	0.47		-0.26	-0.31	-0.41	-0.37	-0.40
(0.050)	(0.209)	(0.126)	(0.093)	(0.224)	a	(0.063)	(0.054)	(0.064)	(0.045)	(0.048)
4.92	8.70	9.48	10.53	12.54	b	1.45	2.29	3.11	3.42	3.59
(0.738)	(0.983)	(0.681)	(1.224)	(0.811)		(0.083)	(0.161)	(0.137)	(0.194)	(0.154)

() : $\pm$ S. D.

Figure 4 Relationship between porcelain thickness and L, a, and b values when margin porcelain materials (A_2M , A_4M , B_2M , B_4M , C_2M , C_4M , and D_3M) were fired on to the Bio cast alloy.

Figure 4 and Table 6 show the relationship between porcelain thickness and L, a, and b values in seven cases where margin porcelain materials (A_2M , A_4M , B_2M , B_4M , C_2M , C_4M , and D_3M) were fired on to the Bio cast. The L values, which ranged from 37.71 (0.907) to 50.18 (0.967), were generally lower when compared with opaque porcelain materials. For the a value, margin porcelain materials tended toward a slight green color in all cases. Especially A_2M remarkably showed this tendency.

Figure 5 and Table 7 show the relationship between porcelain thickness and L, a, and b values when porcelain materials (A_1O , A_4O , 510, and 514) was fired on to Uni metal. The L value of the Uni metal surface was 47.76 (0.182). The L values for A_4O and 514 were more remarkably changed than those of A_1O and 510. For the a values, A_1O tended to indicate a slight green color. 510 and 514 tended to change from slightly red to slightly green, and A_4O tended toward red. From the b values, 514 showed 12.46 (0.416), A_4O showed 11.62 (1.505), 510 showed 8.29 (0.787), and A_1O showed 3.05 (0.734). And each porcelain material tended toward a yellow color.

Figure 6 and Table 8 show the relationship between porcelain thickness and L, a, and b values when porcelain materials B_1O , B_4O , and 515 were fired on to Uni metal. An increasing L value with increasing of each porcelain material occurred in all cases. From the a values, each porcelain material tended to be slightly green. Especially B_1O tended toward green when the porcelain thickness was increased. From the b values, especially B_4O tended to show yellow. The b value of B_4O was 14.05 (0.678); B_1O , 8.95 (0.739); and 515, 8.13 (0.422), and each porcelain tended toward yellow.

Figure 7 and Table 9 show the relationship between porcelain thickness and L, a, and b values when porcelain materials C_1O , C_4O , D_3O , 517, 519, and 563 were fired on to Uni

Table 6 Measured values for L, a, and b when margin porcelain materials (A₂M, A₄M, B₂M, B₄M, C₂M, C₄M, and D₃M) were fired on to the Bio cast alloy

A2M					BIO CAST					C2M				
42.25 (2.134)	42.91 (1.918)	44.68 (1.306)	47.24 (1.395)	50.18 (0.967)	L a b	37.82 (0.448)	39.35 (0.472)	41.38 (0.805)	42.12 (1.585)	44.11 (0.544)				
-0.99 (0.352)	-1.42 (0.401)	-1.54 (0.635)	-2.82 (0.474)	-2.87 (0.717)		-0.68 (0.090)	-0.60 (0.068)	-0.59 (0.052)	-0.58 (0.072)	-0.44 (0.067)				
1.60 (0.500)	1.89 (0.455)	2.20 (0.455)	2.87 (0.202)	3.47 (0.421)		2.02 (0.215)	2.27 (0.213)	2.87 (0.209)	2.91 (0.204)	3.96 (0.251)				
A4M						C4M								
38.09 (0.656)	40.78 (0.636)	43.49 (0.893)	43.79 (1.080)	48.34 (0.877)	L a b	38.87 (0.484)	39.57 (0.753)	39.71 (0.195)	41.69 (0.706)	42.65 (1.043)				
-0.82 (0.046)	-0.75 (0.060)	-0.72 (0.089)	-0.71 (0.058)	-0.71 (0.069)		-0.51 (0.102)	-0.54 (0.051)	-0.56 (0.083)	-0.64 (0.064)	-0.75 (0.131)				
3.46 (0.303)	4.25 (0.272)	4.57 (0.309)	5.71 (0.428)	7.83 (0.257)		3.10 (0.382)	3.98 (0.380)	4.38 (0.125)	4.95 (0.502)	5.54 (0.370)				
B2M						D3M								
37.71 (0.907)	39.45 (0.636)	40.37 (0.547)	42.70 (1.256)	45.62 (0.691)	L a b	40.01 (0.940)	40.57 (0.498)	41.96 (0.941)	43.82 (1.299)	44.86 (0.803)				
-0.89 (0.062)	-0.76 (0.066)	-0.66 (0.053)	-0.47 (0.084)	0.81 (0.512)		-0.53 (0.048)	-0.55 (0.080)	-0.60 (0.090)	-0.75 (0.088)	-0.98 (0.061)				
1.70 (0.034)	1.80 (0.163)	2.47 (0.117)	2.54 (0.112)	3.86 (1.938)		2.06 (0.187)	2.42 (0.174)	2.64 (0.184)	3.33 (0.194)	3.46 (0.213)				
B4M														
38.91 (0.714)	40.16 (0.951)	42.00 (1.743)	43.72 (0.504)	44.59 (0.558)	L a b									
-0.66 (0.072)	-0.88 (0.170)	-1.04 (0.078)	-1.09 (0.052)	-1.20 (0.737)										
2.91 (0.175)	4.19 (0.352)	4.34 (0.510)	4.53 (0.243)	5.37 (0.589)										

