Color Stability and Aging of Plastic Veneering Materials

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The color stability and aging characteristics of commercial plastic veneering materials were studied in vitro *by an accelerated aging method. The veneering materials were similar in color to, but more opaque than, composite restorative materials. Changes in color during aging were minimal. Weight loss occurred during aging.*

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Introduction.

Physical and mechanical properties of plastics for veneering of cast gold restorations have been reported.[1-3] Typical crown and bridge plastics have been formulated from methyl methacrylate or triethylene glycol dimethacrylate monomer and poly (methyl methacrylate) polymer, and have had low inorganic content (less than 2%).[3] Recently, a composite resin with 24.6% inorganic filler[3] was introduced as a veneering material.

An important property of a plastic veneering material is color stability.[1,2] An *in vitro* method of evaluation of color stability by accelerated aging has been utilized for restorative resins.[4,5] Dennison *et al.*[6] have shown that changes in color observed clinically in a 24-month *in vivo* study of class 4 composite restorations correlated well with these *in vitro* data. Accelerated aging of composites has also resulted in surface degradation of samples and may be a useful model for evaluation of chemical durability or aging of resins.[7]

The purpose of this research was to evaluate the color stability and aging characteristics of commercial plastic veneering materials *in vitro* by an accelerated aging method.

Materials and methods.

The color and aging characteristics of five commercial plastic veneering materials were evaluated under conditions of accelerated aging. The code, shade, batch numbers, and manufacturer of each material studied are listed in Table 1.

Three disks (36 mm diameter and 1.3 mm thickness) for evaluation of color and five samples (about 20 x 20 mm square and 1 mm thick) for evaluation of aging characteristics were prepared for each material by polymerization in appropriate dies according to manufacturers' instructions. After preparation, the samples were stored in an oven at 37°C for 24 h. The color samples were evaluated for color at baseline. The aging samples were dried to a constant weight over freshly regenerated silica gel in a desiccator. The balance* was accurate to 0.1 mg.

All samples were exposed to conditions of accelerated aging for a total of 900 h in a weathering chamber† at 43°C and 90% relative humidity. One surface of each sample was subjected continuously to the radiation of a 2500 watt ultraviolet (uv) light source‡ filtered by borosilicate glass and to an intermittent water spray for 18 min every two h. The intensity of the uv radiation was measured with a uv meter§ to be about 11.2 mWatts/cm^2 at the specimen position.

Curves of percent reflectance *versus* wavelength (λ) were obtained for each color sample between 405 and 700 nm with a double-beam, ultraviolet-visible spectrophotometer** and integrating sphere.¶ Lumin-

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*Model H 14, Mettler Instrument Corp., Princeton, NJ 08540
†Weather-Ometer 25WR, Atlas Electric Devices Co., Chicago, IL 60613
‡12-2881 Xenon Burner, Atlas Electric Devices Co., Chicago, IL 60613
§Model J-221, Ultraviolet Products, Inc., San Gabriel, CA 91778

ous reflectance (Y), dominant wavelength (DW), and excitation purity (EP) were obtained for each sample backed by both a black** and a white standard.††[8] An estimate of the opacity of each material was obtained by calculation of the contrast ratio (CR), $Y_{\text{black standard}}/Y_{\text{white standard}}$.[9] Color evaluations were made before weathering (baseline) and after exposure of 300, 600, and 900 h.

After 900 h, the aging samples were again dried to constant weight. The change in weight caused by aging was calculated and used to determine volume loss. Density was determined on one new sample of each material by a water displacement technique. The exposed surface area (mm^2) of a sample was measured to be 520 for BL, 530 for BT, 540 for IS, 500 for PP, and 480 for TJ. Surface morphology of the materials was observed after 900 h of aging by scanning electron microscopy.#

The spectrophotometric parameters (Y, DW, EP, and CR) and aging parameters were studied by analysis of variance[10] to determine the effects of aging. Scheffe intervals[11] at the 95% level of confidence were calculated for comparisons among means.

Results.