() : ± S. D.

metal. The L values for 563 ranged from 35.31 (0.717) to 39.20 (1.573) at thicknesses from 0.05 to 0.91 mm. These low values were identical to those when 563 was fired on to the Bio cast. The a value for C₄O strongly indicated a red color at a 0.09 mm thickness. 563 tended to change from slightly red to slightly green, and the others showed the opposite tendency.

Figure 8 and Table 10 show the relationship between porcelain thickness and L, a, and b values when margin porcelain materials were fired on to Uni metal. The L values for A₂M and B₄M tended to remarkably change with increasing thickness when compared with the others. From a and b values, it appeared that there were no remarkable changes among margin porcelain materials.

Figure 9 and Table 11 show the relationship between porcelain thickness and L, a, and b values when porcelain materials A₁O, A₄O, 510, and 514 were fired on to the Nichrome

Figure 5 Relationship between porcelain thickness and L, a, and b values when A_1O , A_4O , 510, and 514 porcelain materials were fired on to the Uni metal alloy.

Table 7 Measured values of L, a, and b when A_1O , A_4O , 510, and 514 porcelain materials were fired on to the Uni metal alloy

A1O					UNI METAL					510				
66.14 (3.942)	66.94 (1.147)	67.34 (2.968)	73.24 (2.273)	73.30 (1.168)	L a b	58.71 (2.176)	61.35 (2.333)	70.19 (0.793)	73.03 (1.461)	73.31 (0.671)				
-1.36 (0.178)	-1.37 (0.071)	-1.41 (0.057)	-1.50 (0.070)	-1.55 (0.059)		-1.17 (0.146)	-0.95 (0.352)	-0.76 (0.121)	-0.31 (0.269)	-0.19 (0.205)				
2.48 (0.539)	2.99 (0.761)	3.05 (0.734)	6.50 (1.418)	6.65 (1.415)		3.69 (0.656)	4.06 (0.643)	8.29 (0.787)	9.97 (1.011)	10.25 (0.397)				
A4O						514								
58.58 (1.076)	59.06 (2.629)	59.61 (1.845)	61.27 (1.550)	62.27 (1.001)	L a b	58.84 (2.700)	66.25 (2.451)	70.06 (0.527)	71.42 (1.520)	71.82 (1.246)				
0.33 (0.263)	0.39 (0.282)	0.61 (0.287)	0.99 (0.348)	1.40 (0.592)		-1.11 (0.092)	-0.65 (0.146)	-0.14 (0.111)	0.08 (0.380)	0.36 (0.317)				
9.05 (1.240)	9.23 (1.146)	10.03 (1.081)	10.93 (1.307)	11.62 (1.505)		5.60 (0.976)	8.79 (0.718)	12.46 (0.416)	13.16 (1.342)	13.62 (0.978)				

() : $\pm$ S. D.

bond. The L value of the Nichrome bond surface was 49.40 (0.311). The L values for 514 ranged from 53.69 (1.633) to 64.78 (0.973) at thicknesses from 0.06 to 0.07 mm, the changes in L values were remarkable. From the a values, A_4O tended to be slightly red; A_1O , slightly green; and 514, changed from slightly green to non-hue at a 0.10 mm thickness.

Figure 10 and Table 12 show the relationship between porcelain thickness and L, a, and b values when porcelain materials B_1O , B_4O , and 515 were fired on to the Nichrome bond. The L value of the B_1O porcelain material tended to change more than those of B_4O

Figure 6 Relationship between porcelain thickness and L, a, and b values when B₂O, B₄O, and 515 porcelain materials were fired on to the Uni metal alloy.

Table 8 Measured values for L, a, and b when B₂O, B₄O, and 515 porcelain materials were fired on to the Uni metal alloy

B ₂ O					UNI METAL					515				
56.81	66.67	67.91	68.63	71.69	L a b	61.84	63.94	65.76	69.42	71.86	L a b	(0.967)	(1.352)	(0.659)
(1.928)	(2.833)	(1.892)	(0.832)	(0.626)		(0.967)	(1.352)	(0.659)	(0.591)	(1.015)		(0.058)	(0.051)	(0.029)
-1.22	-1.67	-1.72	-1.88	-2.05		-1.13	-1.11	-0.97	-0.95	-0.41		(0.058)	(0.051)	(0.029)
(0.113)	(0.141)	(0.089)	(0.083)	(0.126)		(0.058)	(0.051)	(0.029)	(0.037)	(0.147)		(0.058)	(0.051)	(0.029)
0.54	2.58	3.04	3.53	8.95		3.32	3.56	4.72	6.17	8.13		(0.230)	(0.356)	(0.305)
(0.127)	(0.322)	(0.803)	(0.443)	(0.739)		(0.230)	(0.356)	(0.305)	(0.244)	(0.422)		(0.230)	(0.356)	(0.305)
B ₄ O														
62.54	62.99	66.17	66.71	69.70	L a b						L a b			
(1.802)	(2.325)	(1.241)	(1.690)	(1.086)										
-1.29	-1.28	-1.15	-1.08	-0.52										
(0.081)	(0.079)	(0.157)	(0.176)	(0.224)										
8.57	8.90	11.84	12.36	14.05										
(0.414)	(1.299)	(0.934)	(0.856)	(0.678)										

() : $\pm$ S. D.

and 515. The L value for B₂O ranged from 62.14 (1.857) to 75.63 (0.876) at thicknesses from 0.07 to 0.13 mm.

The a values for B₂O, B₄O, and 515 porcelain materials tended to indicate colors from slightly green to non-hue. The b values for each porcelain tended toward yellow in all cases.

Figure 11 and Table 13 show the relationship between porcelain thickness and L, a, and b values when porcelain materials C₂O, C₄O, D₃O, 517, 519, and 563 were fired on to the Nichrome bond. The L values for 563 tended to be lower than the others (C₂O, C₄O,

Figure 7 Relationship between porcelain thickness and L, a, and b values when C₁O, C₄O, D₃O, 517, 519, and 563 porcelain materials were fired on to the Uni metal alloy.

Table 9 Measured values for L, a, and b when C₁O, C₄O, D₃O, 517, 519, and 563 porcelain materials were fired on to the Uni metal alloy

C1O					UNI METAL					517				
63.00	66.94	69.67	70.18	72.82	L a b	60.94	65.96	67.49	68.87	71.16	L a b	59.15	60.79	66.79
(4.582)	(2.564)	(1.690)	(2.581)	(0.828)		(1.632)	(1.441)	(0.560)	(1.400)	(1.038)		(1.886)	(1.278)	(0.463)
-0.75	-0.59	-0.42	-0.41	-0.09		-1.40	-1.20	-1.12	-1.01	-0.63		-0.51	-0.39	0.37
(0.076)	(0.073)	(0.160)	(0.173)	(0.134)		(0.104)	(0.140)	(0.052)	(0.070)	(0.113)		(0.088)	(0.100)	(0.129)
3.95	4.62	6.66	7.15	8.88		3.76	5.55	6.39	7.36	8.99		4.72	5.67	8.88
(1.149)	(0.677)	(1.012)	(0.727)	(0.482)		(0.665)	(0.566)	(0.205)	(0.569)	(0.612)		(0.709)	(0.517)	(0.554)
C4O										519				
61.30	63.39	63.67	63.89	64.14	L a b	59.15	60.79	66.79	67.18	68.61	L a b	59.15	60.79	66.79
(1.402)	(1.829)	(1.040)	(2.357)	(0.689)		(1.886)	(1.278)	(0.463)	(0.754)	(0.814)		(1.886)	(1.278)	(0.463)
0.33	1.00	1.41	1.73	2.61		-0.51	-0.39	0.37	0.44	0.55		-0.51	-0.39	0.37
(0.153)	(0.548)	(0.729)	(0.215)	(2.427)		(0.088)	(0.100)	(0.129)	(0.238)	(0.226)		(0.088)	(0.100)	(0.129)
9.24	11.19	11.29	12.18	12.46		4.72	5.67	8.88	10.05	10.41		4.72	5.67	8.88
(0.726)	(1.197)	(0.712)	(1.571)	(0.771)		(0.709)	(0.517)	(0.554)	(0.287)	(0.477)		(0.709)	(0.517)	(0.554)
D3O										563				
64.39	65.27	67.41	67.92	68.82	L a b	35.31	36.29	36.64	37.03	39.20	L a b	35.31	36.29	36.64
(1.640)	(1.676)	(1.322)	(1.491)	(0.895)		(0.717)	(0.202)	(0.471)	(0.520)	(1.573)		(0.717)	(0.202)	(0.471)
-0.66	-0.59	-0.16	-0.03	0.49		0.28	0.24	0.14	0.05	0.03		0.28	0.24	0.14
(0.133)	(0.126)	(0.122)	(0.158)	(0.156)		(0.055)	(0.019)	(0.100)	(0.099)	(0.086)		(0.055)	(0.019)	(0.100)
7.54	8.57	10.60	10.95	12.42		2.73	2.99	3.37	3.97	4.34		2.73	2.99	3.37
(0.826)	(0.345)	(0.387)	(0.453)	(0.492)		(0.157)	(0.101)	(0.043)	(0.148)	(0.173)		(0.157)	(0.101)	(0.043)