Mean values and standard deviations of luminous reflectance (Y), dominant wavelength (DW), excitation purity (EP), and contrast ratio (CR) are listed in Table 2 for the plastic veneering materials at baseline. Changes in these parameters at each evaluation period are listed there also. These changes were computed by subtracting the value of the parameter at 300, 600, and 900 h from the baseline value. Values of Scheffe intervals computed from analysis of variance were Y, 1.2; DW, 0.15 nm; EP, 0.007; and CR, 0.004 for comparisons among times at the 95% level of confidence.

Values of luminous reflectance (Y) decreased for IS between zero and 300 h and for PP between zero and 600 h. Subsequent changes in Y for IS and PP, as well as changes in Y for BL, BT, and TJ between zero and 900 h, were not statistically significant.

Values of dominant wavelength (DW) decreased for BL, BT, and PP, increased for IS, but did not change significantly for TJ between zero and 300 h of aging. Further aging caused changes in DW for BL, BT, and PP, but not for IS or TJ.

Values of excitation purity (EP) decreased for IS and TJ, but did not change significantly for BL and BT between zero and 300 h of aging. Further aging resulted in increases in EP for BL and BT, but no significant changes in IS or TJ compared to EP at 300 h. The values of excitation purity

∞ACTA C III UV-visible Spectrophotometer, Beckman Instruments, Inc., Irvine, CA 92664

¶ASPH-U Integrating Sphere, Beckman Instruments, Inc., Irvine, CA 92664

**Part No. 375287, Beckman Instruments, Inc., Irvine, CA 92664

††Part No. 375285, Beckman Instruments, Inc., Irvine, CA 92664

#JSM-US, Japan Electron Optics Laboratory, Japan

TABLE 1
CODE, NAME, BATCH NUMBERS, AND MANUFACTURER OF PRODUCTS TESTED

Code	Product Name (Shade)	Batch Numbers	Manufacturer
BL	Biolon (B-62)	powder – 110278 liquid – 021379	L.D. Caulk Co. Milford, DE
BT	Biotone (G 2)	powder – 012579 liquid – 041878	L.D. Caulk Co. Milford, DE
IS	Isosit (D-4A)	base – 367S catalyst – 432S	Degussa Corp. Teterboro, NJ
PP	Pyroplast (62)	powder – 7276 liquid – 8232	H.D. Justi Co. Philadelphia, PA
TJ	Thermojel (62)	powder – 102778 liquid – 020179	L.D. Caulk Co. Milford, DE

TABLE 2
SPECTROPHOTOMETRIC COLOR DATA AT BASELINE AND CHANGES IN COLOR AFTER AGING FOR PLASTIC VENEERING MATERIALS OBTAINED WITH A WHITE BACKGROUND

Code	Property	Baseline Value	Change in Parameter Compared to Baseline		
			300 h	600 h	900 h
BL	Y	64.0 (0.3)*	−0.9†	−0.4	−0.3
	DW, nm	578.56 (0.05)	−0.50	−0.30	−0.30
	EP	0.259 (0.004)	0.005	0.015	0.017
	CR	0.701 (0.012)	0.002	−0.008	−0.013
BT	Y	62.6 (0.3)	−0.8	−0.7	−0.4
	DW, nm	579.88 (0.13)	−0.44	−0.17	−0.18
	EP	0.294 (0.006)	0.003	0.014	0.016
	CR	0.728 (0.010)	0.010	−0.006	−0.009
IS	Y	56.0 (1.4)	−4.8	−6.0	−5.9
	DW, nm	579.92 (0.05)	0.40	0.48	0.52
	EP	0.262 (0.006)	−0.043	−0.050	−0.050
	CR	0.823 (0.011)	0.011	0.018	0.016
PP	Y	63.4 (1.2)	−0.5	−2.1	−2.0
	DW, nm	577.39 (0.08)	−0.37	0.27	0.19
	EP	0.314 (0.007)	−0.007	0.004	0.006
	CR	0.672 (0.012)	0.001	−0.005	−0.015
TJ	Y	64.4 (2.7)	0.1	−1.1	−0.8
	DW, nm	578.13 (0.14)	0.01	−0.13	−0.14
	EP	0.280 (0.008)	−0.023	−0.022	−0.016
	CR	0.746 (0.019)	0.023	0.019	0.016

*Mean of three replications with standard deviations in parentheses.
†Change equals the value at the specific times minus the value at baseline.

of PP at 300, 600, and 900 h were not significantly different from those at baseline.