() : $\pm$ S. D.

Figure 8 Relationship between porcelain thickness and L, a, and b values when margin porcelain materials (A₂M, A₄M, B₂M, B₄M, C₂M, C₄M, and D₃M) were fired on to the Uni metal alloy.

Table 10 Measured values for L, a, and b when margin porcelain materials (A₂M, A₄M, B₂M, B₄M, C₂M, C₄M, and D₃M) were fired on to the Uni metal alloy

A2M					UNI METAL					C2M					
40.19 (1.078)	40.50 (0.646)	41.85 (0.942)	42.25 (0.189)	45.47 (0.981)	L a b	34.62 (0.575)	35.16 (0.754)	35.61 (0.695)	36.10 (0.436)	38.76 (1.139)	L a b	34.86 (0.696)	36.61 (0.752)	37.04 (0.838)	
0.01 (0.082)	0.01 (0.052)	-0.03 (0.041)	-0.09 (0.055)	-0.14 (0.041)		0.32 (0.028)	0.17 (0.118)	0.15 (0.102)	0.10 (0.040)	-0.07 (0.077)		0.17 (0.067)	0.12 (0.048)	0.11 (0.054)	
1.31 (0.268)	1.94 (0.222)	2.01 (0.101)	2.10 (0.152)	2.33 (0.234)		2.92 (0.186)	3.10 (0.189)	3.12 (0.136)	3.47 (0.132)	4.15 (0.091)		3.94 (0.180)	4.00 (0.096)	4.85 (0.351)	
A4M						C4M						D3M			
33.68 (0.499)	33.72 (0.523)	35.38 (0.318)	38.00 (0.756)	39.16 (0.926)	L a b	34.86 (0.696)	36.61 (0.752)	37.04 (0.838)	37.23 (0.662)	38.46 (0.848)	L a b	35.49 (0.539)	36.46 (0.623)	37.08 (0.284)	
0.34 (0.072)	0.31 (0.047)	0.11 (0.034)	0.01 (0.081)	0.01 (0.102)		0.17 (0.067)	0.12 (0.048)	0.11 (0.054)	0.06 (0.055)	0.04 (0.054)		0.24 (0.048)	0.20 (0.077)	0.15 (0.071)	
2.62 (0.149)	3.30 (0.184)	3.81 (0.162)	4.65 (0.499)	4.65 (0.289)		3.94 (0.180)	4.00 (0.096)	4.85 (0.351)	5.29 (0.373)	5.37 (0.219)		2.77 (0.125)	3.03 (0.200)	3.18 (0.114)	
B2M						D3M						D3M			
35.00 (0.382)	36.28 (0.915)	37.30 (0.950)	37.78 (0.706)	38.05 (0.877)	L a b	35.49 (0.539)	36.46 (0.623)	37.08 (0.284)	37.68 (1.083)	38.32 (1.280)	L a b	0.24 (0.048)	0.20 (0.077)	0.19 (0.071)	
0.22 (0.045)	0.18 (0.063)	0.11 (0.089)	0.01 (0.055)	-0.07 (0.083)		0.24 (0.048)	0.20 (0.077)	0.19 (0.071)	0.15 (0.107)	-0.01 (0.106)		2.77 (0.125)	3.03 (0.200)	3.18 (0.114)	
2.39 (0.203)	2.81 (0.209)	2.95 (0.244)	2.99 (0.238)	3.15 (0.151)		2.77 (0.125)	3.03 (0.200)	3.18 (0.114)	3.35 (0.063)	3.47 (0.317)					
B4M															
36.06 (0.305)	36.98 (1.306)	38.13 (0.717)	40.50 (0.439)	41.92 (0.443)	L a b							L a b			
0.23 (0.073)	0.19 (0.057)	-0.02 (0.066)	-0.09 (0.030)	-0.37 (0.034)											
3.51 (0.223)	3.82 (0.286)	4.46 (0.205)	4.97 (0.171)	5.88 (0.147)											

() : ± S. D.

Figure 9 Relationship between porcelain thickness and L, a, and b values when A₁O, A₄O, 510, and 514 porcelain materials were fired on to the Nichrome bond alloy.

Table 11 Measured values for L, a, and b when A₁O, A₄O, 510, and 514 porcelain materials were fired on to the Nichrome bond alloy

A1O					NICHROME BOND					510
61.02 (1.091)	62.77 (2.039)	70.35 (1.103)	70.53 (2.044)	75.57 (0.970)	L a b	60.81 (1.009)	62.41 (1.741)	69.02 (0.419)	69.56 (0.558)	69.59 (0.353)
-0.26 (0.260)	-1.14 (0.070)	-1.32 (0.086)	-1.47 (0.061)	-1.56 (0.114)		-2.11 (0.052)	-1.82 (0.113)	-1.42 (0.123)	-1.30 (0.036)	-1.21 (0.070)
3.08 (0.205)	4.19 (0.645)	7.73 (0.456)	7.85 (0.852)	11.52 (0.474)		9.28 (0.662)	11.00 (0.204)	12.13 (0.461)	13.07 (0.091)	13.63 (0.206)
A4O						514				
57.30 (1.662)	58.31 (2.024)	58.83 (1.854)	60.35 (0.844)	62.96 (1.150)	L a b	53.69 (1.633)	63.06 (1.417)	64.78 (0.973)	68.60 (0.699)	69.93 (1.402)
0.24 (0.216)	0.34 (0.450)	0.36 (0.298)	0.76 (0.239)	2.04 (0.226)		-1.74 (0.055)	-1.18 (0.194)	-1.14 (0.113)	0.06 (0.391)	0.28 (0.311)
9.31 (1.363)	9.47 (0.958)	9.74 (1.171)	10.84 (0.673)	13.44 (0.316)		9.44 (0.791)	12.48 (1.082)	12.70 (0.667)	16.04 (1.196)	16.69 (0.827)

Figure 10 Relationship between porcelain thickness and L, a, and b values when B₂O, B₄O, and 515 porcelain materials were fired on to the Nichrome bond alloy.

Table 12 Measured values for L, a, and b when B₂O, B₄O, and 515 porcelain materials were fired on to the Nichrome bond alloy

B ₂ O					NICHROME BOND					515
62.14	65.17	68.06	73.83	75.63	L a b	59.01	62.19	62.96	66.90	68.50
(1.857)	(2.695)	(1.771)	(2.125)	(0.876)		(1.799)	(1.127)	(2.142)	(0.982)	(0.520)
-1.75	-1.73	-1.69	-1.65	-1.33		-1.77	-1.75	-1.71	-1.41	-0.87
(0.066)	(0.090)	(0.069)	(0.067)	(0.143)		(0.051)	(0.075)	(0.046)	(0.040)	(0.058)
2.46	3.72	5.05	8.08	9.82	L a b	7.75	8.20	9.79	10.37	11.21
(0.746)	(0.785)	(0.371)	(0.895)	(0.630)		(1.025)	(1.132)	(1.284)	(0.807)	(0.497)
B ₄ O					L a b					
63.15	64.51	64.88	66.74	67.78						
(3.385)	(0.827)	(1.780)	(1.301)	(0.871)						
-1.04	-0.94	-0.83	-0.80	-0.25						
(0.179)	(0.124)	(0.217)	(0.163)	(0.331)						
9.92	12.04	13.09	13.33	15.18	L a b					
(1.110)	(0.448)	(0.922)	(1.252)	(0.835)						

() : ± S. D.

and b values when margin porcelain materials were fired on to the Nichrome bond. The L values for D₃M were variable under thin layer conditions, and the L value of the other materials increased gradually as the layer thickness increased. Especially this tendency was remarkable in the case of B₂M and C₂M. The a values of the margin porcelains tended to indicate a slight green. The b values showed no remarkable changes even if the layer thickness of the margin porcelain was increased. The b values tended to indicate a yellow

Figure 11 Relationship between porcelain thickness and L, a, and b values when C₁O, C₄O, D₃O, 517, 519, and 563 porcelain materials were fired on to the Nichrome bond alloy.