Values of the contrast ratio increased for BT, IS, and TJ, but did not change significantly for BL or PP after 300 h of aging. Further aging resulted in decreased values of CR for BL, BT, and PP and increased values of CR for IS compared to baseline. Further aging of TJ resulted in values of EP that were greater than those at baseline, but less than the 300-hour values.

Parameters describing the aging of the plastic veneering materials are listed in Table 3. Weight loss after 900 h of aging ranged from 0.15 mg/gm^2 for BL to 0.66 mg/cm^2 for BT. Volume loss was determined from the data of weight loss, density, and surface area. It ranged from 1.3 x 10^{-3} mm^3/mm^2 for BL to 5.6 x 10^{-3} mm^3/mm^2 for BT. Values of the Scheffe interval at the 95% level of confidence were 0.14 mg/cm^2 and 1.2 x 10^{-3} mm^3/mm^2, respectively. A scanning electron photomicrograph of the surface of IS after 900 h of aging is shown in the Fig. The surfaces of the other materials before and after aging, as well as IS before aging, were without distinctive morphology.

Discussion.

The baseline colors of the plastic veneering materials fall within the ranges of luminous reflectance, dominant wavelength, and excitation purity observed for typical shades of 13 composite restorative materials as shown in Table 4.[5,12] Values of the contrast ratio of the veneering materials, however, tend to be higher than those of the composites. This increased opacity of the veneering materials may serve to mask the less desirable color of the metal substructure of the crown and bridge restoration. The effect of thickness of the veneering material on color and opacity should be studied further.

Changes in the spectrophotometric parameters of color of the plastic veneering materials were observed as a result of accelerated aging. Material IS showed changes comparable with those observed for microfilled composites,[5] whereas the other facing materials showed many fewer changes. Research on color of denture resins has demonstrated that changes in spectrophotometric parameters of 1.1 units in

TABLE 3
PARAMETERS DESCRIBING AGING OF PLASTIC VENEERING MATERIALS WITH COMPARISONS WITH OTHER RESTORATIVE PLASTICS

Code	Weight Loss/ Surface Area, mg/cm^2	Density, g/cm^3	Volume Loss/ Surface Area, 10^{-3} mm^3/mm^2
BL	0.15 (0.04)*	1.233	1.3 (0.3)
BT	0.66 (0.32)	1.177	5.6 (2.6)
IS	0.35 (0.09)	1.278	2.7 (0.7)
PP	0.20 (0.09)	1.052	1.8 (0.9)
TJ	0.44 (0.04)	1.107	3.9 (0.2)
Sealant[7]	0.46	1.188	3.9
Microfilled Composites (two products)[7]	0.28 – 0.51	1.392 – 1.462	2.0 – 3.5
Conventional Composites (four products)[7]	0.46 – 1.16	1.960 – 2.098	3.6 – 5.9

*Mean values of five replications with standard deviations in parentheses.