Table 13 Measured values for L, a, and b when C₁O, C₄O, D₃O, 517, 519, and 563 porcelain materials were fired on to the Nichrome bond alloy

C1O					NICHROME BOND					517						
62.10 (1.932)	64.88 (1.069)	69.17 (0.840)	69.19 (1.481)	69.93 (1.353)	L a b	64.23 (2.406)	64.40 (1.838)	66.24 (0.794)	68.41 (0.463)	70.82 (1.474)	L a b	64.23 (2.406)	64.40 (1.838)	66.24 (0.794)		
-0.75 (0.069)	-0.61 (0.081)	-0.32 (0.194)	-0.24 (0.072)	0.06 (0.214)		-1.70 (0.070)	-1.56 (0.087)	-1.54 (0.147)	-1.22 (0.047)	-0.73 (0.145)		-1.70 (0.070)	-1.56 (0.087)	-1.54 (0.147)		
4.56 (0.598)	4.70 (1.052)	7.30 (0.684)	7.57 (0.383)	8.92 (0.927)		9.38 (0.721)	9.40 (0.766)	11.42 (1.027)	12.26 (0.223)	12.46 (0.977)		9.38 (0.721)	9.40 (0.766)	11.42 (1.027)		
C4O												519				
56.53 (1.296)	59.11 (1.888)	59.68 (0.651)	62.61 (1.382)	62.89 (0.987)	L a b	57.80 (0.738)	62.21 (1.121)	64.46 (1.164)	67.06 (0.709)	69.43 (0.743)	L a b	57.80 (0.738)	62.21 (1.121)	64.46 (1.164)		
-0.14 (0.121)	0.31 (0.281)	0.35 (0.198)	1.45 (0.322)	1.93 (0.458)		-1.31 (0.087)	-0.49 (0.220)	0.12 (0.322)	0.67 (0.236)	0.94 (0.201)		-1.31 (0.087)	-0.49 (0.220)	0.12 (0.322)		
8.20 (0.226)	10.06 (1.153)	10.58 (0.531)	13.11 (0.868)	13.53 (0.705)		10.28 (0.541)	11.68 (0.587)	11.69 (0.601)	12.22 (0.676)	12.48 (0.317)		10.28 (0.541)	11.68 (0.587)	11.69 (0.601)		
D3O												563				
59.10 (1.167)	62.09 (3.448)	65.55 (1.756)	65.90 (1.302)	65.98 (0.656)	L a b	30.20 (0.778)	30.94 (0.993)	32.08 (0.534)	32.71 (0.902)	34.01 (0.621)	L a b	30.20 (0.778)	30.94 (0.993)	32.08 (0.534)		
-0.48 (0.169)	-0.32 (0.218)	0.01 (0.169)	0.11 (0.331)	0.47 (0.116)		-0.53 (0.087)	-0.58 (0.110)	-0.62 (0.059)	-0.63 (0.070)	-0.66 (0.060)		-0.53 (0.087)	-0.58 (0.110)	-0.62 (0.059)		
8.81 (0.732)	9.90 (0.938)	10.80 (0.784)	11.65 (0.658)	12.06 (0.569)		2.22 (0.123)	2.31 (0.093)	2.32 (0.084)	2.35 (0.162)	2.48 (0.093)		2.22 (0.123)	2.31 (0.093)	2.32 (0.084)		

() : $\pm$ S. D.

Figure 12 Relationship between porcelain thickness and L, a, and b values when margin porcelain materials (A₂M, A₄M, B₂M, B₄M, C₂M, C₄M, and D₃M) were fired on to the Nichrome bond alloy.

Table 14 Measured values for L, a, and b when margin porcelain materials (A₂M, A₄M, B₂M, B₄M, C₂M, C₄M, and D₃M) were fired on to the Nichrome bond alloy

A2M					NICHROME BOND					C2M					
36.14 (0.348)	38.17 (0.962)	39.10 (1.145)	40.55 (0.672)	43.76 (1.248)	L a b	33.16 (0.256)	33.58 (0.663)	35.62 (0.234)	36.80 (1.379)	39.37 (1.067)	L a b	34.85 (0.419)	36.91 (1.136)	37.26 (0.441)	
-0.70 (0.067)	-0.78 (0.108)	-0.82 (0.051)	-0.89 (0.128)	-0.96 (0.156)		-0.62 (0.093)	-0.63 (0.048)	-0.68 (0.019)	-0.70 (0.050)	-0.89 (0.050)		-0.47 (0.100)	-0.53 (0.045)	-0.53 (0.083)	
3.26 (0.313)	3.49 (0.117)	3.71 (0.400)	3.95 (0.291)	3.98 (0.499)		3.30 (0.172)	3.38 (0.216)	3.83 (0.133)	3.88 (0.179)	4.85 (0.258)		5.51 (0.212)	5.67 (0.176)	5.02 (0.302)	
A4M					L a b						L a b	C4M			
33.64 (0.611)	34.38 (0.638)	35.48 0.802	37.99 (1.135)	38.36 (1.110)		34.85 (0.419)	36.91 (1.136)	37.26 (0.441)	38.73 (0.673)	38.99 (1.605)		34.85 (0.419)	36.91 (1.136)	37.26 (0.441)	
-0.58 (0.049)	-0.62 (0.024)	-0.67 (0.078)	-0.68 (0.155)	-0.70 (0.045)		-0.47 (0.100)	-0.53 (0.045)	-0.53 (0.083)	-0.58 (0.055)	-0.66 (0.025)		-0.47 (0.100)	-0.53 (0.045)	-0.53 (0.083)	
3.41 (0.239)	3.72 (0.550)	3.80 (0.175)	4.64 (0.413)	4.82 (0.424)	L a b	4.16 (0.212)	4.93 (0.176)	5.02 (0.302)	5.51 (0.338)	5.67 (0.238)	L a b	4.16 (0.212)	4.93 (0.176)	5.02 (0.302)	
B2M												L a b	D3M		
37.00 (0.728)	37.37 (1.268)	37.46 (1.059)	38.84 (0.432)	45.09 (1.277)		38.59 (0.241)	40.69 (0.431)	41.58 (0.517)	43.14 (1.004)	44.15 (0.469)			38.59 (0.241)	40.69 (0.431)	41.58 (0.517)
-0.71 (0.063)	-0.73 (0.044)	-0.76 (0.083)	-0.89 (0.086)	-1.19 (0.093)	-0.83 (0.088)	-0.84 (0.059)	-0.88 (0.025)	-0.88 (0.066)	-0.89 (0.056)	-0.83 (0.088)	-0.84 (0.059)		-0.88 (0.025)		
2.53 (0.035)	2.56 (0.181)	2.84 (0.157)	3.14 (0.147)	5.12 (0.336)	L a b	3.60 (0.249)	3.85 (0.096)	3.98 (0.142)	4.52 (0.084)	5.19 (0.221)	L a b	3.60 (0.249)	3.85 (0.096)	3.98 (0.142)	
B4M												L a b			
34.44 (0.547)	35.11 (0.733)	37.99 (0.203)	39.65 (0.419)	42.74 (1.347)											
-0.62 (0.085)	-0.63 (0.055)	-0.75 (0.073)	-0.78 (0.027)	-1.06 (0.044)											
3.87 (0.040)	4.34 (0.125)	5.14 (0.230)	5.65 (0.174)	6.22 (0.508)	L a b						L a b				
												L a b			
													L a b		

() : ± S. D.

color in all cases.

Since the color aesthetics of porcelain bond crowns are adversely affected by a reduced film on the non-precious alloy surface, the opaque porcelain layer covering method¹⁴⁾ was used. However as the opaque porcelain layer was unnecessarily thicker, the other porcelain layer became thinner, and the proper expressions of transparency and color tone became more difficult to achieve. For this reason, a bright and non-chromatic for the non-precious alloy surface is desirable.¹²⁾ Concerning the L values of the non-precious alloy surfaces, Bio cast, treated by firing with a bonding agent, was 35.44 (3.614), which was lower than the 47.76 (0.182) of Uni metal and the 49.40 (0.311) of Nichrome bond. However the L values for porcelain materials fired on to the Bio cast were generally higher under thin layer conditions. Especially this tendency was true in the case of Al_2O_3 , B_2O_3 , and CaO .

Generally L values are lowered by the production of NiO , Cr_2O_3 , $\text{NiO}\cdot\text{Cr}_2\text{O}_3$, $\text{NiO}\cdot\text{MoO}_3$ and Mn_3O_4 during firing. And a and b values are also lowered, and the color tone is expressed from dark blue to dark green. When 2% Beryllium was added to Ni-Cr alloys,¹³⁾ the L value for this non-precious metal tended to be slightly low, and the a and b values indicated a gray color. These results demonstrated that Beryllium controls the production of Chromium and Nickel oxide film. On the other hand, in the case of Co-Cr alloys, the b value was decreased, indicating a light blue color, from the firing process of opaque porcelain materials; and it was increased, indicating a light brown color, from the firing process of Body porcelain materials.¹²⁾ Also Bio cast (Co-Cr system) was reduced by Aluminum in the bonding agent (as formula ① shows). Metal surfaces treated by bonding agent undergo the following reactions:

This is recognized to be the mechanism which produces the minimum Cr_2O_3 necessary to combine with alloy and porcelain materials. The oxide, Al_2O_3 , combines with silicate ($\text{K}_2\text{O}\cdot\text{Na}_2\text{O}\cdot\text{SiO}_2$), as shown in formula ②. Reduced Chromium is eliminated from the alloy surface, combines with the silicate of the bonding agent, and becomes a colored film, as shown in formula ③. From this point of view, the alloy surface treated with bonding agent is considered to combine well with porcelain materials because the elements — K_2O , Na_2O , SiO_2 — are similar to the porcelain materials for bonding.^{15,16)} As the formation of these elements is similar to that of porcelain materials, the degree of light reflection is similar between them, and the L value becomes high even if the porcelain layer is thin.