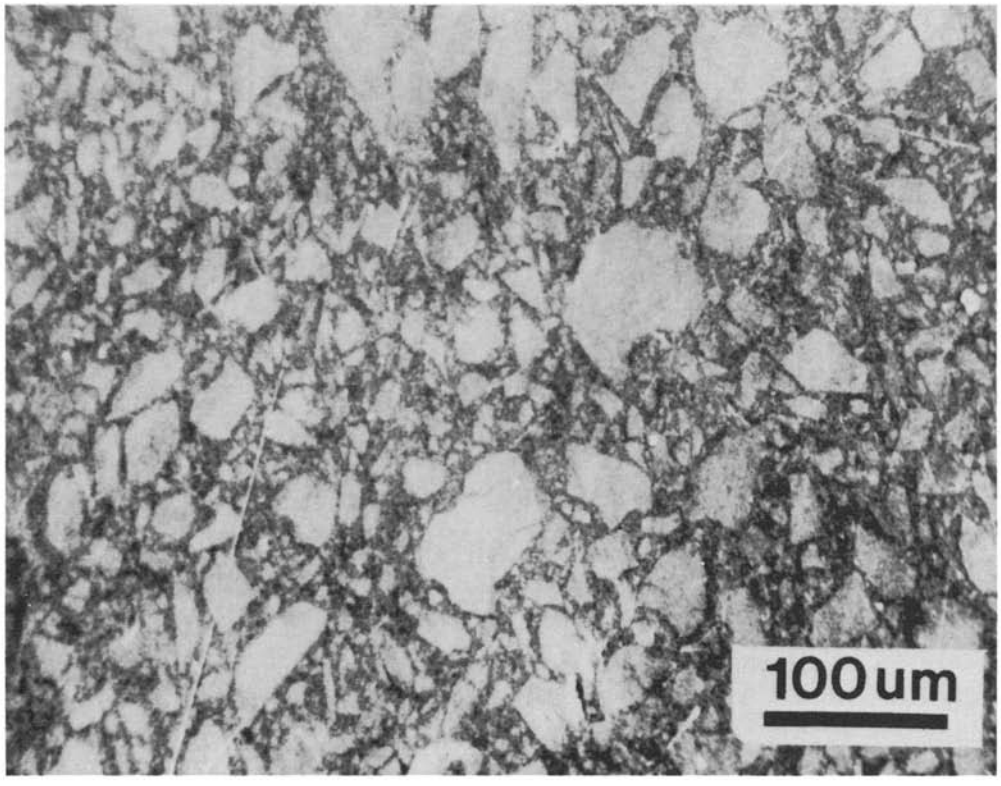

Fig. – Scanning electron photomicrograph of surface of IS after 900 h of accelerated aging.

luminous reflectance, 0.012 units in excitation purity, and 2.2 nm in dominant wavelength can be detected visually by a trained observer.[13] The changes observed instrumentally for BL, BT, IS, PP, and TJ as a result of accelerated aging were very difficult to detect visually.

The plastic veneering materials lost weight as a result of aging for 900 h. With the exception of BT, the ranges of weight loss and volume loss were more similar to those ranges observed for microfilled composites than for those of conventional composites or a sealant as shown in Table 3. The

TABLE 4
COMPARISON OF COLOR DATA AT BASELINE FOR PLASTIC VENEERING MATERIALS AND COMPOSITE RESTORATIVE MATERIALS

	Spectrophotometric Parameter*			
	Y	DW, nm	EP	CR
Plastic Veneering Materials (five products)	56.0 – 64.4	577.39 – 579.92	0.259 – 0.314	0.672 – 0.823
Composites (13 products)[5,12]	51.6 – 78.9	573.72 – 579.57	0.160 – 0.355	0.559 – 0.742

*Data obtained with a white background.

solubility of restorative resins in water for 14 d has been reported to range from less than 0.01 to 0.19 mg/cm^2 for composites and 0.23 mg/cm^2 for an unfilled acrylic.[14] Although the plastic veneering materials were exposed directly to water spray for only 5.6 d during aging for 900 h, their weight loss is comparable to or greater than the solubility of an unfilled acrylic. The weight loss associated with the veneering materials as a result of *in vitro* aging apparently is more complex than solubility and may involve chemical degradation.

Conclusions.

The color stability and aging characteristics of commercial plastic veneering materials were studied *in vitro* by an accelerated aging method. Values of luminous reflectance, dominant wavelength, and excitation purity at baseline were similar to values reported for composite restorative materials. The veneering materials were more opaque than composites. After aging for 900 h, small changes in color were observed instrumentally, but were difficult to detect visually. Weight loss of some of the veneering materials after aging was greater than that anticipated from solubility in water alone.

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