CONCLUSIONS

We investigated by color analysis the effects of covering oxide films in non-precious alloys (Bio cast of the Co-Cr system, Uni metal of the Ni-Cr-Be system, and Nichrome bond of the Ni-Cr system) by firing with varying thicknesses of opaque porcelain materials and margin porcelain materials.

The results are as follows:

(1) The L value of the Bio cast treated with bonding agent was 35.44 (3.614). This

value was lower than those for the other two alloys. But the L value of the porcelain—fired Bio cast was high even under thin layer conditions in all cases. Especially this tendency was remarkable in the case of A_1O , B_1O , and C_1O .

(2) There were no remarkable differences in the a value of porcelain materials fired on to three kinds of non-precious metal alloys. A_1O , B_1O , and 563 fired on to the Bio cast and Uni metal and A_1O and 563 fired on to the Nichrome bond tended to indicate a slight green color as the porcelain thickness was increased. The other porcelains tended to change from slightly green to non-chroma.

(3) The L values for margin porcelain materials tended to increase as their thickness was increased. But this tendency was less than in the case of porcelain materials. The a values for porcelains fired on to the Bio cast were nearly non-chromatic even if the thickness was increased, and there was no difference.

(4) From analysis of the L and b values, a covering thickness of only 0.08–0.09 mm was found necessary to provide the desired color tone on oxide films of non-precious alloys.

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短時間内に進行し終結することがわかった。このように硬化特性からみても、かなり性格の異なるアロイが同時

に多数市販されているので、臨床的な使用に際しては注意が必要であることがわかった。

焼付用陶材の色彩分析について

II. オペーク陶材の卑金属合金への遮蔽効果

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焼付用卑金属合金 (Co-Cr 系 Bio cast, Ni-Cr-Be 系 Uni metal, Ni-Cr 系 Nichrome bond) 三種類に、オペーク陶材 (Uni bond 7種, Vita VMK 68 Paint-on 88 6種)とマージン陶材7種の層厚を変化させて焼付け、陶材の厚みの変化による酸化被膜の遮蔽効果を色彩分析で検討したところ、Bio cast に築盛焼成した陶材は薄層においても全体的にL値が高く、特に A_1O , B_1O , C_1O にこの傾向が著しく表われた。Bio cast および Uni metal

に焼成した A_1O , B_1O , 563 と, Nichrome bond に焼成した A_1O , 563 は、陶材の厚さが増すにつれて、緑色傾向が強くなり、他陶材は緑色傾向から無彩色への変化が見られた。マージンポーセレンは、厚さの増加によってL値が大きくなったが、他の陶材に比べてわずかの変動であった。L値およびb値より、焼付用卑金属合金の酸化被膜の遮蔽および色調再現効果は、0.08~0.09 mm あれば十分にその効果が表われるものと思われる。

パラジウムを含む市販金合金の時効硬化

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Pd を含む市販 16 K, 14 K 金合金の時効硬化機構を明らかにするため、電顕直接観察、X線および電子線回折を行った。

1) 時効過程は f.c.c. 不規則固溶体→準安定 $AuCuI'$ 規則格子相→平衡相 $AuCuI$ 規則格子相+Ag-rich α_2 相 (f.c.c.) であった。

2) $AuCuI'$ 相は時効初期にマトリックス中の $\{100\}$ に平行に形成され、正方晶化にともなうひずみを軽減するためにC軸は $\langle 100 \rangle$ に沿う3方向に分布した。時効

硬化の主要な原因は $AuCuI'$ 板状相の $[001]$ 方向のひずみ場であった。

3) $AuCuI$ 相は α_2 相と共に結晶粒界からラメラ構造となって粒内に成長し、同時に $AuCuI'$ 相は消失した。ラメラの界面は非整合と考えられ、硬化の原因となるひずみは観察されなかった。

4) 長周期構造を持つ $AuCuII$ 型規則格子相は本実験では観察されなかった。

X線光電子分析 (ESCA) による陶材焼付用金合金の酸化表面の解析

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陶材焼付用金合金—85.5 Au, 6 Pt, 6 Pd, 1 Ag, 0.6 Sn, 0.9 In (wt%)—を1000℃, 大気中で30 sec~60 min

加熱し、その酸化表面を ESCA で解析した。その結果、加熱時間にかかわりなく、Au (4f), Pt (4f), Pd (3d)